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Persistence of Various Types of Innovation Analyzed and Explained

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JEL codes: D22, L20, O31, O32

Keywords: Persistence, innovation, product innovations, process innovations, market innovations, organizational innovations, state dependence, heterogeneity, firms, Community Innovation Survey

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1. Introduction

The performance of firms even in the same industry is highly skewed and this heterogeneity in performance is to a high extent persistent over time. Innovation[1] can be seen as one major determinant of the performance of firms, which would imply that the observed heterogeneity in performance among firms actually mirrors persistent differences in innovation behavior among firms (Geroski, Van Reenen & Walters, 1997). This implies that in every industry we should be able to observe firms that innovate persistently, firms that innovate now and then and firms that never innovate. Although evidence shows that firms tend to innovate persistently in high-tech industries, e.g. semiconductor (Jelinek and Schoonhove, 1990), it is still interesting to understand what factors induces firms to choose strategies implying continuous, intermittent or no innovation (Brown & Eisenhardt, 1998).

Innovation is here seen as the purposeful result of the ability of firms to generate new knowledge and their decisions to apply it to new products and product varieties, processes, organizational designs, and combinations of inputs and markets (Fagerberg, Mowery & Nelson, 2005). The persistence of innovation highlights the influence of past and current innovation on future innovation. It has become an important topic in applied industrial economics since the publication of a seminal paper by Geroski, Van Reenan & Walters (1997), while already pointed out in the key contribution of "Innovation Marathon" (Jelinek and Schoonhove, 1990). The line of empirical research that followed gave rise to an increased conviction that the competitive advantage of firms mainly depends on their ability to innovate over longer periods of time (Le Bas & Scellato, 2014). However, this ability is a function of environmental, organizational, process and managerial characteristics of firms (Koberg, Detienne & Heppard, 2003). We still have a limited understanding of the long-term determinants of the innovation behavior of firms including their investments in different types of innovation, such as products, processes, organization and markets. To increase our understanding of these issues, we in this paper try to answer the following five related questions: Is innovation persistent at the firm level? Is this true for all types of innovation? Does the degree of persistency the same or differ from each other in different types of innovation? If innovation persistence exists, is it a "true" or "spurious" one? Are the drivers of persistency the same for all types of innovation?

[1] In this paper, we will not discuss the problems of actually defining an innovation since we are using the definitions used in the European Community Innovation Surveys. The definition problem is highlighted in, for example, Garcia & Calantone (2002).

Why are these questions interesting and important? Persistence in innovation has far-reaching effects for various fields of economics dealing with innovation, for the strategic management and operation of innovation processes and for public policy focusing innovation (Peters 2007). Firstly, they are important from the point of view of economic theory. A proven persistence would validate endogenous growth theory, since according to that theory sustainable economic growth is a function of firms' capacity to accumulate economically useful technological knowledge. However, different endogenous growth models make different fundamental assumptions about the determinants of the innovation performance of firms. In the Romer model, it is assumed that innovation mainly is persistent at the firm level and the cumulative knowledge creation are the fundamental sources of innovation and economic growth (Romer, 1990)[2]. Secondly, from a strategic management perspective persistence of innovation, i.e. a continuous loop of innovation, supplies a fundamental building block of maintained competitive advantage and long-lived inter-firm performance differences (Ganter & Hecker, 2013). Thirdly, knowledge about the drivers of firms' innovation behavior is critical for policy makers. If innovation is persistent in the sense that innovation drives innovation, policies designed to support innovation can be expected to have more far-reaching effects since they not only affect innovation in the current period but also in future periods and thus in principle should be able to raise innovation to new levels. Thus, true innovation persistence implies the existence of inter-temporal and inter-generational spillovers, which provides a foundation for the evaluation public programs designed to stimulate innovation. The existence of true and strong innovation persistence also suggests that innovation policies should avoid stimulating the start-up of firms and firms entering new markets. On the other hand, if the observed persistence is the result of other underlying firm characteristics, policy makers should rather try to stimulate those underlying characteristics of firms that drive innovation.

The purpose of this paper is to analyze persistent patterns of innovation for different types of innovation using Swedish data from five waves of Community Innovation Surveys and to test possible explanations for proven persistence. The contribution of this paper is as follows: (i) moving beyond commonly used technology-related innovation and instead incorporating four types of innovation based on actual Schumpeterian classification, i.e. product, process,

[2] However, the Romer approach neglects the role of new entrants and creative destruction as drivers of innovation and economic growth and to acknowledge this we have to turn to endogenous growth models including creative destruction processes, which, for example, assume a process of a perpetual renewal of innovators (Aghion & Howitt, 1992). The only way to assess these different representations of the economic growth process and the dynamics in the innovation behavior of firms is through empirical analyses (Cefis, 2003).

marketing, and organizational innovations in an economy-wide setting[3], (ii) theoretically and empirically distinguish between the persistency of four Schumpeterian types of innovation and showing that these four types do not behaving with the same degree of persistency[4], (iii) using a long panel of Community Innovation Survey (CIS) data and tracing the innovative behavior of firms during ten years period (this is, to our knowledge, the longest panel of CIS that is constructed), and (iv) moving beyond the usual manufacturing sector and including the service sector in the analysis as well[5].

The rest of the paper is organized as follows. Section 2 provides the general theoretical causes of innovation persistence (2.1) and specifically for each types of innovation (2.2). Section 3 offers a short overview on empirical evidence concerning the persistency of innovation. Section 4 shows the data. Section 5 investigates whether there is a persistency in various types of innovation, while Section 6 analyses whether it is a true persistency or not and distinguishes between the degree of persistency in various types of innovation. Section 7 concludes.

2. Literature Review

2.1 The General Underlying Theoretical Causes of Innovation Persistence

The underlying theoretical causes of innovation persistence are not well understood to put it mildly. And when it is discussed, it is mostly biased toward technological innovation and non-technological innovations are less discussed (Le Bas & Scellato, 2014). However, by consulting a few different fields of economics and also management, we may at least be able to present some general causes to why innovation might demonstrate state dependence over time, no matter which innovation type is in question. The main underlying theoretical causes of innovation persistence can be seen through the lens of knowledge, learning and dynamic scale economies. Already, Geroski, Van Reenen & Walters (1997) suggested that innovation persistence could 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. Thus, innovation is the result of cumulative knowledge patterns and learning dynamics (Colombelli & von Tunzelmann,

[3] Ganter and Hecker (2013) is an exception. Nevertheless, this study did not incorporate marketing innovation.
[4] In the theoretical part, this is done by bringing together arguments from a wide range literature spanning from management to economics.
[5] Peters (2009) is an exception.

2011). Knowledge is as an economic good characterized by being cumulative and non-exhaustible (Nelson, 1959; Nelson & Winter, 1981; Ruttan, 1997). At the same time as knowledge is an input in knowledge production process, it is also an output from the same process (David, 1993). These attributes have distinct implications for innovation persistence, no matter which types of innovation is in question. The creation of new knowledge vintages have an effect on the disposable knowledge stock that can be used as an input in knowledge generation due to that knowledge is non-exhaustible. This implies that firms that have been able to start creating new knowledge use their own knowledge stock to create new additional knowledge at a lower cost compared to competitors at the same time as they develop their innovative capability exploiting dynamic economies of scale. Such generation of knowledge is important not only for technological innovation (product and process), but also for non-technological innovation (marketing and organizational) because all types of innovation entails some degrees of novelty that has not existed before (at least for the firm) and can be only introduced through knowledge generation.

Experience of innovation among the employees generate dynamic increasing returns as a result of learning effects, which increase a firm's knowledge stock and hence increase their innovative capabilities (Arrow, 1962a). This implies to both technological and non-technological types of innovation. By innovating, a firm is engaged in a learning process through which it discovers new ideas be recombining existing ideas in new ways. The more knowledge pieces and ideas it has generated in the past, the higher is its ability to recombine them in order to generate new ideas and pieces of knowledge (Weitzman, 1996), which implies that past innovation affects current innovation (Duguet & Monjon, 2002). Furthermore, a firm's absorptive capacity is a function of the human capital of its employees and with increased learning in one period that further increases this absorptive capacity the firm will be able to more efficiently accumulate external knowledge in subsequent periods (Cohen & Levinthal, 1990). The cumulative nature of innovative capabilities represents a process that might induce state dependence in various types of innovation of firms. To put it in other words, all types of innovation demands organizational capabilities, even if the type of capabilities varies for the different types of innovation. Such capabilities are difficult to create 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 (while they may make it difficult to shift between different types of innovation).[6]

2.2 Persistence in Four Different Types of Innovations

Beside a general argument for potential persistency of all types of innovation (Section 2.1), one could go further and find other arguments (theories) that are innovation type-specific, i.e. they speak in favor of one but against the other types of innovation). This would raise a critical question here whether we shall expect equal persistence in all four types of innovation or not? The type-specific arguments comes from both economics and management literature and they are as follows: “Success Breeds Success” (Flaig and Stadler, 1994), R&D Sunk Cost (Sutton, 1991; Máñez et al, 2009), Appropriation Theory (Teece, 1986), Resistance to Change (Hannan and Freeman, 1984), Market Orientation (Narver and Slater, 1990), and Disruptive Technologies (Bower and Christensen, 1995). We will use these theories (arguments) in favor/against high degree of persistency for each and every innovation types, whenever applicable. This is explained in below sections (2.2.1 to 2.2.4) and summarized in Appendix 1. But before that, in line with Schumpeter (1934), we distinguish between four main types of innovation, namely, product, process, organizational and market innovation[7]. As we will argue below, the degree of persistency among various types of innovation should not be equal. This is because all types of innovation do not receive equal amount of supporting arguments for their possible persistency. Below we will explain what we mean by each type of innovation as well as what we expect when it comes to degree of persistency in each type of innovation.

2.2.1 Product Innovations

Product innovations emerge when a new product or a new variety of an existing product is introduced in the market place aiming at satisfying a specific customer demand (See Appendix 2 for exact definition). Product innovations can but need not involve a technological innovation. This is obvious since products include both goods and services. A prime goal of product innovations is to introduce new products and new product varieties that

[6] Perhaps it is worthy to note that it is important to make a distinction between ‘path-dependent’ and ‘past-dependent’ innovation persistence (Antonelli et al, 2013). If current innovation can be explained by past innovation, we have ‘past-dependent’ innovation persistence. If, on the other hand, current innovation is a result of processes determined by initial conditions, we talk about ‘past-dependent’ innovation persistence. However, also ‘path-dependent’ processes are affected by context factors that influence the rate and direction of innovative processes in different periods and different locations.

[7] The innovation taxonomy offered by Edquist et al (2001) can be an alternative but similar reference here.

allow the firm to gain at least a temporary monopoly position, which gives it a freedom to set prices above marginal costs[8]. Given the critical role of product innovations for the long-term competitiveness of firms in many industries and markets, we believe that we will find the highest degree of innovation persistence for product innovations.

More specifically, the persistent behavior of product innovators can be explained by three supporting arguments: R&D Sunk Cost, "Success Breeds Success", and Appropriation Theory. First, the long-term commitments and investments of firms to setup of R&D infrastructures and laboratories are fixed outlays, which represent distinct sunk costs[9]. The sunk cost hypothesis implies that firms deciding to invest in R&D incur start-up costs that usually are not recoverable except through the incomes from successful innovations. This implies that R&D investments over time generate a stock of physical and knowledge capital that in the longer term can be used in innovative activities and contribute to a more or less continuous flow of innovations. This implies that when such investments have been taken, these firms are expected to have a continuous flow of product innovations. Moreover, as R&D investments are a driver of product innovation, the persistence of the former might lead to persistence of the latter, i.e. innovation (Cohen & Klepper, 1996). Moreover, sunk cost hypothesis implies 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 have to observe that the presence of sunk costs reduce the costs of future innovative activities and thus induce innovating firms to continue innovating while it may prevent non-innovating firms to engage in innovative activities (Máñez et al., 2009).

The second argument that can explain the persistency of product innovators are so called "Success breeds Success" and Resource Constraints (Phillips, 1971). Successful product innovation can have a positive impact on innovative firms' conditions for subsequent innovations by normally providing prosperous innovators with higher market power for an extended period, i.e. 'success breeds success'. The innovation success of firms may broaden

[8] In one hand, according to Arrow (1962b), when a monopolist innovates she basically replaces herself as the monopolist in his market. Because of such replacement effect, the monopolist gains less from innovating than does a competitive firm. This approach based on the "replacement effect" predict limited persistence in. However, on the other hand, Gilbert and Newberry (1982) showed that a monopolist can be threatened by a potential entrant. In this situation it is possible to demonstrate, because such entry possibly reduce her profits, the monopolist's incentives to remain a monopolist are greater than the entrant's incentive to become a duopolist. Therefore, she prefers to persist to innovate.

[9] These cost includes, for instance, establishing, equipping and supporting R&D facilities, employment and training of specialized R&D staff, and establishing advanced information systems for the collection and distribution of internal and external R&D results including patent applications as well as the implementation of the necessary routines (Máñez et al, 2009).

the space of available technological opportunities and opens up for exploiting economies of scope, which increases the probability of subsequent product innovation success (Mansfield, 1968; Scellato & Ughetto, 2010). Successful product innovations also reduce the financial constraints of innovating firms partly because of increased market power. Resource constraints have been launched in the literature as an explanation of innovation persistence, which takes its starting point in the general observation that firms often meet serious financial limitations in financing their product innovation projects. R&D and innovation ventures are often risky, capital-intensive and difficult for external financiers to assess (Arrow, 1962 b), which limits the possibility to use capital markets and other external sources of finance to get funding to finance innovation (Czarnitzki & Hottenrott, 2010) and instead force firms to finance them by means of internal funds. A stream of successful product innovations provides firms with increased internal funding that can be used to finance innovations. It also lifts the external financing restrictions and makes banks and investors more interested and more willing to provide financing for ongoing innovative activities, 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 launching commercially successful product innovations gain a kind of lock-in advantage over less successful competitors.

And finally, a persistent behavior of firms introducing product innovation can be explained by Appropriation Theory. Basically, a new products get the persistence gold medal, because that is where outcomes can be protected with strong intellectual property (Teece, 1986). This is of course relatively speaking in compare with other types of innovation, where assigning intellectual property is harder and imitation is easier (will be discussed further below). All in all, considering the three supporting arguments (plus the general argument in Section 2.1), we expect a high degree of persistency in product innovation.

2.2.2 Process Innovations

Process innovations involve the introduction of new methods of production, including new ways of handling a good or a service commercially. A primary goal for process innovations are the reduction of the unit costs of the products produced, which is achieved not least by introducing new machinery containing embodied knowledge. Other important goals are to preserve or increase the quality of the products produced. We must observe that, in particular, product innovations that involve the launching of completely new products may demand associated process innovations. It is not clear-cut how one should distinguish process innovations from organizational innovations. However, we prefer to think that process innovations are associated with investments in new physical equipment embodying new knowledge, i.e. investments generating embodied technical change within the firm. On the other hand, we must acknowledge that process innovations differ from product innovations (in a more distinct way).

A possible persistency of firms engaging in process innovation can be explain by the "R&D Sunk Cost" argument (as in product innovation). This is because the R&D investment and its associated sunk costs can not only be used for the purpose of introducing product innovation, but also for process innovation. An example is when firms engage in heavy R&D investments in order to introduce a new method of production (such as Additive Manufacturing) for their own production line. However, in many industries most of the firms do not do major R&D to develop process innovations. Instead, machinery and process equipment is bought from firms in the machinery industries, who are specialized in developing and producing machinery and equipment that can be used for process innovations. These type of process innovation are not R&D investment-based. Therefore, we may not expect high persistency process innovation in this case. Moreover, in many industries, and in particular in process industries major process innovations are associated with the construction of totally new production units or factories such as paper machines and new pulp factories. Here process innovations involve large lumpy investments and once again we may not be able to observe persistence for (major) innovations. In these industries, it is not necessary to invest in large process R&D units, since the relevant research will be performed by the industries selling machinery and equipment for process industries. This is why one can argue that appropriability condition (e.g. through patenting) for process innovation is low (Teece, 1986). This gives another reason not to expect a high persistency when it comes too process innovation (especially in compare with product innovation).

2.2.3 Organizational Innovations

Organizational innovations[10] are innovations involving changes in the routines of firms aiming at improving the efficiency, productivity, profitability, flexibility and creativity of a

[10] Sometimes in the literature, organizational innovations are also termed administrative innovations (Afuah, 1998) or management innovations (Birkinshaw, Hamel, Mol, 2008).

firm using disembodied knowledge[11]. Examples of such innovations are: (i) introduction and implementation of new strategies, (ii) introduction of knowledge management systems that improves the skills in searching, adopting, sharing, coding, storing and diffusing knowledge among employees, (iii) introduction of new administrative and control systems and processes, (iv) introduction of new internal structures with their associated incentive structures including decentralized decision-making and team work (e.g. self-managed teams), (v) introduction of new types of external network relations with other firms and/or public organizations including, vertical cooperation with suppliers and/or customers, alliances, partnerships, sub-contracting, out-sourcing and off-shoring, and (vi) hiring of new personnel for key positions in the firm.

Organizational innovations are argued to be “Fertile Ground for Innovation” and shown to be beneficial in several aspects (Volberda, Van Den Bosch, Heij, 2013). For instance, they are beneficial for other types of innovation, especially (technological) process innovation, since they reduce the tension within the firm who is going to implement the process innovation (Hollen, Van Den Bosch, Volberda, 2013). They are also important for a firm's ability to effectively adopt an emerging core technology (Khanagha, Volberda, Sidhu, Oshri, 2013) as well as firm’s performance and also increased dynamic capabilities (Volberda, Van Den Bosch, Heij, 2013). Organizational innovations are distinct from product innovations but have some resemblances with process innovations because of its nature (as noted earlier). For instance it is shown that organizational and process innovations are combined over time in an intertwined way (Hollen, Van Den Bosch, Volberda, 2013).

We expect that major organizational innovations are performed relatively seldom (low persistency) in the firm, for three reasons. First, a firm who generates, diffuses, or adopts a new organizational innovation needs a substantial periods to make such organizational innovation actually works (Amburgey, Kelly, Barnett, 1990). This is mainly because developing an organizational innovation is a complex process and involves internal as well as external “change agents” (Birkinshaw, Hamel, Mol, 2008). And there is an established literature on the existence of “resistance to change” (Hannan and Freeman, 1984)[12]. Such change can be due to external factors, i.e. organizations are embedded in the technical and institutional structures of their environment (Granovetter, 1985) or due to internal factors, i.e.

[11] For several related definition of organizational (management) innovation, see (Volberda, Van Den Bosch, Heij, 2013).
[12] Hannan and Freeman (1984) propose the structural inertia theory, which portrayed organizations as relatively inflexible in which change is not only difficult but also hazardous.

resistance among the employees within organizations (Coch and French, 1948). These resistance to change factors make organizational innovation to be hard to repeat over time (low persistency). Second, looking at change agents, internal change agents include a firm's managers and employees who are engaged in the organizational innovation. External change agents can be consultants, academics or other external actors who influence the adoption of organizational innovations (Volberda, Van Den Bosch, Heij, 2013). And relying on external change agent is particularly important for small firms, which implies that the firms do not always have to invest in large specialized units to carry through organizational innovations (Volberda et al, 2014). Such reliance on external agents (such as consultant) shows a low-appropriability condition for firms who adopt the organizational innovation, and hence incentive to be persistent on their organizational innovation[13]. Third, neither "R&D Sunk Cost" nor "Success Bread Success" arguments are applicable for organizational innovation, hence cannot speak in favor of persistency of organizational innovation. This is because organizational innovation is neither R&D-based innovation, nor income generating innovation (at least directly). To sum up, we expect a lower degree of innovation "persistence" in organizational innovation in compare with technological innovation (especially product innovation) because of: (i) difficulty of "change" in organizational routine, (ii) low-appropriability condition, and (iii) lack of applicability of "R&D Sunk Cost" nor "Success Bread Success" arguments.

2.2.4 Market Innovations

Market innovations involve the opening of new markets according to Schumpeter's classification but are in the modern management literature interpreted as improvements of the mix of target markets including market segmentation, and in methods to serve these markets (Johne, 1999). Innovations concerning the mix of markets include manipulation of the four famous marketing P's, i.e. product, price, promotion and place (including distribution methods and channels). This implies that the dividing line between product innovations and market innovations are not as clear-cut as one would wish. Primary goals here are to increase the total sales volume to make the exploitation of economies of scale possible to compete effectively with price, to effectively segment markets to catch a larger share of the consumer

[13] In many cases, relying on external change agent is due to imitative behaviour regardless of whether there is any evidence that the innovation actually enhances performance. This view is based on neo-institutional and fashion theory perspective (Volberda et al, 2014). In this cases, appropriability condition is expected to be very low and hence low persistency is expected.

surplus and offer product characteristics and associated services that increase the willingness of customers to pay for these products. However, firms have to make a strategic choice between trying to supply (i) products at the lowest cost, (ii) products that are special in some way (differentiation), or (iii) products focusing a distinct niche market, since firms cannot optimize their performance if they pursue different market strategies at the same time (Porter, 1985). Empirical evidence shows that marketing innovation is beneficial for developing and sustaining competitive advantages, at least based on lowering cost and differentiation (Naidoo, 2010).

We expect that major market innovations are performed relatively seldom (low persistency) in the firm due to three reasons. First, through the lens of Market Orientation[14] argument, firms cannot confuse their customers with continuous changes in their marketing methods, such as promotions, pricing, and positioning of the same product. This naturally means low degree of persistency here. Second, according to Disruptive Technologies argument, change in markets (or technologies) is an important driver of the failure of leading companies (Bower and Christensen, 1995). While companies cannot avid the emergence of disruptive technologies, they may at least avoid to consistently change their market (since it may give chance to their competitors to take over such emerging markets). Moreover, firms should be very cautious about the actual need of the customer when it comes to the new channels they introduce a technology to the market (i.e. marketing innovations)[15]. This implies one would expect a low persistency in market innovation. Third, for doing market innovation, firms and, in particular, smaller firms may rely on specialized consultancy firms to come up with new way of pricing, promotion, positioning etc. of their product, which implies low-appropriability condition and hence low incentive for firms to persistently engage in marketing innovation (this argument is similar to organizational innovation). Moreover, when a firm has started to exploit a particular market, it often has limited resources to exploit simultaneously other markets. Fourth, the R&D Sunk Cost and Success Breed Success arguments are not applicable in the case of marketing innovation (similar reasoning as for organizational innovation here). To sum up, we expect a lower degree of innovation "persistence" in marketing innovation in compare with technological innovation (especially product innovation) because of: (i) violence of

[14] Market Orientation is an important concept in marketing literature. Narver and Slater (1990) defined it as the organizational culture that most effectively and efficiently creates the necessary behaviours for the creation of higher value for customers and, hence, continuous superior performance for the business. Evidences show that market orientation of firms has stronger effect on performance in compare with the effect of marketing innovation on performance (Shergill & Nargundkar, 2005)

[15] As Bower and Christensen (1995, p.43) said: "Before managers decide to launch a technology,.., or establish new channels of distribution, they must look to their customers first: Do their customers want it?".

Market Orientation argument (if firms persistently engage in market innovation), (ii) low-appropriability condition, and (iii) lack of applicability of “R&D Sunk Cost” and “Success Bread Success” arguments.

3. Empirical Evidence on persistency of innovation

Earlier empirical studies on innovation persistence used patent data as the measure of innovation and persistency of innovation. More recently, with the availability of Community Innovation Survey (CIS), it has become possible to measure innovation more directly and hence persistence studies used these data in various countries. Thanks to CIS, it has become also possible to go beyond product innovation and incorporate various types of innovation (although the empirical studies are still rare on this issue). Indeed it is argued that the panel data which is derived from innovation surveys reveals very different results to previous analyses of innovation persistence primarily based on patents data (Roper and Hewitt-Dundas, 2008; Peters, 2009). When it comes to estimation strategy, it seems the recently developed approach by Wooldridge (2005) become a method of choice in the empirical literature. We will use this approach and elaborate it in Section 6. The summary of major empirical studies dealing with persistency of innovation is presented in Table 1.

Table 1. Recent empirical studies concerning the persistence of innovation

Study	Sample and Time	Innovation Activities	Methodology	Measure of Persistency	Finding
Geroski et al. (1997)	British manufacturing firms, 1969–1988	Patents granted by the US PTO	Duration dependence, Weibull model	Length of innovation spell	Low persistence
Cefis & Orsenigo (2001)	French, German, Italian, Japanese, British., and American manufacturing firms, 1978-1993	Patent applications at EPO	Transition Probability Matrix used in first- and second order Markov chains	Probability of remaining in the same state of patenting	Bimodality, i.e. both great innovators and non-innovators have a high probability to remain in their state, while persistence is much lower in the intermediate classes.
Cefis (2003)	British manufacturing firms, 1978-1991	Patent applications at EPO	Transition Probability Matrix used in first- and second order Markov chains	Probability of remaining in the same state of patenting	Bimodality
Martinez-Ros & Labeaga (2009)	Spanish manufacturing firms, 1990-1999	Binary variables for product and process innovation obtained from ESEE survey	Dynamic random effects probit model and Wooldridge (2005) method	lagged (t-1) product and process innovations	(1) Persistence in innovation increases at least 15% the probability to develop more innovations (2) The introduction of the alternative innovation increases the probability to innovate in a range from 2 to 4% (complementarities)
Peters (2009)	German manufacturing and service firms, 1994-2002	A binary variable for innovation *input* (sum of investment in six innovation activities)	Dynamic random effects discrete choice model and Wooldridge (2005)'s method	lagged (t-1) binary measure of innovation input	High persistency (true state dependency)
Raymond et al (2010)	Dutch manufacturing firms, 1994-2002 (4 waves of CIS)	(1) A binary, indicating whether a firm is a technological product or process (TPP) innovator. (2) Share of innovative sales	Dynamic type 2 Tobit model with Wooldridge (2005) method (accounting for individual effects and handling the initial conditions problem)	(1) lagged (t-1) TPP innovator (2) lagged (t-1) share of innovative sales	(1) True persistence in the probability of innovating in the high-tech industries and spurious persistence in low-tech. (2) Past innovation output intensity affects current innovation output intensity in high-tech, while it has no such effect in low-tech.
Clausen et al (2011)	Norwegian firms in industrial sector, 1995-2004 (3 waves of CIS)	Binary variables for product and process innovation obtained from CIS and R&D survey	Dynamic random effects probit model with Wooldridge (2005) method (accounting for individual effects and handling the initial conditions problem)	lagged product and process innovations	Differences in innovation strategies across firms are an important determinant of the firms' probability to repeatedly innovate.
Ganter & Hecker (2013)	German firms, 2002-2008 (3 waves of CIS). Only balanced panel is used.	Binary variables for product, process, and organizational innovation	(1) Dynamic random effects probit model with Wooldridge (2005) method (2) Bivariate dynamic random effects probit model (to assess the potential interrelatedness between the adoption of organizational and technological innovation.)	lagged (t-2) product, process, and organizational innovations	(1) True persistence of product innovation (new to market) (2) No true persistence of product (new to firm), process, and organizational innovations
Haned et al (2014)	French manufacturing firms, 2002-2008 (3 waves of CIS). Only balanced panel is used.	Binary variables for product, process, and organizational innovation	Dynamic random effects probit model with Wooldridge (2005) method	lagged (t-2) product, process, both product t and process, and organizational innovations	A positive effect of organizational innovation on persistence in technological innovation (complementarities)

4. 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 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[16]. Then we construct two panel datasets: (i) a balanced dataset consists of 2,870 observations, corresponding to 574 firms who participated in all five waves of CIS and (ii) 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). 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 both panel and unbalance datasets in investigating state dependency (Section 5), while we only use panel dataset in investigating true state dependency, where we estimate a dynamic discrete choice model (Section 6). The definition of all variables is reported in the Appendix 2. The mean VIF score for all variables is 1.91 and each variable get a VIF score of below 3.5. This implies that multicollinearity is rather mild and may not bias the regression analyses results in the subsequent sections.

[16] This is obtained after the usual data cleaning, i.e. dropping observations with zero turnover or zero employees.

5. Is there a persistency in firms' innovation (state dependency)?

In order to investigate whether persistency exist or not (and if yes, to what extent), we used Transition Probabilities Matrix (TPM). TPM reveals the information about the probability of transitioning from one state to another. In our case, "state" is the innovation status of firms in each period, i.e. being an innovator (*INNO*) or being a non-innovator (*NON-INNO*). In particular, let a sequence of random variables $\{Y_1, Y_2, \dots, Y_n\}$ be a Markov chain. Then the TPM is formulated as follows:

$$\boldsymbol{TPM} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1d} \\ p_{21} & p_{22} & \dots & p_{2d} \\ \vdots & \dots & \dots & \vdots \\ p_{d1} & p_{d2} & \cdots & p_{dd} \end{bmatrix} \quad (1)$$

Where,

$$p_{ij} = P(Y_t = j \,|Y_{t-1} = i) \quad (2)$$

Where p_{ij} measure the probability of moving from state *i* to state *j* in one period for the vector ***Y***. Finally, ***Y*** consists of several variables measuring different types of innovation, i.e. y_1 is product, y_2 is process, y_3 is marketing, and y_4 is organizational innovations. This TPM offers useful information for analyzing persistence since it measures the probability that a firm goes from one state to another, while moving from one period to another period in time. p_{ij} are unknown parameters in our case and they can be estimated by Maximum Likelihood. It can be shown that the estimated parameters of p_{ij} equals to $\widehat{p_{ij}} = \frac{n_{ij}}{ni}$, where n_{ij} is the number of observed transitions from state *i* to state *j* and n_i is the total number of state *i*. In the context of innovation persistence, it is shown that persistency can exist in two forms of weak or strong (Cefis and Orsenigo, 2001; Roper and Hewitt-Dundas, 2008). First, there is a weak innovation persistency if sum of diagonal elements of the matrix ***TPM*** $(\mathrm{p_{ij}}, \text{if } \mathrm{i} = \mathrm{j})$ is equal or bigger than 100% probability *but* not all elements of the diagonal of the matrix are equal to or higher than 50%. Second, there is a strong innovation persistency if sum of diagonal elements of the matrix ***TPM*** $(\mathrm{p_{ij}}, \text{if } \mathrm{i} = \mathrm{j})$ is equal or bigger than 100% probability *and* all elements of the diagonal of the matrix ***TPM*** equal to or higher than 50%. Using ***TPM***, one can also calculate the Unconditional State Dependence (*USD*) as follows:

$$USD = p_{jj} - p_{ij} = P(Y_t = j \,|Y_{t-1} = j) - P(Y_t = j \,|Y_{t-1} = i) \quad (3)$$

Where, state j is *INNO* and state i is *NON-INNO*. *USD* is measured as Percentage Point (hereafter PP) and shows how much of the probability of being innovative in year t ($Y_t = j$) can be explained by the difference between being innovative ($Y_{t-1} = j$) versus being non-innovative ($Y_{t-1} = i$) in year *t-1*. *USD* is unconditional because it does not condition the state dependency on any observed or unobserved characteristics of the firm[17]. Table 2 reports the estimated parameters of Transition Probabilities Matrix as well as *USD*, using both balanced and unbalanced panel datasets.

Table 2-Transition Probabilities

		Unbalanced Panel			Balanced Panel		
		Innovation status in t+1		USD	**Innovation status in t+1**		USD
Types of Innovation	**Innovation status in t**	NON-INNO	INNO		NON-INNO	INNO	
All types	NON-INNO	65%	35%	39 PP	60%	40%	37 PP
	INNO	26%	74%		23%	77%	
Product	NON-INNO	87%	13%	50 PP	85%	15%	55 PP
	INNO	37%	63%		30%	70%	
Process	NON-INNO	78%	22%	29 PP	75%	25%	31 PP
	INNO	49%	51%		44%	56%	
Organizational	NON-INNO	78%	22%	24 PP	77%	23%	24 PP
	INNO	54%	46%		53%	47%	
Marketing	NON-INNO	75%	25%	29 PP	72%	28%	22 PP
	INNO	46%	54%		50%	50%	

Notes: The table consists of ten 2x2 ***TPM*** matrices (five matrices under unbalanced panel and five under balanced panel). The table reports the estimated parameters of Transition Probabilities Matrices ($\widehat{p_{ij}} = \frac{n_{ij}}{ni}$). n_{ij} is the number of observed transitions from state *i* to state *j* and n_i is the total number of state *i*. Innovations status are the “state”, which can be NON-INNO: Non-Innovative or INNO: Innovative. There are in total 10,644 transitions in the unbalanced panel and 2,296 transitions in the balanced panel. The sum of the rows in each matrix equals to 100%. The table also reports the *USD* (Unconditional State Dependence), as the Percentage Points (PP), which shows how much of the probability of being innovative in year *t* can be explained by the difference between being innovative versus being non-innovative in year *t-1*. t=2004, 2006, 2008, 2010, 2012.

Table 2 shows that there is a general pattern of strong persistency in innovative behavior of firms, regardless of choosing balanced or unbalanced panel data sets. This is because the diagonal elements are usually above 50%. Since result of using balanced and unbalanced panels are similar, we will only discuss the result of balanced one for the sake of brevity. First, 77%[18] of innovative firms (could be any four types of innovation) persisted to stay

[17] Other notations can be used for *USD*. For instance, Peters (2009) called it Observed State Dependence (OSD).
[18] This probability is obtained as follows: dividing 1093 transitions (that had innovation status as INNOVATIVE in year *t* and year *t+1*) by 1428 transitions (that had innovation status as INNOVATIVE in year *t*).

innovative in the subsequent period, while only 23% shifted to become non-innovative. On the other hand, 60% of non-innovative firms also persisted to stay non-innovative in the subsequent period, while 40% shifted to become innovative. Moreover, the probability of being innovative in year *t+1* was about 37 PP higher for innovators than non-innovators in year *t* (37=77-40). This can be seen as a measure of unconditional state dependence[19]. Secondly, breaking down the innovative firms to the type of innovations they are engaging, Table 2 shows that there is also a general persistency pattern in all four types of innovations. However, as discussed in Section 2, the degrees of persistency in various types of innovation are not equal. In product innovation, 70% of the innovators in one year persisted in innovation in the subsequent year while 30% stopped their engagement. Moreover, the probability of being product innovator in year *t+1* was about 55 PP higher for product innovators than non-innovators in year *t*. In process innovation, 56% of the innovators in one year persisted in innovation in the subsequent year, while 44% stopped their engagement. Moreover, the probability of being product innovator in year *t+1* was about 31 PP higher for process innovators than non-innovators in year *t*. In organizational innovation, 47% of the innovators in one year persisted in innovation in the subsequent year, while 53% stopped their engagement. Moreover, the probability of being organizational innovator in year *t+1* was about 24 PP higher for organizational innovators than non-innovators in year *t*. Finally, in marketing innovation, half of the innovators in one year persisted in innovation in the subsequent year, while the other half stopped their engagement. Moreover, the probability of being marketing innovator in year *t+1* was about 22 PP higher for marketing innovators than non-innovators in year *t*. To sum up, among the various types of innovation, product innovators show relatively higher persistency in staying innovative in compare with other types of innovation (higher state dependence). Then process and marketing innovators are persistent in their innovative behavior more or less with the same transition probabilities. Finally, organizational innovators seems to be the least persistent innovators compared with other types of innovation. They could be seen as an exception the general pattern of strong persistency among various types of innovations. These firms indeed do not show strong persistency to staying organizationally innovative (47%). Nevertheless, they still show weak innovation persistency, since the sum of diagonal elements exceed 100% (77%+47%=124%).

[19] This measure is an unconditional state dependence, since we have not controlled neither observed nor unobserved characteristics of firms yet. Therefore, we do not know yet how much of this state dependence is “true” or alternatively “spurious”. We will deal with it by incorporating the conditional state dependence in Section 6.

Such variation in the degree of persistency in various types of innovation is what we expected and elaborated in Section 2.

6. Is there a true persistency in firms' innovation (true state dependency)?

6.1. Estimation Strategy

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 or if we like 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. Innovation persistence is here the result of the serial correlation in unobservables 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 (Pen¬rose, 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. Such model is able to analyze the conditional state dependence, hence allows us to distinguish between "true" state dependence from "spurious" one. This is necessary to do because the preliminary evidence of persistency found in Section 5 maybe (at least in part) due to observed and observed heterogeneity in firm's characteristics, i.e. spurious state dependency. 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:

$$y_{it}^{*} = \gamma y_{i,t-1} + \beta \boldsymbol{X}_{it} + \tau_i + \varepsilon_{it} \quad (4)$$

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 $\{y_{i0}, \dots, y_{iT}\}$ 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:

$$\tau_i = \alpha_0 + \alpha_1 y_{i0} + \alpha_2 \boldsymbol{X}_i + \alpha_i \quad (5)$$

Where $\boldsymbol{X}_i = \{\boldsymbol{X}_{i1}, \dots, \boldsymbol{X}_{iT}\}$ 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:

$$Prob(y_{it} = 1 | y_{i0}, \dots, y_{i,t-1}, \boldsymbol{X}_{it}, \boldsymbol{X}_i, \alpha_i) = \boldsymbol{\phi}(\gamma y_{i,t-1} + \beta \boldsymbol{X}_{it} + \alpha_0 + \alpha_1 y_{i0} + \alpha_2 \boldsymbol{X}_i + \alpha_i) \quad (6)$$

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).

The main advantage of this estimator is that marginal effects can be estimated which is not possible in semi-parametric approaches. This allows us not only to determine whether true state dependence exists by referring to the significance level but also to highlight the magnitude of this phenomenon (if any) (Peters, 2009). τ_i is an unknown parameter, nevertheless, it can be estimated if we assume that it can gets its average value. Then, the Marginal Effects at Means (MEMs) of binary variable $y_{i,t-1}$ can be estimated as follows:

$$\widehat{MEMs} = \boldsymbol{\phi}\left(\hat{\gamma} + \widehat{\boldsymbol{\beta}}\boldsymbol{X^o} + \widehat{\alpha_0} + \widehat{\alpha_1}\bar{y}_{i0}\right) - \boldsymbol{\phi}(\widehat{\boldsymbol{\beta}}\boldsymbol{X^o} + \widehat{\alpha_0} + \widehat{\alpha_1}\bar{y}_{i0}) \quad (7)$$

Where $\boldsymbol{X^o}$ is the vector of explanatory variables which is a fixed value that needs to be chosen (we used the mean values for all variables across *i* and *t*). Moreover, $\widehat{\boldsymbol{\beta}}$, $\widehat{\alpha_0}$, and $\widehat{\alpha_1}$ are the estimated parameters in Equation (6). The marginal effect estimated by Equation (7) shows the magnitude of the true state dependency or in other words, conditional state dependency.

6.2. Estimation Results

Table 3 reports the estimation results of random effect dynamic probit models in order to investigate the possible true state dependency in persistency of various types of innovations. The random effect probit model (elaborated in Section 6.1) assumes the strict exogeneity of explanatory variables. This is a strong assumption, because, for instance, it rules out the feedback effect between the future innovation introductions and size or R&D investment of firms. In order to assess the impact of including the explanatory variables, which may potentially fail the assumption of strict exogeneity, we follow the Peters's (2009) strategy of step-wise procedure. This means we start by specifying an extremely parsimonious model, in which only lagged innovation, initial condition and time and industry dummies are included, i.e. models (1), (3), (5), and (7). Then we add explanatory variables and inspect whether this affect the estimated state dependence effect, i.e. models (2), (4), (6), (8). The results of the estimations are presented in Table 3.

Table 3- Dynamic Random Effect Probit models for various types of innovations

	$PRODUCT_{it}$		$PROCESS_{it}$		$ORGANIZATIONAL_{it}$		$MARKETING_{it}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$PRODUCT_{it-1}$	0.480***	0.354***						
	(0.115)	(0.127)						
$PRODUCT_{i0}$	1.037***	0.688***						
	(0.145)	(0.131)						
$PROCESS_{it-1}$			0.394***	0.199*				
			(0.089)	(0.102)				
$PROCESS_{i0}$			0.503***	0.257***				
			(0.089)	(0.083)				
$ORGANIZATIONAL_{it-1}$					0.456***	0.328*		
					(0.177)	(0.179)		
$ORGANIZATIONAL_{i0}$					0.070	-0.067		
					(0.158)	(0.143)		
$MARKETING_{it-1}$							0.353*	0.200
							(0.191)	(0.188)
$MARKETING_{i0}$							0.218	0.142
							(0.170)	(0.155)
$SIZE_{it-1}$		0.062		0.049		0.117*		0.080
		(0.072)		(0.058)		(0.065)		(0.059)
$INNOV.\ INPUTS_{it-1}$		0.016*		0.030**		0.037***		0.027**
		(0.015)		(0.013)		(0.013)		(0.013)
$COOPERATION_{it-1}$		0.208		0.236		0.197		0.144
		(0.192)		(0.158)		(0.161)		(0.152)
$CONT.\ R\&D_{it-1}$		0.399**		0.276		-0.363**		0.081
		(0.200)		(0.169)		(0.179)		(0.171)
$IMPORT_{it-1}$		-0.398		-0.463		-0.055		-0.184
		(0.515)		(0.461)		(0.421)		(0.402)
$EXPORT_{it-1}$		0.859***		0.062		0.037		0.211
		(0.302)		(0.244)		(0.254)		(0.242)
PHYSICAL CAP_{it-1}		0.044*		0.067***		0.036		0.012
		(0.025)		(0.020)		(0.024)		(0.020)
HUMAN CAP_{it-1}		1.059***		0.467		1.107***		0.284
		(0.386)		(0.291)		(0.384)		(0.362)
UNINATIONAL		-0.277*		-0.124		0.058		0.087
		(0.142)		(0.111)		(0.155)		(0.146)
DOMESTIC MNE		-0.206		-0.163		-0.007		-0.195
		(0.156)		(0.126)		(0.172)		(0.165)
FOREIGN MNE		-0.165		-0.304**		-0.206		-0.313*
		(0.164)		(0.131)		(0.184)		(0.176)
ρ	0.333	0.231	0.154	0.087	0.085	0.005	0.0051	0.008
	(0.059)	(0.066)	(0.048)	(0.051)	(0.138)	(0.143)	(0.148)	(0.139)
Log Likelihood	-1012.36	-945.67	-1330.94	-1257.69	-650.94	-609.83	-693.15	-663.80
Observations	2,296	2,296	2,296	2,296	1,140	1,140	1,140	1,140
Number of firms	574	574	574	574	574	574	574	574

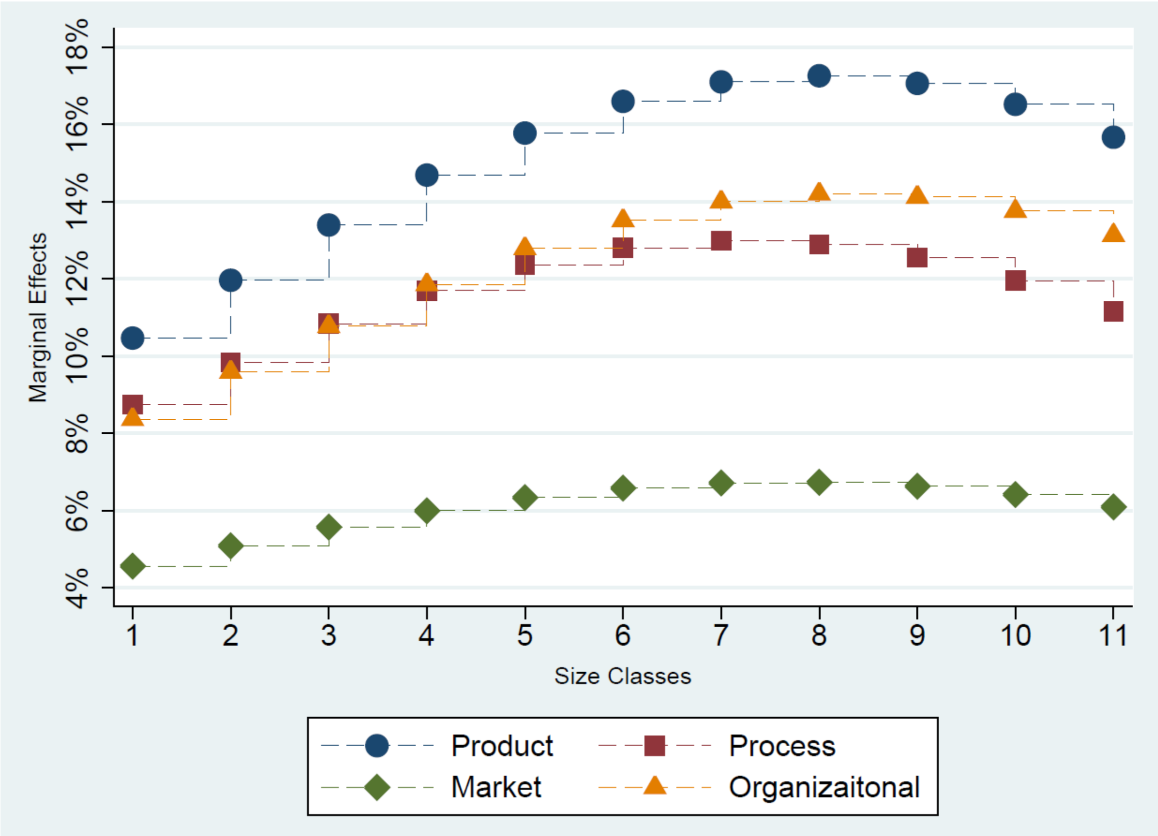
Notes: The table reports the estimated parameters with standard errors in the parentheses. ***,** and * indicate significance on a 1%, 5% and 10% level. The estimation approach follows Wooldridge (2005). All models include sets of sector and time dummies. Models (2), (4), (6), (8) also include $\boldsymbol{x}_i$, 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. ρ is the proportion of variance due to unobserved group level variance.

Concerning product innovation, it can be said that even after accounting for firms' unobserved heterogeneity (Model (1)) and observed heterogeneity (Model (1) and (2)); past innovation has a behavioral effect on future innovation. Particularly Model (2) controls for initial conditions, observed, and unobserved heterogeneity. This allows interpreting the significant effect of past innovation on future innovation as a "true" state dependency. The results concerning process innovation (in Model (3) and (4)) are similar to product innovation, in terms of significance of past innovation. Here again, it is possible to interpret the significant effect of past innovation on future innovation as a true state dependency. The result for organizational innovation is somewhat similar to process innovation (referring to Model (5)). Nevertheless, in Model (6), the past organizational innovation barely shows the significant effect on future behavior. Finally, past marketing innovation has the significant effect on the future innovation in Model (7). However, this significance is vanished in Model (8), where we control for observed heterogeneity and initial conditions. This shows that marketing innovation does not have true state dependency on future behavior and hence no casual inference can be drawn.

In order to interpret the magnitude of the effect (true state dependency) properly, we have estimated the Marginal Effect at Means (*MEMs*) using Equation (7)[20]. Furthermore, we have distinguished the marginal effects based on size classes of firms. The result is reported in Figure 1.

[20] Alternatively, estimating Average Marginal Effect (AME) reveals more or less the same magnitude effects, albeit slightly lower compared with MEMs for most of the innovation types.

Figure 1-Marginal Effects for various types of innovation



Notes: The figure shows the marginal effects for four types of innovation over different size classes. Marginal effects are estimated as Marginal Effect at Means (MEMs) and shown in the above figure in terms of Percentage Points (PP). Equation (7) is used for estimation of MEMs and for Product, Process, Organizational, and Marketing innovations the estimation is based on Models (2), (4), (6), (8) in Table 3 respectively. Size classes is the logarithm of number of employments.

Looking at the general pattern, Figure 1 shows that the effect of previous innovation on future innovation (persistency) is the strongest among the product innovators. Then it comes to process and organizational innovators and finally the least persistency effect is identified for market innovators. Such general pattern is in place regardless of firms' size (i.e. in all size classes). To be more specific we look at each innovation type separately. First, being a product innovator increase the probability of introducing product innovation in the next period by 10.5 PP to 17.3 PP depending on the size classes, while the average is 15.3 PP (considering all size classes together). This means in average, introducing product innovation in current period increase the chance of introducing again a product innovation in the next period by 15.3 PP, controlling for observed and unobserved heterogeneity in firms' characteristics. This is indeed the magnitude of true state dependency (or conditional state dependency). Furthermore, it is interesting to compare the magnitude of such true state dependency with the Unconditional State Dependency (*USD*). The *USD* to introduce product innovation in $t + 1$ was 55 PP higher for product innovators than for non-innovators in period *t* (referring to Table 2). Controlling for unobserved and observed characteristics, this difference reduces to 15.3 PP. This implies that nearly one third (15.3/55=0.28) of the initially observed product innovation persistency (identified by *USD*) can be attributed to "true state dependence", while the rest is due to observed and unobserved characteristics.

Second, being a process innovator increase the probability of introducing product innovation in the next period by 8.7 PP to 12.9 PP depending on the size classes, while the average is 12 PP. This means in average, introducing process innovation in current period increase the chance of introducing again a process innovation in the next period by 12 PP, controlling for observed and unobserved heterogeneity in firms' characteristics. Furthermore, more than one third (12/31=0.38) of the initially observed process innovation persistency (identified by *USD*) can be attributed to "true state dependence", while the rest is due to observed and unobserved characteristics[21].

Third, being an organizational innovator increase the probability of introducing organizational innovation in the next period by 8.3 PP to 13.9 PP depending on the size classes, while the average is 12 PP (same as process innovation). This means in average, introducing organizational innovation in current period increase the chance of introducing the same type of innovation in the next period by 12 PP, controlling for observed and unobserved heterogeneity in firms' characteristics. Furthermore, half (12/24=0.5) of the initially observed organizational innovation persistency (identified by *USD*) can be attributed to "true state dependence". Another interesting point is that in terms of persistency, organizational and process innovations show very similar pattern. An exception can be found in larger firms, where the persistency in organizational innovations seems slightly to overtake the process innovation. This could be, for instance, due to higher persistency of strategic decisions taken by management in larger firms.

Lastly, being a marketing innovator increase the probability of introducing product innovation in the next period by 4.5 PP to 6.6 PP depending on the size classes, while the average is 6

[21] Comparing the 28% and 38% in product and process innovation respectively, one could say that the "noise" in capturing the persistency based on USD was higher in product innovation in compare with process innovation.

PP. This is in line with the lack of significant persistency in market innovation (Table 3). This simply means market innovators are the least persistent innovators in compare with other types. This is what we expected (elaborated in Section 2), since firms do not want to confuse their customers by persistency changing the positioning, pricing strategy, and packaging features of their products in the market.

In a nutshell, what we get from our empirical result is expected based on the various theories we reviewed in Section 2.2 (and summarized in Appendix 1). The product innovation gets the gold medal of persistency and it can be explained by "Success Breeds Success", R&D Sunk Cost, and Appropriability theory. Other types of innovation shows the lower degree of persistent behavior and it can be explained by either (i) due to existence of "against" arguments, such as Resistance to Change theory for organizational innovation (ii) or lack of supporting arguments, such as lack of applicability of Success Breeds Success (as an income generating process) for organizational innovation.

Apart from the lagged innovation, that shows the persistency, some observable firm characteristics turn out to affect the future innovation significantly. First, innovation input positively affects all type of innovation. This is not a surprise since this variable has some elements that can act as the input for technologically related innovations (e.g. product innovation) and non-technologically related innovation (e.g. marketing innovation). The elements for the former are, for instance, internal and external R&D investments and the elements for the latter is investment in activities dealing with market introduction of an innovation. Second, doing continuous R&D positively affects product innovation, while it negatively affects organizational innovation. The former can be explained by absorptive capacity concept (Cohen & Levinthal, 1990), while the latter shows the allocation of scarce resources and the choice that firms make in their innovation strategy. Third, the export intensity of firm shows the positive effect on product innovation, which is in line with trade version of endogenous growth models predict that export contributes to innovation and growth (Grossman and Helpman, 1991). Finally, human capital positively affects product and organizational innovation, while physical capital affects product and process innovation. The effect of human capital (and refreshing it periodically) can be explained through an argument that high degrees of human capital stock avoids the "competency traps", which in turn would lead to the creation of new knowledge and routines, reflected in product and organizational innovations (Al-Laham, Tzabbar, Amburgey, 2011; Tavassoli & Carbonara, 2014).

6.3. Robustness check

We performed several robustness check to see whether our results obtained in previous section still holds. The main point here is that so far we have investigated the persistency of various types of innovation independently. However, a closer look to our data told us that indeed 57% of innovators in our sample introduce more than one type of innovation at a given point in time. This necessitates a robustness check to account for possible interdependencies between firm's decisions to introduce various types of innovation simultaneously (and therefore avoid the potential bias resulting from modelling these decisions separately). Hence, as a first step, we decided to breakdown the original four types of innovation. Such breakdown gave us 15 different "innovation strategies" that a firm may choose. These fifteen strategies composed of four simple and eleven complex innovation strategies. The simple strategies are the ones when firms decide to introduce only product innovation or only process innovation, etc. The complex strategies are the ones when firms decide to combine two or more of the simple strategies and introduce them simultaneously. The frequency of the fifteen innovation strategies are reported in Appendix 3 in order to provide some descriptive empirical evidences. It shows that the simple strategies are among the top ones, however, as noted earlier, considering all complex innovators together, the figure mount up to 57%. Nevertheless, we do not think our original main result can be affected by breaking down the original four types into the fifteen innovation strategies. We have two reasons for such claim: (i) there is a low correlation between the fifteen innovation strategies[22]. And more importantly, (ii) we employ multivariate random effect probit model, which is based on GHK simulation method for maximum likelihood estimation[23]. This model allows for correlated random effects and error terms between various types of innovation[24]. The result of such estimation shows that our main findings concerning persistency pattern in various types of innovation (Table 3 and Figure 1) still holds[25].

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[22] This is obtained by treating all innovation strategies as right hand side variables in an OLS setting with productivity as left hand side variable and then calculating the Vector Inflation Factor (VIF) score. The overall score was lower than 4.

[23] Similar approach is used in other studies as a robustness check (e.g. Ganter and Hecker, 2013).

[24] If a high correlation in error terms of various innovation equations exists, it implies complementarities between various types of innovation through unobservable effects. Multivariate probit model makes a tetrachoric correlation conditional on covariates.

[25] The result of such robustness check is available upon request.

Another robustness check concerns the time lag in our analysis. Both TPM and our dynamic probit model took into account one period time lag. Such analyses can be extended in two ways. First, while keeping the dependent variable of Equation (6), the independent now is innovation with 2 time lags (See Model (1), (3), (5), (7) in Appendix 4). Second, we construct an alternative dependent variable for Equation (6), where it is 0/1 and gets value 1 NOT whether an innovation has been introduced at time t, BUT whether an innovation has been introduced at time t AND time t-1. This way, persistency is somehow built in the dependent variable. Then on the right-hand-side, innovation variables are entered with a 2 year time lags (See Model (2), (4), (6), (8) in Appendix 4). The estimation result of such two alternative specifications are reported in Appendix 4. It is evident that our main result still holds (the superior persistency of product innovation in compare with other types of innovation is even more pronounced here).

7. Conclusions

In this paper we investigated whether persistency exist in innovation of firms. Following Schumpeter, we distinguished between four types of innovation, while employing a long panel of Community Innovation Survey, which enabled us to trace the innovative behavior of firms in Sweden over a ten years period. First, using Transition Probability Matrix, we found the persistency behavior in all types of innovation. However, the degree of persistency is not equal among various types of innovation, among which product innovators turns out to be the strongest persistent innovators. Second, using dynamic probit models, we investigate whether the persistency pattern that we found (state dependency) is a true state dependency or a spurious one. It turns out that product, process and organizational innovation have the true state dependency, while market innovation has the spurious one. This is because after controlling for observed and unobserved heterogeneity in firms' characteristics, the persistency effect still remained in all types of innovation except marketing innovation. When it comes to the magnitude of such true state dependency, once again, product innovators are ranked the highest. Being a product innovator increase the probability of introducing product innovation in the next period by 10.5 PP to 17.3 PP depending on the firm's size classes, while the average of 15.3 PP. Among the few existing studies, Ganter and Hecker (2013) found similar magnitude (17.7 PP) using German data.

But what does our results implies for firms and policy makers? When it comes to innovating firms, they must have strong reasons to give up product innovation because product innovation seems to be a self-efficient process that is expected to reproduce itself over time. On the other hand, it is less of a problem if innovating firms take a break in marketing innovations (and process and organizational innovations are somewhere in between). Concerning non-innovating firms, particularly about introducing product innovation, they must be prepared to make a long-term commitment. If they manage to introduce product innovation to the market, the high degree of persistency confirmed in this paper implies that more product innovation is expected to come (although there is no guarantee because of inherent uncertainty in any successful innovation). The finding in this paper may have implication for policy makers too. If persistency thesis holds, then innovation policy programs are expected to have a long-lasting effect on innovative behavior of firms. This is particularly true for product innovation, because as soon as a program succeeds to stimulate a successful introduction of product innovation for firms, it is expected that there may be less need for continuation of that program (because of self-efficiency of firms in reproducing such innovation over time and hence lack of additionalities of the program). For Marketing (and other two types of innovation), if policy makers have a strong reason to stimulate these types of innovation, then innovation policies must be prepared to do such stimulation as a longer term commitment and not change policies in the short or medium term. This is because firms do not tend to persist on engaging in these types of innovation by themselves[26].

At the end, we would like to mention that we detected 57% of innovators in our sample introducing more than one type of innovation at a given point in time. We have controlled for this phenomenon in our robustness check analysis. However, we think such issue deserves further investigation. For instance, do firms have persistency in doing “combined” innovation strategy (e.g., whether firms persist to do both process and organizational innovation simultaneously)? Does engagement in any types of innovation lead to other types of innovation in future? Moreover, starting from the assumption that there exist product cycles, we have reason to believe that the existence of persistence for the different types of innovation could vary over the life cycle of a product, firm and industry. Unfortunately, limitations in the available data imply that there are several hypotheses that we will not be able to test. These questions could be area of further research.

[26] All said above are conditional on the fact that policy makers actually distinguish between different types of innovations in reality in the first place. That is not an easy task, as various innovation styles can be intertwined over time, e.g. a process innovation can be a product innovation sometimes later.

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Appendix 1-The expected high/low persistency in four types of innovations, based on various theories

Persistency in Innovation Types	**Theories/Arguments**						
	Knowledge Dynamics	R&D Sunk Cost	Success Breeds Success	Appropriation Theory	Resistance to Change	Market Orientation	Disruptive Technologies
PRODUCT	+	+	+	+	NA	NA	NA
PROCESS	+	+	NA	-	NA	NA	NA
ORGANIZATIONAL	+	NA	NA	-	-	NA	NA
MARKETING	+	NA	NA	-	NA	-	-

Notes: Based on various theories (arguments), the table shows the expected high (+) or low (-) persistency in four types of innovation. NA means the corresponding theory is not applicable to the persistency of the corresponding innovation type. For instance, "Success Breeds Success" argument is not applicable to persistency in process innovation, because this argument is based on income-generation while process innovation is not an income-generating process. Knowledge Dynamic theory provides a general argument in favor persistency of all types of innovation (Section 2.1). The rest of the theories provide in favor or against arguments for persistency of various types of innovation (Section 2.2).

Appendix 2-Variable definitions

Variables	Type	Definitions
$PRODUCT_{it}$	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.
$PROCESS_{it}$	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.
$ORGANIZATIONAL_{it}$	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.
$MARKETING_{it}$	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.
$INNOV\ INPUTS_{it}$	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)
$COOPERATION_{it}$	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)
$UNINATIONAL_{i}$	0/1	1 if firm *i* belongs to a group and is uninational, 0 otherwise (Non-affiliated as based)
$DOMESTIC\ MNE_{i}$	0/1	1 if firm *i* belongs to group and is a domestic multinational enterprise, 0 otherwise
$FOREIGN\ MNE_{i}$	0/1	1 if firm belongs to group and is a foreign multinational enterprise, 0 otherwise
$PHYSICAL\ CAP_{it}$	C	Sum of investments in Buildings and Machines at year's end for firm *i* in year *t* (log)
$HUMAN\ CAP_{it}$	C	Share of employees with 3 or more years of university educations in firm *i* in year *t*
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 variable

Appendix 3-Innovation types and various combinations (Innovation Strategies)

		Balanced Panel			Unbalanced Panel		
#	**Innovation Strategy**	Frequency	Percentage (Total)	Percentage (Innovative)	Frequency	Percentage (Total)	Percentage (Innovative)
1	NON-INNO	1089	38%	-	9718	46%	-
2	PROD	269	9%	15%	1512	7%	13%
3	PROC	288	10%	16%	1799	9%	16%
4	ORG	88	3%	5%	746	4%	7%
5	MAR	96	3%	5%	826	4%	7%
6	PROD PROC	369	13%	21%	1580	7%	14%
7	PROD MAR	51	2%	3%	453	2%	4%
8	PROD ORG	44	2%	2%	220	1%	2%
9	PROC MAR	39	1%	2%	305	1%	3%
10	PROC ORG	69	2%	4%	508	2%	4%
11	MAR ORG	63	2%	4%	630	3%	6%
12	PROD PROC MAR	70	2%	4%	381	2%	3%
13	PROD PROC ORG	63	2%	4%	347	2%	3%
14	PROD MAR ORG	48	2%	3%	351	2%	3%
15	PROC MAR ORG	61	2%	3%	774	4%	7%
16	PROD PROC MAR ORG	163	6%	9%	955	5%	8%
	Total	2870	100%	100%	21105	100%	100%

Notes: The table shows the 16 possible combinations of innovation strategies that firms make considering four main types of innovation. NON-INNO: non-innovative, PROD: doing only product innovation in year *t*, PROC: doing only process innovation in year *t*, MAR: doing only marketing innovation in year *t*, ORG: only organizational innovation in year *t*, PROD PROC: doing product and process innovations in year *t*, PROD PROC MAR doing product, process and marketing innovations in year *t* and so on. Time period is from 2002 to 2012.

Appendix 4- Robustness check with alternative model specifications

	PRODUCT		PROCESS		ORGANIZATIONAL		MARKETING	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PRODUCT_{it-2}	0.459***	0.553***						
	(0.144)	(0.200)						
PRODUCT_{i0}	0.494***							
	(0.158)							
PROCESS_{it-2}			0.082	0.160*				
			(0.111)	(0.161)				
PROCESS_{i0}			0.283***					
			(0.107)					
$\text{ORGANIZATIONAL}_{it-2}$					0.021	0.048		
					(0.596)	(0.276)		
MARKETING_{it-2}							0.203	0.298
							(0.317)	(0.314)
SIZE_{it-2}	0.234***	0.146	0.214***	0.318***	0.160	0.176	0.080	0.178
	(0.085)	(0.131)	(0.043)	(0.072)	(4.428)	(0.847)	(0.126)	(0.177)
$\text{INNOV. INPUTS}_{it-2}$	-0.001	0.023	0.011	0.012	-0.001	0.005	0.007	0.011
	(0.016)	(0.024)	(0.008)	(0.011)	(0.038)	(0.026)	(0.014)	(0.016)
$\text{COOPERATION}_{it-2}$	0.093	0.455*	0.217**	0.338**	0.303	0.248	0.006	-0.086
	(0.204)	(0.267)	(0.102)	(0.136)	(8.396)	(1.206)	(0.162)	(0.202)
$\text{CONT. R}\&D_{it-2}$	0.136	0.544*	0.054	0.304**	0.022	0.008	0.147	0.186
	(0.214)	(0.280)	(0.111)	(0.149)	(0.630)	(0.217)	(0.276)	(0.270)
IMPORT_{it-2}	0.327	0.849	0.111	-0.251	-0.292	-0.032	0.014	-0.490
	(0.548)	(0.786)	(0.283)	(0.436)	(8.099)	(0.495)	(0.382)	(0.655)
EXPORT_{it-2}	0.623*	0.992**	0.302*	0.692***	0.143	0.588	0.292	0.426
	(0.319)	(0.467)	(0.158)	(0.244)	(3.979)	(2.828)	(0.466)	(0.462)
PHYSICAL CAP_{it-2}	0.057*	0.135**	0.031*	0.031	0.012	0.047	0.006	0.002
	(0.033)	(0.058)	(0.018)	(0.030)	(0.325)	(0.229)	(0.024)	(0.029)
HUMAN CAP_{it-2}	1.856***	3.433***	-0.021	0.072	0.825	1.117	0.408	0.248
	(0.509)	(0.889)	(0.278)	(0.436)	(22.861)	(5.366)	(0.678)	(0.473)
UNINATIONAL	0.075	0.080	0.037	-0.212	0.136	0.216	-0.051	0.093
	(0.178)	(0.282)	(0.138)	(0.217)	(3.779)	(1.073)	(0.208)	(0.250)
DOMESTIC MNE	-0.221	-0.044	-0.106	-0.322	0.029	0.060	0.010	-0.186
	(0.196)	(0.300)	(0.159)	(0.242)	(0.827)	(0.413)	(0.217)	(0.315)
FOREIGN MNE	-0.140	0.083	-0.222	-0.521**	-0.077	-0.283	-0.251	-0.472
	(0.206)	(0.312)	(0.164)	(0.250)	(2.134)	(1.391)	(0.423)	(0.519)
Observations	1,722	1,722	1,722	1,722	574	574	574	574
Number of firms	574	574	574	574	574	574	574	574

Notes: The table reports the estimated parameters of dynamic random effect probit model with standard errors in the parentheses. ***,** and * indicate significance on a 1%, 5% and 10% level. The dependent variables in Models (1), (3), (5), (7) are the same as in Table 3. Instead, the independent variables are lagged two time periods. The dependent variables of Model (2), (4), (6), (8) are defined in a new way in compare with Table 3. For instance, for Model (2), it gets value 1 if firm introduced product innovation in period t and t-1. The estimation approach follows Wooldridge (2005). Whenever initial conditions are not identified in the estimation, they are not reported in the table. All models include sets of sector and time dummies and $\boldsymbol{x}_i$, which correspond to each of the explanatory variables in each period from t=2006 to t=2012. These 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.