The Role of Firms' Location on Persistency of Various Types of Innovation

To be presented in Uddevalla Symposium 2016

Theme: VIII: Knowledge, firms and locations in the era of global networks

Sam Tavassoli [a*] and **Charlie Karlsson** [b,c]

[a] Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE), Lund University, Lund, Sweden
[b] Centre of Excellence for Science and Innovation Studies (CESIS), KTH, Stockholm, Sweden
[c] Jönköping International Business School, Jönköping, Sweden

*Corresponding author: Sam Tavassoli: sam.tavassoli@circle.lu.se

Abstract

This paper analyzes the role of regional characteristics on innovation persistency among firms. Using five waves of the Community Innovation Survey in Sweden, we have traced the innovative behavior of firms over a ten-year period, i.e. between 2002 and 2012. On the one hand, we distinguish between four types of innovations: process, product, organizational, and marketing innovations. On the other hand, we consider various regional characteristics that may affect the innovation persistency, including regional labor market and supplier thicknesses, as well as the extent of intra-regional knowledge spillovers. Using a dynamic Probit model, we find that, in general, those firms located in the regions with thicker labor market, thicker knowledge intensive suppliers, or higher extent of knowledge spillovers exhibit higher probability of being a persistent innovators. Such higher persistency is mostly pronounced for product innovators.

Keywords: location, persistence, innovation, product innovations, process innovations, market innovations, organizational innovations, firms, Community Innovation Survey

JEL-Codes: D22, L20, O31, O32

1. Introduction

In this paper, we analyse the effect of location on innovation persistence among firms. Innovation is the deliberate and intentional result of the willingness and ability of firms to generate new ideas and knowledge and implement them in the form of new products, production processes, organisational solutions and markets (Fagerberg, et al., 2005). However, innovation is not a general characteristic of firms. Many firms never innovate, some firms innovate now and then, while many other firms are persistent innovators (Tavassoli & Karlsson, 2005).

Persistence of innovation is an important aspect of the innovation strategy of firms and related to the decisions made by firms about what kind of innovation inputs to use (Verspagen & Clausen, 2012) but also about location, as we will demonstrate in this paper. Thus, we identify two groups of explanatory factors as critical for innovation persistence among firms. The first group of factors builds upon the resource based view of the firm and relates innovation persistence to intrinsic characteristics and endowments of firms. Firms vary in terms of their initial allocation of innovation and learning capabilities and routines as well as in their capacity, resources, competence and routines in developing these learning capabilities and routines over time (Langlois & Foss, 1999).

The second group of explanatory factors takes its starting point in the assumption that innovation persistence is a path-dependent process, where innovation by a firm in one period increases the probability that it will make an innovation in the next period. However, this probability is not stable and can over time be influenced by unexpected external events and not least by changes in the options to absorb new external knowledge. The external events can come from product and/or input markets and from the knowledge production activities. The signals may be transmitted via markets, via spillovers from other economic agents and from other firms in the group for firms belonging to a company group. The signals may be transmitted over long distance but will in many cases come from within the region where the firm is located. This implies that the spatial context influences the probability that a firm is innovative in one period will be innovative in the next period. We may assume that the richer and more developed the local spatial context the higher the probability that firms will react creatively on external events and continue to introduce innovations.

Firms react on unexpected external events by mobilizing its creative staff and encouraging it to use the internal stocks of new and old ideas and knowledge accumulated over time through R&D, learning and trial-and-error processes to generate innovations. The probability that innovations are generated increases with the access to external ideas and knowledge and in particular new ideas and knowledge accessible in the region where the firm is localized. Thus, innovations are a function of internally accumulated ideas and knowledge and competence, the access conditions for new external ideas and knowledge and the matching between the two potential knowledge sources (Antonelli, 2011).

We claim in this paper that that the probability that firms will be persistent innovators is a function of to what extent their location context provides access to complementary and indispensable inputs in terms of external ideas, knowledge and innovation capabilities. Thus, we assume that location matters for innovation persistence among firms. Our motivation for this claim and assumption is that innovation is the result of a combination of the knowledge and competence accumulated through internal learning processes and knowledge and competence accessed from external knowledge and competence pools, in particular, in the firms' location (Antonelli, 2011). Thus, geographical proximity to a variety of economic agents with diverse ideas and knowledge bases enhances the internal knowledge processes and stimulate innovation persistence. As a path-dependent process innovation persistence is the result not only of the internal characteristics of firms but also of the characteristics of the context where firms are located (Antonelli, et al., 2013).

Locations, i.e. regions, vary in terms of volume and type of knowledge production, in terms of local and interregional links and arenas for knowledge interaction, transfer and diffusion, the supply of knowledge agents, i.e. knowledge-intensive business services, universities and research institutes and their knowledge handlers, which influence the knowledge generation processes among firms as well as among the knowledge agents. Actually, firms cluster to get access to the right supply of knowledge and in particular new knowledge (Baptista & Swann, 1999). However, organized proximity not least within multinational firms may allow for and stimulate long-distance knowledge interactions among firms and other knowledge agents (Torre & Rallet, 2005). Empirical findings indicate that the higher the ability of firms to use external knowledge as an input in their own innovation processes the higher their rate of innovation (Fritsch & Franke, 2004) indicating the positive effects of knowledge flows and spillovers.

It is obvious that locations are different in the extent to which they promote innovation persistence. For example, the higher the spatial proximity between economic agents they offer, the more they support the introduction of innovations, the diffusion of ideas and knowledge and collective learning processes (Boschma, 2005). Larger agglomerations have generally been highlighted as locations offering advantages to firms in general and innovative firms in particular in the form of i) access to a market for specialized labour (Krugman, 1991), ii) access to localized dynamic capabilities (von Tunzelmann & Wang, 2003), iii) cost advantages due to sharing of infrastructure capital and other collective resources, iv) reduced transaction costs for trade with co-located customers and suppliers (Arthur, 1994), and access to knowledge spillover mechanisms including links research universities and institutes. The knowledge spillovers generate knowledge externalities and give the innovative firms access to external knowledge at advantageous costs, which affects their knowledge production functions and thus their ability to generate innovations (Antonelli, 2008).

Location is critical for innovative firms for in particular three reasons: i) innovative firms located in regions with thick labour markets can more easily recruit the specialised high-skilled labour they need in the innovation process, ii) innovative firms located in regions with thick markets with specialized services can more easily access the specialized services they need in the innovation process, and iii) innovative firms located in regions with many other innovative firms can gain from knowledge spillovers in their innovation processes. Regions with these characteristics offer different types of increasing returns in the form of dynamic and interactive economies of scale and scope that foster knowledge accumulation and learning dynamics, which promotes innovation persistence (Colombelli, & von Tunzelmann, 2011).

Based upon the above discussion we claim that innovation persistence is both past- and path-dependent. It is past-dependent because it is partly the result of the internal characteristics of firms as asserted by the resource-based theory of the firm. It is path-dependent because it is partly the result of the changing conditions of the spatial context where the firm is localized. The presence of knowledge externalities might be critical to induce firms to continue to be innovative. Even if the knowledge externalities are external to the firms, they are clearly internal to the economic system and in particular the economic system of each region. Changes in the spatial context will induce changes in the innovative efforts of firms as well as in the results of these efforts. Thus, innovation persistence cannot be regarded as the result of given historical capabilities of firms but also the conditional result of a systemic and interactive dynamic process that differs between regions and which changes over time since it is shaped by a number of complementary and contingent factors (Antonelli & Scellato, 2013).

This paper is based upon the assumption that external knowledge constitutes an augmenting and facilitating factor in the development and introduction of innovations. In line with Antonelli, Crespi and Scellato (2013), we claim that external knowledge and in particular external knowledge from a firm's location region is a key factor in determining path-dependent innovation persistence driven by processes characterized by contextual and conditional feed-backs. The introduction of innovations is seen as a fundamental characteristic of an economic system characterized by knowledge cumulability and complementaries both internally in firms and other knowledge agents and in the economic system as a whole. The introduction of innovations affect the economic system in three ways: (i) it releases new wave of unexpected events, (ii) it stimulates Schumpeterian rivalry, and (iii) it creates new opportunities for knowledge spillovers which increases the existing stock of external knowledge.

Knowledge is a special type of economic good. It is characterized by indivisibility and non-exhaustability. New knowledge vintages adds to the existing stock of knowledge and knowledge doesn't wear out because of repeated use but it may become obsolete. The generation of new knowledge by firms is possible only by "standing on the shoulders of giants", which implies that access to and use of the existing internal and external stock of knowledge, where the external stock of knowledge is partly embedded in other firms and knowledge agents located in the same region but also in other regions (Colombelli & von Tunzelmann, 2011).

The structure of the intra- and inter-regional systems changes endogenously as a consequence of (i) the mobility of knowledge handlers, (ii) changing modes of interaction among firms and other knowledge agents, and (iii) the entry, exit, mobility and growth of firms and other knowledge agents. The launching of innovations is by itself a major factor changing the structure of the intra- and inter-regional systems. The external spatial conditions into which firms are embedded are at the same time a cause and a consequence of the recursive feed-backs that support the persistence of innovation activities (Beaudry & Swann, 2009).

The accumulation of internal and external knowledge influences the dynamics of innovation processes since the internal and external stock of knowledge that each firm can access and use determine the probability of generating new knowledge, and thus introducing innovations. The rates of internal and external knowledge accumulation and the conditions for accessing external knowledge are not fixed over time, which implies that what knowledge a firm can access changes over time. Innovations by suppliers, customers or competitors can make parts of the current internal knowledge obsolete. Changes in the structure of knowledge interactions and transactions can alter the conditions for accessing external knowledge. The accumulation of internal and external knowledge as well as the effects of such accumulation is typically path-dependent due to the contingent changes that take place along the process. The dynamics of such processes are affected by a weak irreversibility that permits changes along the process that alters both the rate and the direction of the dynamics with the associated typical path-dependent effects (David, 2007).

Against the above background the purpose of this paper is to contribute to the research on innovation persistence by analysing empirically what factors that can explain differences in persistence in product, process, organizational and market innovations between functional economic regions.

Interestingly, the critical role of location for innovation persistence has not been a major research question in most of the earlier research on the determinants of innovation persistence. The one exception we have found is Antonelli, et al. (2013). They found that the external conditions, i.e. the quality of local knowledge pools and the strength of Schumpeterian rivalry, along with internal conditions (the actual levels of dynamic capabilities, as proxied by wage levels and firm size) exert a specific and localized effect upon the persistent introduction of innovations.

2. Geography and innovation persistence

Persistence characterizes all types of innovation, i.e., product, process, organizational and market innovations, but to a varying degree as demonstrated by Tavassoli & Karlsson (2015). It is against this background intriguing that the underlying causes of innovation persistence are not well understood. Furthermore, the literature in the field is rather heavily biased toward persistence in technological innovations with only a very limited discussion of the causes of persistence in non-technological innovations (Le Bas & Scellato, 2014).

In the sequel, we will discuss some possible general explanations to why innovation tend to demonstrate state dependence over time, no matter if we talk about technological or non-technological innovations. We start from a non-spatial perspective and will after that discuss to what extent location factors might influence innovation persistence, i.e. if the probability that a firm will exhibit innovation persistence is higher in some locations than in other locations.

2.1 General causes of innovation persistence

To explore the underlying general causes of innovation persistence, we apply a knowledge perspective involving learning and dynamic scale economies. It has been suggested that innovation persistence might be explained by a combination of learning effects from the innovation process and positive feed-back mechanisms between the accumulation of knowledge and innovation processes generating dynamic scale economies (Geroski, Van Reenen & Walter, 1997). Thus, innovation persistence is the result of cumulative knowledge patterns and learning dynamics (Colombelli & von Tunzelmann, 2011). Knowledge is a unique economic good characterized by being cumulative and non-exhaustible (Nelson, 1959; Nelson & Winter, 1982; Ruttan, 1997) and it is both an input in and an output from knowledge production processes (David, 1993). These attributes have distinct implications for innovation persistence, no matter what type of innovation we are analysing. The creation of new knowledge increases the existing knowledge stock that can be used as an input in the knowledge production process, since knowledge is non-exhaustible. This implies that firms who have chosen to invest in their own production of knowledge over time can use their own growing knowledge stock to produce new knowledge more efficiently and/or at a lower costs exploiting dynamic economies of scale at the same time as they develop their innovative capability and innovation routines. Such internal knowledge generation is important for all types of innovation because all types of innovation entails some degree of novelty that has not existed before (at least for the firm) and can be introduced only through the generation of some new knowledge.

Firms' investment in knowledge generation with the ambition to further innovation generate costs, which represent distinct sunk cost. The sunk cost hypothesis implies that firms deciding to invest in knowledge generation incur costs that usually are not recoverable except through the income increases and/or cost reductions from successful innovations. Over time the investments in knowledge generation generate a stock of knowledge capital, which can be used as an input in future knowledge generation as well as contribute to a more or less continuous flow of innovations. Thus, persistence in knowledge generation may lead to persistence in innovation (Cohen & Klepper, 1996). Moreover, the sunk cost hypothesis imply that the opportunity cost of ending the innovative activities are often quite high since the costs incurred mainly are unrecoverable. At the same time we must observe that the presence of sunk costs reduce the costs of future of future innovative activities and thus induce innovating firms to continue innovating, i.e. to be persistent innovator, at the same time as they function as a barrier of entry to innovation for non-innovative firms (Máñez, et al., 2009).

Successful innovation can have a positive impact on innovative firms' conditions for subsequent innovations by normally providing successful innovators with a head start, i.e. a first mover advantage, with a higher market power, a stronger brand or lower costs which generate advantages for an extended period, i.e. "success breeds success" (Phillips, 1971). The innovation success of firms may broaden the space of available opportunities and opens up for exploiting economies of scale and scope, which increases the probability of subsequent innovation success (Scellato & Ughetto, 2010). Successful innovations also reduce the financial constraints of innovating firms because of increased market power and/or reduced costs. Firms often meet serious financial limitations in financing their knowledge generation and their innovation projects, which might explain why some firms are non-innovators while successful innovators can continue innovate and be persistent innovators. Investments in knowledge generation and innovation projects are often costly, risky and difficult for external financiers to assess (Arrow, 1962 b), which limits the opportunities of firms to use capital markets and other external sources of finance to finance them (Czarnitzki & Hottenrott, 2010) and forces firms to finance them by means of internally generated funds. A stream of successful innovations provides firms with increased internal funding that can be used to finance investments in knowledge generation and innovation projects. At the same time it partly lifts the external financing restrictions, since banks and investors might become more interested and more willing to contribute to the financing of such projects, since past success in innovation can be interpreted as an indicator of innovative capability and of possible future success in innovation. A bearing idea here is that firms that launch commercially successful innovations gain a kind of lock-in advantage over less successful innovators.

Innovation persistence can also be explained by appropriation theory, since innovation outcomes can be protected intellectual property rights, such as patents, copyrights, trade-marks, etc. (Teece, 1986) and sometimes with business secrets.

Experience of innovation among a firm’s employees generates dynamic increasing returns as a result of learning effects, which increase the firm’s knowledge stocks and its innovative capabilities (Arrow, 1962 a). This applies to both technological and non-technological innovation. By investing in innovation a firm is engaged in a learning process through which it discovers new ideas by recombining existing ideas in new ways. The more knowledge pieces and ideas it has generated in the past, the higher its ability to recombine them in order to generate new ideas and new pieces of knowledge (Weitzman, 1998). This implies that past innovation affects current innovation, which gives rise to path-dependence (Duguet & Monjon, 2002). However, internal investments in knowledge production is also associated with the development of internal innovation routines and practices (Nelson & Winter, 1982) that due to learning effects will improve over time making it easier for a firm to be a persistent innovator.

Furthermore, a firm’s capacity to absorb new ideas and pieces of knowledge is a function of the human capital of its employees but this absorptive capacity increases with the learning in each period, which increases the innovative capacity in future periods. The cumulative nature of innovative capabilities represents a process that might induce state dependence for different types of innovations. Actually, all types of innovation demands organizational capabilities and innovation routines, even if they may vary for different types of innovation. Such capabilities and routines are difficult to create and to imitate and costly to adjust (Hannan & Freeman, 1984), which implies that when they have been created they tend to support persistence in various types of innovation and generate a barrier to entry for non-innovators. However, we can expect that the actual capabilities and routines needed vary for different types of innovation. Firms that pursue several types of innovation at the same time may need further capabilities and routines to coordinate the different types of innovation.

2.2 Location and innovation persistence

It is obvious that the above discussion builds upon one very unrealistic assumption, namely that innovation activities within firms build upon the knowledge and ideas they have generated in-house and upon the absorption and creativity of their employees only. Certainly, firms in their innovation activities use knowledge and ideas developed by suppliers, customers and competitors as well as by universities and research institutes and laboratories including specialized R&D firms. In certain parts of economic theory and in particular the new endogenous growth theory (Romer, 1990), it is assumed that all new knowledge and ideas immediately are available to all economic agent to be used as an input in future knowledge production. This is of course misleading. In fact, the most realistic assumption is that flows of knowledge and ideas are affected by frictions that retard their diffusion. In every specific case of transmission or transfer of knowledge and ideas, the strength of the frictions vary because of geographic and other communication distances. Frictions appear when knowledge and ideas are complex (Beckmann, 1994 & 2000) and/or tacit Polanyi (1966), which implies that knowledge and ideas are sticky (von Hippel, 1994). Under such circumstances are face-to-face interaction essential for the transmission or transfer of knowledge and ideas between economic agents to calibrate their coding, decoding and interpretation (Johansson & Karlsson, 2009).[1]

Furthermore, the stickiness of knowledge and ideas implies that knowledge and ideas can be shared by firms in the economic environment of a functional region with little risk that the knowledge and ideas diffuses outside the region at least in the short run (Antonelli, et al., 2003). An implication of this is of course that the innovation activities in a functional region only to a limited extent in the short run will benefit from new knowledge and ideas developed in other functional regions. This implies that firms that invest in knowledge production are mainly referred to use their own internal knowledge stock and the knowledge stock in the functional region where they are located. Thus, the ability of firms to be persistent innovators is not independent of their location, since innovation requires both internal knowledge investments and learning and the acquisition of external tacit and

[1] We must acknowledge that over time new communication technologies can modify the role of geographical proximity in such calibrations (Teece, 1981). However, casual observation of the continued and increased use of, e.g., trade fairs, scientific conferences and business travel, indicates that the new communication technologies still have a long way to go to substitute the role of face-to-face interactions for such calibrations.

codified knowledge as well external innovation capabilities. The reason is that new ideas and knowledge are generated through the recombination of existing ideas and bits of knowledge in a cumulative and interactive process (Weitzman, 1998). Thus, efficient innovation is dependent upon firms' access to and ability to absorb external ideas and knowledge (Love & Roper, 2009). Certainly, we have a chicken and egg problem here, since we don't if persistent innovators chose certain locations or if firms located in certain regions tend to become persistent innovators.

We think that there are in particular three aspects of regions or forces of agglomeration that exerts an influence on the probability that firms can continue over time to be persistent innovators:

1. The thickness of regional labour markets
2. The regional supply of specialised service provider, and
3. The availability of knowledge spillovers.

2.2.1 The thickness of regional labour markets and innovation persistence

Thick labour markets – those with many employers and employees – are particularly attractive to innovative firms because they make it easier to recruit the specialized skills needed in the innovation process and to come close to an ideal match between the jobs to be filled and the competence profile of the people in the regional labour force. High-skilled employees in thick labour markets tend to be more specialised than employees in thin labour markets but also more experienced, since employees in thick labour markets change jobs more often than employees in thin labour markets. The easier it is for innovative firms to recruit exactly the right kind of high-skilled and specialised labour the lower the costs for these firms to be persistent innovators. The time to fill vacancies is also normally shorter in thick labour markets. The better matching in the labour market in regions with thick labour markets tends to make innovative firms in such labour markets more productive and more innovative that tends to result in higher profits, which makes it easier for firms to finance persistent innovation. Higher productivity makes it easier for these firms to pay higher salaries, which attracts skilled labour to stay in and move to thick labour markets.

In thick labour markets it is possible for innovative firms to locate close to other innovative firms and by clustering close to each other these firms become more productive and more creative, which will tend to stimulate innovation persistence. Such innovation clusters have a clear advantage in attracting even more high-skilled people, which increases the regional supply of such people. Firms and workers that join an innovation cluster enjoy private benefits in terms of higher productivity and creativity. However, they also generate a benefit for all innovative firms and employees in the cluster, which are made more productive and more creative by new entrants making it easier for these innovative firms to continue to be persistent innovators.

This leads to our first hypothesis:

H 1: The probability that a firm will be a persistent innovator increases if it is located in a region with a thick labour market.

2.2.2 Specialized service providers and innovation persistence

Specialized service providers in advertising, legal services, technical and management consulting, financial services, logistics services, etc. in particular are important to innovative firms. These services enable innovative firms to focus on what they are good at, i.e. innovation without having to worry about secondary functions. By being located in a region with many innovative firms, an innovative firm can draw on specialized regional expertise making it more productive and more creative and helping it to be a persistent innovator. From the viewpoint of the specialized service providers, geographical proximity to clients is crucial. They need to be close to actual and potential clients to assess their needs and demonstrate how they can help. This is critical for firms developing new and innovative products and not least for persistent innovators.

Specialized service producers is one important factor that keeps innovative eco-systems together. Here we have advantages to innovative firms and specialized service providers due to thick specialized service markets that provide advantages similar to the thick labour market effect for innovative firms and employees. Thick specialized service markets tend to stimulate productivity and creativity in innovative firms and reduce the costs for them to be persistent innovators. Similarly, thick specialized service markets with many innovative firms tend to attract specialised service producers leading to a larger and more specialised service producers and lower delivery costs, which further will enhance innovation persistence.

Possibly, the most important part of an innovation eco-system is access to specialized finance and not least venture capital. A strong and diverse financial system in a region makes it easier for firms to continue to be persistent innovators, since they then more easily can access the necessary external financing of their investments in innovation.

The discussion in this subsection leads us to the following hypothesis:

H 2: The probability that a firm will be a persistent innovator increases if it is located in a region with a thick specialized service market.

2.2.3 Knowledge spillovers and innovation persistence

In this sub-section we claim that firms located in regions offering good opportunities for knowledge spillovers have a higher probability of beeing persistent innovators. This claim is built upon a simple fact: New ideas and knowledge are rarely born in a vacuum. They are created through new combinations of existing ideas and knowledge, which diffuse within circles of friends, colleagues, researchers and innovators. Earlier research shows that social and professional interactions among creative and innovative knowledge workers living and working in geographical proximity tend to generate learning opportunities that enhance creativity, innovation and productivity. Interacting with smart people tend to make us smarter, more creative and innovative and ultimately more productive and able to produce an output with a higher quality. The smarter the people, the stronger the effect. Good opportunities for knowledge flows and interactions between smart people represents a crucial advantage for innovative people and firms and increases the probability that firms will be persistent innovators.

The opportunities for knowledge flows and interactions are dependent upon location, since knowledge is subject to a significant degree of “home bias”, for example, in the sense that innovators are substantially more likely to cite other innovators living nearby than innovators living far away (Jaffe, Trajtenberg & Henderson, 1993). The magnitude of the “home bias” is substantial. Excluding intra-firm citations, citations are twice as likely to come from the inventors’ place of residence as from other places. This implies that researchers and inventors tend to be more familiar with knowledge generated by those who live (and work) near them. The reason is probably that they share information, ideas and knowledge through informal and formal observations, networks and interactions. Interactions taking place both inside and outside the work place. And, it is the free and unstructured interactions that generate new ideas and knowledge in mysterious and unpredictable ways. Hence, geographical space matters for the diffusion and generation of knowledge. Since it takes time for knowledge to reach places that are more distant despite mobile phones, the Internet and air travel, firms that are located in regions offering good opportunities for knowledge spillovers are more likely to be persistent innovators than firms residing in locations with poorer options for knowledge spillovers.[2]

It is obvious that innovative firms that are located close to other innovative firms have substantial advantages. Having innovative neighbours, including competitors, increases the creativity and innovativeness of firms and their employees. By being located close to each other innovative firms and their employees foster each other's creative and innovative spirit and become more successful. This implies that location is very important for innovative firms and that a location in a region and in particular an innovation eco-system offering good opportunities for knowledge spillovers increase the probability that a firm will be a persistent innovator.

We are now able to formulate our third hypothesis:

H 3: The probability that a firm will be a persistent innovator increases if it is located in a region offering good opportunities for knowledge spillovers.

3. Data

The innovation related data in this study comes from five waves of the Swedish Community Innovation Survey (CIS) in 2004, 2006, 2008, 2010, and 2012. The CIS 2004 covers the period 2002-2004 and CIS 2006 covers the period 2004-2006 and so on, hence using the five ways, provide us with information about innovation activities of firms over a ten years period, i.e. from 2002 to 2012. In all five waves, there is information concerning

[2] Information and telecommunication technologies are excellent means to transmit routine information but new ideas and knowledge is normally not generated by means of mediated communication.

product and process innovations as well as to innovation inputs (e.g. R&D investments). In the last three waves, there is also information concerning the marketing and organizational innovations. The survey consists of a representative sample of firms in industry and service sectors with 10 and more employees. Among them, the stratum with 10-249 employees has a stratified random sampling with optimal allocations and the stratum with 250 and more employees is fully covered. The response rates in the five waves vary between 63% and 86%, in which the later CIS waves having higher response rates compared with the earlier ones.

There are 21,105 observations in total, after appending all five waves of CIS. Then we construct a balanced dataset consists of 2,870 observations, corresponding to 574 firms who participated in all five waves of CIS[3]. Finally, we merged the innovation-related data with other firm-characteristics data (e.g. export, import, ownership structure) coming from registered firm-level data maintained by Statistic Sweden (SCB). We use panel dataset in investigating true state dependency, where we estimate a dynamic discrete choice model (Section 5). The definition of all variables is reported in the Appendix 1 and descriptive statistics is presented in Table 1. The mean VIF score for all variables is 1.98 and each variable get a VIF score of below 3.1. This implies that multicollinearity is rather mild and may not bias the regression analyses results in the subsequent sections.

[Table 1 about here]

4. Empirical Strategy

4.1 Regional factors

As elaborated in literature review, we want to investigate the effect of three regional factors on the extent of innovation persistency of firms. These factors are: (i) labor market thickness, measured as total number of employees in the region minus firm's own employment, (ii) service provider thickness, measured as total number of employment in Knowledge Intensive Service (KIS) sectors minus firm's own employment if firm belongs to KIS sector, and (iii) the extent of knowledge spillovers, captured by the extent of related variety of knowledge, measured as weighted sum of entropy of total employment within

[3] We also constructed an unbalanced dataset consists of 16,166 observations, corresponding to 4,958 firms participated in at least two consecutive waves (2,488 firms participated in two waves, 1,534 firms in three waves, and 936 firms in four waves). The result of using unbalanced panel is similar to balanced panel.

two-digit NACE codes. Specifically, following Frenken et al. (2007), it is assumed that 5-digit industries are technologically related when they share the same 2-digit class. These industries are perceived to show some degree of cognitive proximity, because these 5-digit sectors (e.g., sub-branches in chemicals) will share some technology and product characteristics in the same 2-digit class (e.g., chemicals). At the same time, these industries are considered to show some degree of cognitive distance, because these sectors differ at the 5-digit level. Then, the more sectors at the 5-digit level within each 2-digit level in a region, higher the value of related variety, i.e the higher assumed inter-industry knowledge spillovers. Mathematically, related variety (RV) follows entropy measure and he (1) RV in region r and year t, is given by:

$$RV_{rt} = \sum_{g=1}^{G} Pg_{rt} Hg_{rt}$$

Where:

$$Hg_{rt} = \sum_{i \epsilon Sg} \frac{Pi_{rt}}{Pg_{rt}} \, log_2 (\frac{1}{Pi_{rt}/Pg_{rt}})$$

Where, Pi_{rt} is the employment share in five-digit NACE code for region r in year t, Pg_{rt} is the employment share in two-digit NACE code for region r in year t, and G is the maximum number of two-digit sectors in region r and year t.

For each of the three regional factors, we will split the total number of firms into three groups, based on equal quantile values of each of the regional factors (see Table 1). Doing so, we will be able to run the innovation persistency regressions separately for these groups of firms in order to delineate the possible structural effect of regional factors on innovation persistency of firms. Next section will elaborate the specific estimation strategy that can model the innovation persistency pattern of firms.

4.2 Innovation persistency

Two mechanisms can explain persistence in innovation of firms. Innovation persistence may be the result of "true" state dependence and/or "spurious" state dependence (Heckman, 1981 a & b). True state dependence represents a casual behavioral relationship (a path-dependent process), where the decision to innovate in one period increases the probability to decide and to succeed to innovate in the following period. Spurious state dependence, on the other hand, prevails when the determinants of innovation persistency (e.g. size of firms) are persistent themselves, hence making firms to be more inclined to innovate in a persistent way. Here the observed innovation persistence is the result of the serial correlation in unobservable(s) that generate different innovation competencies and capabilities of firms, i.e. dynamic capabilities (Teece & Pisano, 1994) in line with the resource-based theory of the firm (Penrose, 1959; Langlois & Foss, 1999). However, if these unobservable and serially correlated characteristics (e.g. risk attitudes or managerial skills) are not controlled for in the econometric estimations, they may generate the impression that innovation in one period drives innovation in the following period. Therefore, in reality what is observed is the effect of unobservable characteristics of firms, and not the true persistence of innovation itself.

We employed a dynamic probit model in order to investigate the determinants of persistency of firms' innovation, in line with previous similar studies (Tavassoli and Karlsson, 2015). Such model is able to analyze the conditional state dependence, hence allows us to distinguish between "true" state dependence from "spurious" one. The starting point is to assume that firm *i* invests in innovation activities in period *t*, if the expected present value of profits happening to the investment in $y*_{it}$ is positive. The latent variable $y*_{it}$ depends on the previous and realized innovation $y_{i,t-1}$, observable vector of explanatory variables $\boldsymbol{X}_{it}$, and unobservable time-invariant firm-specific elements τ_i. Other time-varying unobservable elements are captured in the idiosyncratic error ε_{it}. Such relation can be formulated as follows:

$$y_{it}^{*} = \gamma y_{i,t-1} + \beta \boldsymbol{X}_{it} + \tau_i + \varepsilon_{it} \qquad (2)$$

If the latent $y*_{it}$ is positive then we observe that firm *i* introduces innovations, that is y_{it} = 1, and 0 otherwise. Furthermore, there are good reasons to believe that many firms in our sample do not start their innovation processes in the beginning of the period of this study, i.e. 2002. This means that the initial condition,y_{i0}, is presumably correlated with unobservable time-invariant firm-specific elements τ_i, leading to inconsistent estimators, known as initial condition problem. Moreover, it is possible that explanatory variables, X_{it}, are also correlated with τ_i (Ganter and Hecker, 2013; Antonelli et al, 2013). If these individual effects and the initial conditions are not properly accounted for, then the coefficient of the lagged dependent variable can be overestimated (Peters, 2009; Raymond et al, 2010). In order to accommodate such situation, Wooldridge modifies the original procedure of Heckman (1981a) by suggesting to model the distribution of $\{y_{i0}, \ldots, y_{iT}\}$

given y_{i0} and to use Conditional Maximum Likelihood (CML) estimator (Wooldridge, 2005). Applying this approach, the time-invariant firm-specific elements can be decomposed as:

$$\tau_i = \alpha_0 + \alpha_1 y_{i0} + \alpha_2 \boldsymbol{X}_i + \alpha_i \quad (3)$$

Where $\boldsymbol{X}_i = \{\boldsymbol{X}_{i1}, \ldots, \boldsymbol{X}_{iT}\}$ is the vector of explanatory variables in each period from t=1 to t=T and $\alpha_i \sim N(0, \sigma_a^2)$, which is assumed to be independent of y_{i0} and $\boldsymbol{X}_i$. Plugging (5) in (4), the probability that firm *i* introduce an innovation in period *t* can be formulated as follows:

$$Prob(y_{it} = 1 | y_{i0}, \ldots, y_{i,t-1}, \boldsymbol{X}_{it}, \boldsymbol{X}_i, \alpha_i) = \boldsymbol{\phi}(\gamma y_{i,t-1} + \beta \boldsymbol{X}_{it} + \alpha_0 + \alpha_1 y_{i0} + \alpha_2 \boldsymbol{X}_i + \alpha_i) \quad (4)$$

Where y_{it} is a dichotomous variable getting value 1 if a firm *i* introduces innovation in year *t*. We operationalize introducing innovation in four ways: product, process, organizational, and marketing innovation. This way, we distinguish between four types of innovation rooted in Schumpeter's definition; hence, we have four different dependent variables. The parameter γ shows the effect of previous innovation on the probability of future innovation, i.e. persistency in innovation behavior. $\boldsymbol{\phi}$ is the standard normal cumulative distribution function and $\boldsymbol{X}_{it}$ composed of observable firm characteristics: size, innovation input, physical capital, human capital, import, export, ownership structure, cooperation, and continuous R&D strategy (refer to Appendix 2 for exact definition of each variable).

Equation (4) has four different dependent variables, as noted earlier. Moreover, for each dependent variable, we will break down the overall sample of firms into three subsamples based on the three equal quantile value of a given regional factors. For instance, for estimating the innovation persistency for product innovation, we grouped total number of firms into those who are located in a region that fall under the category of either (i) 0-33% value of labor market thickness (i.e. low-thick labor market), or (ii) 34-66 % (i.e. medium-thick labor market), or (iii) 67%-100% (i.e. high-thick labor market). Based on Hypothesis 1, we expect that the product innovation persistency for firms in the last group is significantly higher than the other two groups, especially in compare with the first group. The same procedure is done to investigating the persistency of process, organization, and marketing innovation.

5. Estimation Results

Table 2 to 4 report the estimation results of dynamic probit models in order to investigate the effect of regional factors on possible true state dependency in persistency of various types of innovations. Table 2 incorporates labor market thickness, Table 3 incorporates specialized service providers' thickness, and Table (4) investigates the effect of knowledge spillovers. Each table investigates four the persistency on four types of innovation by incorporating the structural effect of regional factors on such persistency pattern.

[Table 2 about here]

Table 2 incorporates the effect of labor market thickness on persistency pattern of innovation. Models (1) to (3) shows the extent of persistency in product innovation for firms located in regions with labor markets thickness being low, medium, and high, respectively. Models (4) to (6) shows the extent of persistency in process innovation for firms located in regions with labor markets thickness being low, medium, and high, respectively. Similarly, models (7) to (9) shows the persistency pattern for organizational innovation and finally models (10) to (12) for marketing innovations. In all models, we controlled for an extensive set of firm-level characteristics as well as initial conditions. It is clear from the table that firms located in thicker labor markets are more persistent in introducing product, process, and organizational innovation in compare with less thick labor markets. The effect of labor market thickness is slightly more pronounced for product innovators. Marketing innovation is the type of innovation that labor market thickness does not matter for enhancing persistency pattern. Previous studies show that marketing innovators are not really persistent innovators (Tavassoli and karlsson, 2015). Our result shows that labor market thickness does not change that picture.

[Table 3 about here]

Table 3 incorporates the effect of knowledge intensive suppliers' thickness on persistency pattern of innovation. Models (1') to (3') shows the extent of persistency in product innovation for firms located in regions with knowledge intensive suppliers thickness being low, medium, and high, respectively. Models (4') to (6') shows the extent of persistency in process innovation for firms located in regions with knowledge intensive suppliers' thickness being low, medium, and high, respectively. Similarly, models (7') to (9') shows the persistency pattern for organizational innovation and finally models (10') to (12') for marketing innovations. It is clear from the table that firms located in thicker labor markets are more persistent in introducing product innovation. Some weak effect is found for organizational innovation as well. On the other hand, market thickness does not matter for process and (again) marketing innovation.

Table 4 incorporates the effect of intraregional knowledge spillovers on persistency pattern of innovation. In the same fashion as Table (2) and (3), here models (1'') to (3'') shows the extent of persistency in product innovation for firms located in regions with the extent of knowledge spillovers being low, medium, and high, respectively. Models (4'') to (6'') shows the extent of persistency in process innovation for firms located in regions with the extent of knowledge spillovers being low, medium, and high, respectively. Similarly, models (7'') to (9'') shows the persistency pattern for organizational innovation and finally models (10'') to (12'') for marketing innovations. The results in this table is similar to the Table (2) in that the higher extent of knowledge spillovers, the higher persistency in product, process, and organizational innovations. The difference here is that firms located in not only high but also medium level of knowledge spillovers experience significantly higher persistency pattern in their innovation in compare with those firms located in regions characterized by low level of knowledge spillovers. Nevertheless, the main message here is the same as in Table 2: firms located in regions characterized by higher level of intraregional knowledge spillovers, show stronger pattern of persistency in three out of four types of innovation.

[Table 4 about here]

6. Conclusions

In this paper, we have analysed the effect of location on innovation persistence among firms using five waves of the Community Innovation Survey for Sweden. With help of the survey, we have traced the innovation behaviour of firms over a ten-year period, i.e. between 2002 and 2012. We have distinguished between four types of innovation: product, process, organizational and market innovation and we have determined how three different characteristics of the regions where the firms are located affect innovation persistence. The three regional characteristics are labour market thickness, thickness of knowledge-intensive suppliers and the potential for intra-regional knowledge spillovers. Using a dynamic Probit model, we find that, in general, that firms located in regions with thicker labour markets, thicker supply of knowledge-intensive suppliers or a higher potential for knowledge spillovers have a higher probability of being persistent innovators. This higher persistency probability is in particular pronounced for product innovation. Thus location matters for innovation and for innovation persistency in particular. Our results indicate that policy-makers at the regional level can support innovation persistence through well-designed infrastructure, industrial, education and innovation policies. However, more research on these issues is needed. Actually, firms do not only perform simple innovation, i.e. product, process, organizational or market innovation. Often firms perform two, three or four types of innovation simultaneously and as far as we know, nobody has analysed persistence in these more complex types of innovation. Our hypothesis is that firms that are persistence in more complex types of innovation are more dependent upon the characteristics of the regions where they are located.

References

Antonelli, C. (2008), *Localized technological Change: Towards the Economics of Complexity*, Routledge, London

Antonelli, C. (2011) (Ed.), *Handbook on Economic Complexity of Technological Change*, Edward Elgar, Cheltenham

Antonelli, C., F. Crespi & G. Scellato (2013), Internal and External Factors in Innovation Persistence, *Economics of Innovation and New Technology 22*, 256-280

Antonelli, C., R. Marchionatti & S. Usai (2003), Productivity and External Knowledge: The Italian Case, *Rivista Internazionale di Scienze Economiche e Commerciali 50*, 69-90

Antonelli, C. & G. Scellato (2013), Complexity and Technological Change: Knowledge Interactions and Firm Level Total Factor Productivity, *Journal of Evolutionary Economics 23*, 77-96

Arrow, K.J. (1962 a), The Economic Implications of Learning by Doing, *Review of Economic Studies 29*, 155-173

Arrow, K.J. (1962 b), Economic Welfare and the Allocation of Resources for Invention, in Nelson, R.R. (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton University Press, Princeton, NJ, 609-625

Arthur, W.B. (1994), *Increasing Returns and Path Dependence in the Economy*, University of Michigan Press, Ann Arbor

Baptista, R. & G.M.P. Swann (1999), The Dynamics of Firm Growth and Entry in Industrial Clusters: A Comparison of the US and UK Computer Industries, *Journal of Evolutionary Economics 9*, 373-399

Beaudry, C. & G.M.P. Swann (2009), Firm Growth in Industrial Clusters of United Kingdom, *Small Business Economics 32*, 409-424

Beckmann, M.J. (1994), On Knowledge Networks in Science: Collaboration among Equals, *Annals of Regional Science 28*, 233-242

Beckmann, M.J. (2000), Interurban Knowledge Networks, in Batten, D. (Ed.), *Learning, Innovation and Urban Evolution*, Kluwer Academic, London, 127-135

Boschma, R.A. (2005), Proximity and Innovation: A Critical Assessment, *Regional Studies 39*, 61-74

Cohen, W.M. & S. Klepper (1996), Firm Size and the Nature of Innovation within Industries: The Case of Process and Product R&D, *The Review of Economics and Statistics 78*, 232-243

Colombelli, A. & N. von Tunzelmann (2011), The Persistence of Innovation and Path Dependence, in Antonelli, C. (Ed.), *Handbook on the Economic Complexity of Technological Change*, Edward Elgar, Cheltenham, 105-119

Czarnitzki, D. & H. Hottenrott (2010), Financial Constraints for Industrial Innovation: What Do We Know?. Faculty of Business and Economics, K.U. Leuven

David, P.A. (1993), Knowledge Property and the Dynamics of Technological Change, in *Proceedings of the World Bank Annual Conference on Development Economics*, The World Bank, Washington, D.C.

David, P.A. (2007), Path Dependence: A Foundational Concept for Historical Social Science, *Cliometrica: Journal of Historical Economics and Econometric History 1*, 91-114

Duguet, E. & S. Monjon (2002), Creative Destruction and the Innovative Core: Is Innovation Persistent at the Firm Lelvel?, Discussion Paper 02-07, Department of Economics, University College of London

Fagerberg, J., D. Mowery & R.R. Nelson (2005) (Eds.), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford

Fritsch, M. & G. Franke (2004), Innovation, Regional Knowledge Spillovers and R&D Cooperation, *Research Policy 33*, 245-255

Geroski, P., J. Van Reenen & C.F. Walters (1997), How Persistently Do Firms Innovate?, *Research Policy 26*, 33-48

Hannan, M.T. & J. Freeman (1984), Structural Inertia and Organizational Change, *American Sociological Review 49*, 149-164

Jaffe, Trajtenberg & Henderson (1993),

Johansson, B. & C. Karlsson (2009), Knowledge and Regional Development, in Capello, R. & P. Nijkamp (Eds.), *Handbook of Regional Growth and Development Theories*, Edward Elgar, Cheltenham, 239-255

Krugman, P. (1991), *Geography and Trade*, The MIT Press, Cambridge, MA

Langlois, L.N. & N.J. Foss (1999), Capabilities and Governance: The Rebirth of Production in the Theory of Organization, *Kyklos 52*, 201-218

Le Bas, C. & G. Scellato (2014), Firm Innovation Persistence: A Fresh Look at the Frameworks of Analysis, *Economics of Innovation and New Technology 23*, 423-446

Love, J.H. & S. Roper (2009), Organizing the Innovation Process: Complementarities in Innovation Networking, *Industry and Innovation 16*, 273-290

Máñez, J.A., et al., (2009), The Role of Sunk Costs in the Decision to Invest in R&D, *Journal of Industrial Economics 57*, 712-735

Nelson, R.R. (1959), The Simple Economics of Basic Scientific Research, *Journal of Political Economy 67*, 297-306

Nelson, R.R. & S.G. Winter (1982), *An Evolutionary Theory of Economic Change*, The Belknap Press, Cambridge, MA

Phillips, A. (1971), *Technology and Market Structure: A Study of the Aircraft Industry*, Heath Lexington Books, Toronto

Polanyi, M. (1966), *The Tacit Dimension*, Routledge, Kegan & Paul, London

Romer, P. (1990), Endogenous Technological Change, *Journal of Political Economy 98*, 71-102

Ruttan, V.W. (1997), Induced Innovation, Evolutionary Theory and Path Dependence: Sources of Technological Change, *The Economic Journal 107*, 1520-1529

Scellato, G. & E. Ughetto (2010), The Basel II Reform and Provision of Finance for R&D Activities, *International Small Business Journal 28*, 65-89

Tavassoli, S. & C. Karlsson (2015), Persistence of Various Types of Innovation Analyzed and Explained, *Research Policy 44*, 1887-1901

Teece, D.J. (1981), The Market for Know-How and the Efficient International Transfer of Technology, *Annals of the American Association of Political and Social Sciences 458*, 54-67

Teece, D.J. (1986), Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy, *Research Policy 15*, 285-305

Torre, A. & A. Rallet (2005), Proximity and Localization, *Regional Studies 39*, 47-59

Verspagen, B. & T.H. Clausen (2012), The Dynamics of Innovation Strategies, in Andersson, M., et al. (Eds.), *Innovation and Growth*, Oxford University Press, Oxford, 38-56

von Hippel, E. (1994), Sticky Information and the Locus of Problem Solving: Implications for Innovation, *Management Science 40*, 429-439

von Tunzelmann, G. & Q. Wang (2003), An Evolutionary View of Dynamic Capabilities, *Economie Appliquée 16*, 33-64

Weitzman, M.L. (1998), Recombinant Growth, *Quarterly Journal of Economics 113*, 331-360

Table 1-Descriptive statistics

VARIABLES	Observ.	Mean	Std, Dev,	Min	Max	P.cut#1	P.cut#2
$PROD_{it}$	2870	0,38	0,48	0	1	-	-
$PROC_{it}$	2870	0,39	0,49	0	1	-	-
ORG_{it}	1722	0,35	0,48	0	1	-	-
MAR_{it}	1722	0,34	0,47	0	1	-	-
$SIZE$	2870	4,50	1,52	2,30	9,88	-	-
$INN.INP_{it}$	2870	7,92	6,68	0	24,18	-	-
$COOP_{it}$	2870	0,35	0,48	0	1	-	-
$CON.R\&D_{it}$	2870	0,31	0,46	0	1	-	-
$IMPORT_{it}$	2870	0,12	0,17	0	1	-	-
$EXPORT_{it}$	2870	0,24	0,33	0	1	-	-
$PHY.CAP_{it}$	2870	16,55	3,29	0	23,95	-	-
$HUM.CAP_{it}$	2870	0,16	0,17	0	0,89	-	-
$UNIN_{i}$	2870	0,31	0,46	0	1	-	-
$D.MNE_{i}$	2870	0,26	0,44	0	1	-	-
$F.MNE_{i}$	2870	0,29	0,46	0	1	-	-
$LABORMARKET_{it}$	2870	27076	34020	10	88336	2097	36403
$SUPPLIER_{it}$	2870	3230	4121	0,00	12304	23	4106
RV_{it}	2870	2,43	0,41	0,81	2,95	2.27	2.72

Note: P.cut#1 is the cutting point for the percentile 33% and P.cut#2 is the cutting point for the percentile 66%

Table 2- The effect of Low, Medium, and High regional labor market thickness on persistency of various types of innovation

	$PROD_{it}$			$PROC_{it}$			ORG_{it}			MAR_{it}		
Variables	(1) Low	(2) Medium	(3) High	(4) Low	(5) Medium	(6) High	(7) Low	(8) Medium	(9) High	(10) Low	(11) Medium	(12) High
$PROD_{it-1}$	0.416*	0.247	0.634***									
	(0.225)	(0.233)	(0.237)									
$PROD_{i0}$	0.598***	1.154***	0.637**									
	(0.215)	(0.295)	(0.251)									
$PROC_{it-1}$				-0.083	0.253	0.352**						
				(0.205)	(0.184)	(0.157)						
$PROC_{i0}$				0.671***	0.174	0.100						
				(0.190)	(0.148)	(0.134)						
ORG_{it-1}							0.329	-0.001	0.388**			
							(0.307)	(0.345)	(0.182)			
ORG_{i0}							-0.167	0.248	0.021			
							(0.244)	(0.314)	(0.186)			
MAR_{it-1}										-0.085	0.480*	0.243
										(0.366)	(0.194)	(0.192)
MAR_{i0}										0.534	-0.131	0.090
										(0.329)	(0.195)	(0.194)
$SIZE_{it-1}$	-0.184	0.124	0.243**	0.125	-0.016	0.007	0.178	0.242*	0.071	0.142	-0.138	0.098
	(0.158)	(0.149)	(0.109)	(0.148)	(0.104)	(0.083)	(0.150)	(0.136)	(0.092)	(0.158)	(0.110)	(0.081)
$INN.INP_{it-1}$	0.004	0.010	0.033	-0.015	0.082***	0.030	0.028	0.059**	0.030	0.029	0.008	0.036*
	(0.025)	(0.030)	(0.026)	(0.025)	(0.025)	(0.021)	(0.025)	(0.030)	(0.021)	(0.028)	(0.024)	(0.020)
$COOP_{it-1}$	0.612*	-0.014	0.136	0.881***	-0.442	0.326	-0.001	0.274	0.364	0.263	0.517*	-0.113
	(0.327)	(0.359)	(0.352)	(0.314)	(0.281)	(0.273)	(0.301)	(0.333)	(0.274)	(0.307)	(0.273)	(0.261)
$CON.R\&D_{it-1}$	0.993***	0.130	0.215	0.436	0.041	0.398	-0.209	-0.530	-0.384	0.059	0.385	0.000
	(0.363)	(0.377)	(0.360)	(0.345)	(0.293)	(0.285)	(0.310)	(0.416)	(0.287)	(0.319)	(0.334)	(0.278)
$IMPORT_{it-1}$	-0.149	-0.422	-0.513	0.133	-1.626**	-0.327	-0.978	-0.301	0.027	0.133	-0.152	-0.064
	(0.932)	(0.990)	(0.855)	(0.994)	(0.784)	(0.721)	(0.941)	(0.909)	(0.609)	(0.829)	(0.762)	(0.597)
$EXPORT_{it-1}$	-0.166	1.285**	1.571***	-0.261	0.127	-0.104	-0.179	0.388	0.245	0.402	-0.143	0.755*
	(0.496)	(0.569)	(0.564)	(0.488)	(0.416)	(0.396)	(0.447)	(0.543)	(0.403)	(0.450)	(0.425)	(0.403)
$PH.CAP_{it-1}$	0.059	0.057	-0.024	0.079	0.089**	0.048*	0.016	0.002	0.055	0.005	0.076	0.017
	(0.057)	(0.051)	(0.037)	(0.062)	(0.036)	(0.029)	(0.060)	(0.050)	(0.033)	(0.065)	(0.047)	(0.025)
$HUM.CAP_{it-1}$	-0.679	1.696**	1.595***	-0.071	0.685	0.279	2.657**	0.300	0.407	-0.585	0.431	-0.387
	(1.024)	(0.749)	(0.556)	(0.947)	(0.485)	(0.383)	(1.037)	(0.818)	(0.515)	(1.093)	(0.621)	(0.497)
UNIN	-0.222	-0.382	-0.262	-0.305	0.080	-0.158	-0.001	0.360	-0.126	0.126	0.212	-0.063

	(0.224)	(0.281)	(0.277)	(0.221)	(0.188)	(0.226)	(0.268)	(0.344)	(0.296)	(0.300)	(0.254)	(0.286)
D.MNE	-0.189	-0.330	-0.510*	-0.369	-0.007	-0.205	0.208	-0.095	-0.293	-0.267	-0.046	-0.217
	(0.247)	(0.306)	(0.297)	(0.252)	(0.213)	(0.238)	(0.300)	(0.375)	(0.324)	(0.328)	(0.278)	(0.307)
F.MNE	-0.101	-0.487	-0.457	-0.455*	-0.262	-0.257	-0.239	-0.329	-0.447	-0.199	-0.308	-0.497
	(0.264)	(0.328)	(0.307)	(0.269)	(0.223)	(0.242)	(0.322)	(0.412)	(0.321)	(0.351)	(0.296)	(0.307)
Nr. of firms	200	244	211	211	255	211	208	214	201	210	218	201
Observation	717	718	768	752	753	768	400	367	356	404	374	357

Notes: The table reports the estimated parameters with standard errors in the parentheses. ***,** and * indicate significance on a 1%, 5% and 10% level. For each innovation type, the total sample is broken down into firms located in low, medium, and high labor market thickness. These three categories are obtained by means of three equal percentiles value of total regional employment in all regions as follows. Low: if total regional employment<2097, Medium: if total regional employment>=2097 & total regional employment<=36403, High: if total regional employment>36403. The estimation approach follows Wooldridge (2005). All models include sets of sector and time dummies as well as $\boldsymbol{x}_i$, which correspond to each of the explanatory variables in each period from t=2006 to t=2012. They are not shown in the table for the sake of brevity. Estimations are based on Gauss–Hermite quadrature approximations using twelve quadrature points. The accuracy of the results has been checked by applying eight, fourteen and sixteen quadrature points.

Table 3- The effect of Low, Medium, and High regional service provider thickness on persistency of various types of innovation

Variables	$PROD_{it}$			$PROC_{it}$			ORG_{it}			MAR_{it}		
	(1') Low	(2') Medium	(3') High	(4') Low	(5') Medium	(6') High	(7') Low	(8') Medium	(9') High	(10') Low	(11') Medium	(12') High
$PROD_{it-1}$	0.672**	0.111	0.767***									
	(0.225)	(0.238)	(0.238)									
$PROD_{i0}$	0.294	1.200***	0.586***									
	(0.213)	(0.300)	(0.217)									
$PROC_{it-1}$				-0.029	0.319*	0.189						
				(0.204)	(0.188)	(0.166)						
$PROC_{i0}$				0.651***	0.293*	0.100						
				(0.189)	(0.154)	(0.135)						
ORG_{it-1}							0.552	0.027	0.333*			
							(0.350)	(0.392)	(0.173)			
ORG_{i0}							-0.266	0.191	-0.035			
							(0.306)	(0.315)	(0.177)			
MAR_{it-1}										0.434*	0.206	0.202
										(0.204)	(0.338)	(0.176)
MAR_{i0}										0.041	-0.132	0.307*
										(0.214)	(0.254)	(0.181)
$SIZE_{it-1}$	-0.110	0.060	0.335***	0.068	0.105	-0.020	0.293	0.224*	0.047	0.113	-0.192	0.110
	(0.156)	(0.127)	(0.127)	(0.145)	(0.086)	(0.105)	(0.197)	(0.132)	(0.088)	(0.145)	(0.120)	(0.077)
$INN.INP_{it-1}$	0.012	0.002	0.060*	0.015	0.024	0.079***	-0.015	0.075**	0.052***	0.018	0.003	0.042**
	(0.024)	(0.028)	(0.034)	(0.023)	(0.021)	(0.027)	(0.030)	(0.031)	(0.019)	(0.025)	(0.026)	(0.019)
$COOP_{it-1}$	0.436	-0.119	0.679	0.390	0.055	0.002	0.104	-0.021	0.395	0.581**	0.369	-0.149
	(0.304)	(0.352)	(0.439)	(0.285)	(0.250)	(0.359)	(0.365)	(0.319)	(0.252)	(0.286)	(0.293)	(0.241)
$CON.R\&D_{it-1}$	0.744**	0.401	0.155	0.601*	0.131	0.317	0.297	-0.597*	-0.528*	0.327	0.042	0.026
	(0.339)	(0.348)	(0.456)	(0.314)	(0.267)	(0.363)	(0.395)	(0.359)	(0.272)	(0.324)	(0.313)	(0.263)
$IMPORT_{it-1}$	0.231	-0.813	0.949	1.031	-1.455**	0.448	-0.071	-1.124	0.138	-0.313	-0.052	0.095
	(1.001)	(0.810)	(1.253)	(0.973)	(0.651)	(1.030)	(1.169)	(0.961)	(0.536)	(0.885)	(0.803)	(0.532)
$EXPORT_{it-1}$	0.151	1.368***	1.612**	-0.479	0.355	-0.622	-0.812	0.570	0.106	-0.009	0.473	0.503
	(0.487)	(0.505)	(0.767)	(0.461)	(0.355)	(0.525)	(0.611)	(0.497)	(0.357)	(0.454)	(0.444)	(0.355)
$PH.CAP_{it-1}$	0.043	0.047	-0.078*	0.084	0.053*	0.052	0.068	-0.030	0.062*	-0.026	0.097*	0.018
	(0.065)	(0.044)	(0.044)	(0.062)	(0.030)	(0.037)	(0.086)	(0.044)	(0.033)	(0.066)	(0.051)	(0.025)
$HUM.CAP_{it-1}$	-0.927	2.060***	1.392***	0.177	0.566	0.319	0.577	0.047	0.408	-1.310	0.286	-0.357
	(0.938)	(0.776)	(0.509)	(0.829)	(0.468)	(0.417)	(1.143)	(0.789)	(0.491)	(0.946)	(0.679)	(0.484)
UNIN	-0.599***	-0.002	-0.099	-0.333*	0.177	-0.269	-0.170	0.367	-0.187	-0.169	0.384	0.070

	(0.224)	(0.279)	(0.290)	(0.200)	(0.180)	(0.251)	(0.327)	(0.301)	(0.301)	(0.240)	(0.266)	(0.292)
D.MNE	-0.283	-0.200	-0.227	-0.437*	-0.140	-0.286	0.401	-0.323	-0.446	-0.283	0.062	-0.147
	(0.245)	(0.299)	(0.300)	(0.245)	(0.198)	(0.263)	(0.399)	(0.324)	(0.319)	(0.297)	(0.283)	(0.307)
F.MNE	-0.484*	0.144	-0.368	-0.457*	-0.355*	-0.362	-0.335	-0.486	-0.486	-0.481	0.063	-0.502
	(0.273)	(0.312)	(0.316)	(0.262)	(0.214)	(0.266)	(0.430)	(0.364)	(0.316)	(0.328)	(0.303)	(0.308)
Nr. of firms	202	269	244	214	275	247	175	198	240	181	198	240
Observation	687	771	752	735	793	760	349	347	431	361	347	432

Notes: The table reports the estimated parameters with standard errors in the parentheses. ***,** and * indicate significance on a 1%, 5% and 10% level. For each innovation type, the total sample is broken down into firms located in low, medium, and high employment in Knowledge Intensive Services (KIS) sectors as a proxy for regional service suppliers. These three categories are obtained by means of three equal percentiles value of KIS employment in all regions as follows. Low: if KIS regional employment<23, Medium: if KIS regional employment>=23 & KIS regional employment<=4106, High: if KIS regional employment>4106. The estimation approach follows Wooldridge (2005). All models include sets of sector and time dummies as well as $\boldsymbol{x}_i$, which correspond to each of the explanatory variables in each period from t=2006 to t=2012. They are not shown in the table for the sake of brevity. Estimations are based on Gauss–Hermite quadrature approximations using twelve quadrature points. The accuracy of the results has been checked by applying eight, fourteen and sixteen quadrature points.

Table 4- The effect of Low, Medium, and High regional knowledge spillovers on persistency of various types of innovation

	$PROD_{it}$			$PROC_{it}$			ORG_{it}			MAR_{it}		
Variables	(1'') Low	(2'') Medium	(3'') High	(4'') Low	(5'') Medium	(6'') High	(7'') Low	(8'') Medium	(9'') High	(10'') Low	(11'') Medium	(12'') High
$PROD_{it-1}$	0.313	0.603***	0.500***									
	(0.250)	(0.209)	(0.241)									
$PROD_{i0}$	0.819***	0.527**	0.839***									
	(0.254)	(0.206)	(0.265)									
$PROC_{it-1}$				-0.158	0.397***	0.388**						
				(0.198)	(0.150)	(0.170)						
$PROC_{i0}$				0.409**	0.381***	0.057						
				(0.167)	(0.131)	(0.136)						
ORG_{it-1}							-0.297	0.604***	0.412**			
							(0.417)	(0.203)	(0.204)			
ORG_{i0}							0.319	-0.194	-0.013			
							(0.322)	(0.202)	(0.208)			
MAR_{it-1}										0.020	0.402*	0.230
										(0.332)	(0.209)	(0.343)
MAR_{i0}										0.036	0.393*	0.178
										(0.244)	(0.211)	(0.301)
$SIZE_{it-1}$	-0.189	-0.079	0.366***	0.122	0.034	-0.036	0.144	0.166	0.094	-0.004	0.026	0.095
	(0.170)	(0.127)	(0.123)	(0.141)	(0.096)	(0.088)	(0.180)	(0.127)	(0.094)	(0.132)	(0.125)	(0.085)
$INN.\,INP_{it-1}$	-0.000	-0.006	0.046*	0.055**	-0.006	0.051**	0.021	0.008	0.073***	0.035	0.006	0.043*
	(0.031)	(0.024)	(0.027)	(0.028)	(0.021)	(0.021)	(0.030)	(0.023)	(0.022)	(0.025)	(0.022)	(0.022)
$COOP_{it-1}$	-0.006	0.429	0.455	0.358	0.147	0.136	0.290	0.047	0.366	0.465*	0.225	0.030
	(0.403)	(0.297)	(0.353)	(0.322)	(0.250)	(0.281)	(0.340)	(0.287)	(0.289)	(0.277)	(0.274)	(0.277)
$CON.\,R\&D_{it-1}$	0.802*	0.549*	0.193	0.186	0.616**	0.033	-0.253	-0.063	-0.773**	0.218	-0.119	0.081
	(0.416)	(0.327)	(0.367)	(0.353)	(0.271)	(0.282)	(0.357)	(0.331)	(0.321)	(0.290)	(0.322)	(0.316)
$IMPORT_{it-1}$	2.105	-0.171	-1.080	-1.261	-0.168	-1.159*	-0.636	-0.502	-0.021	0.022	-0.060	-0.049
	(1.588)	(0.804)	(0.838)	(1.160)	(0.694)	(0.693)	(1.014)	(0.725)	(0.654)	(0.801)	(0.684)	(0.656)
$EXPORT_{it-1}$	0.331	0.574	1.408***	0.330	-0.100	-0.200	0.184	0.146	0.134	0.196	0.878**	0.107
	(0.563)	(0.490)	(0.542)	(0.484)	(0.393)	(0.391)	(0.519)	(0.434)	(0.415)	(0.404)	(0.422)	(0.441)
$PH.\,CAP_{it-1}$	0.068	0.061	-0.053	0.036	0.040	0.096***	0.104	-0.021	0.043	0.041	0.013	0.012
	(0.056)	(0.050)	(0.040)	(0.048)	(0.038)	(0.031)	(0.088)	(0.062)	(0.031)	(0.059)	(0.060)	(0.027)
$HUM.\,CAP_{it-1}$	1.192	1.287**	1.488**	0.276	0.569	0.173	2.483*	0.730	0.207	-0.600	-0.515	0.108
	(0.941)	(0.614)	(0.584)	(0.769)	(0.447)	(0.393)	(1.275)	(0.657)	(0.509)	(0.901)	(0.690)	(0.512)
UNIN	-0.123	-0.354	-0.295	-0.017	-0.124	-0.149	0.162	0.140	-0.146	-0.100	0.310	0.150

	(0.237)	(0.226)	(0.315)	(0.203)	(0.174)	(0.237)	(0.334)	(0.279)	(0.325)	(0.244)	(0.271)	(0.320)
D.MNE	0.011	-0.167	-0.432	-0.207	-0.276	-0.106	-0.280	0.115	-0.293	-0.365	-0.138	-0.091
	(0.273)	(0.241)	(0.333)	(0.243)	(0.190)	(0.245)	(0.380)	(0.300)	(0.339)	(0.289)	(0.298)	(0.330)
F.MNE	0.182	-0.281	-0.451	-0.427	-0.357*	-0.235	-0.570	-0.046	-0.569*	-0.442	-0.290	-0.379
	(0.300)	(0.266)	(0.327)	(0.266)	(0.212)	(0.240)	(0.434)	(0.334)	(0.331)	(0.321)	(0.329)	(0.328)
Nr. of firms	213	239	195	221	247	195	208	191	189	216	190	192
Observation	746	735	748	776	758	748	398	355	369	414	353	375

Notes: The table reports the estimated parameters with standard errors in the parentheses. ***,** and * indicate significance on a 1%, 5% and 10% level. For each innovation type, the total sample is broken down to firms located in low, medium, and Related Variety as a proxy for knowledge spillovers. These three categories are obtained by means of three equal percentile values of Related Variety index in all regions as follows. Low: if Related Variety<2.274, Medium: if Related Variety >=2.274 & Related Variety<=2.721, High: if Related Variety>2.721. The estimation approach follows Wooldridge (2005). All models include sets of sector and time dummies as well as $\boldsymbol{x}_i$, which correspond to each of the explanatory variables in each period from t=2006 to t=2012. They are not shown in the table for the sake of brevity. Estimations are based on Gauss–Hermite quadrature approximations using twelve quadrature points. The accuracy of the results has been checked by applying eight, fourteen and sixteen quadrature points.

Appendix 2-Variable definitions

Variables	**Type**	**Definitions**
$PROD_{it}$	0/1	1 if firm *i* introduces a product innovation into the market in year *t*, 0 otherwise. A product innovation is the market introduction of a new or significantly improved good or service with respect to its capabilities, user friendliness, components or sub-systems. Product innovations (new or improved) must be new to the enterprise, but they do not need to be new to the market.
$PROC_{it}$	0/1	1 if firm *i* introduces a process innovation in year *t*, 0 otherwise. A process innovation is the implementation of a new or significantly improved production process, distribution method, or support activity for goods or services, such as maintenance systems or operations for purchasing, accounting, or computing (exclude purely organizational innovation). Process innovations must be new to the enterprise, but they do not need to be new to your market.
ORG_{it}	0/1	1 if firm *i* introduces an organizational innovation in year *t*, 0 otherwise. An organizational innovation is a new organizational method in the enterprise's business practices (including knowledge management), workplace organization and decision making, or external relations that has not been previously used by the enterprise. It must be the result of strategic decisions taken by management. It exclude mergers or acquisitions, even if for the first time.
MAR_{it}	0/1	1 if firm *i* introduces a marketing innovation in year *t*, 0 otherwise. A marketing innovation is the implementation of a new marketing concept or strategy that differs significantly from the enterprise's existing marketing methods and which has not been used before. It requires significant changes in product design or packaging, product placement, product promotion or pricing. It exclude seasonal, regular and other routine changes in marketing methods.
$INN.INP_{it}$	C*	Innovation inputs is the sum of following six expenditures in firm *i* year *t* (log): engagement in intramural R&D, engagement in extramural R&D, engagement in acquisition of machinery, engagement in other external knowledge, engagement in training of employees, and engagement in market introduction of innovation
$SIZE_{it}$	C	Number of employees in firm *i* year *t* (log)
$COOP_{it}$	0/1	1 if firm *i* in year *t* had any cooperation with other customers, suppliers, competitors in, 0 otherwise
$CONT.R\&D_{it}$	0/1	1 if firm *i* in year *t* had continuous R&D investments over the past two years, 0 otherwise
$IMPORT_{it}$	C	The amount (value in SEK) of import per employee for firm *i* in year *t* (log)
$EXPORT_{it}$	C	The amount (value in SEK) of export per employee for firm *i* in year *t* (log)
$UNIN_{i}$	0/1	1 if firm *i* belongs to a group and is uninational, 0 otherwise (Non-affiliated as based)
$D.MNE_{i}$	0/1	1 if firm *i* belongs to group and is a domestic multinational enterprise, 0 otherwise
$F.MNE_{i}$	0/1	1 if firm belongs to group and is a foreign multinational enterprise, 0 otherwise
$PH.CAP_{it}$	C	Sum of investments in Buildings and Machines at year's end for firm *i* in year *t* (log)
$HUM.CAP_{it}$	C	Share of employees with 3 or more years of university educations in firm *i* in year *t*
$LABPORMAR_{it}$	C	The total number of employees in functional region r in year t minus firm i's employment (log)
$SUPPLIER_{it}$	C	The number of employees in KIS** sector in functional region r in year t minus firm i's employment, if firm I is in KIS sector itself (log)
RV_{rt}	C	The related variety of knowledge in region r year t (see Equation 1)
Time Dummies	0/1	Time-specific component captured by five time dummies
Sector Dummies	0/1	Sector-specific component captured by forty two sector dummies

*C corresponds to continuous variables

**KIS: Knowledge Intensive Services, which corresponds to following NACE codes: 61-62 (Water transport; air transport), 64 (Post and telecommunication), 65-67 (Financial intermediation), 70 (Real estate activities), 71 (Renting of machinery and equipment), 72 (Computer and related activities), 73 (Research and development), 74 (Other business activities), 80 (Education), 85 (Health and social work), 92 (Recreational, cultural and sporting activities).