Persistence in Innovation and Innovative Behavior in Unstable Environments

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Abstract

Analyzing the persistence of the innovative activities can improve the understanding of firm dynamics, forecast the effectiveness of different policy actions, reinforce innovation cycles and promote sustainable and responsible innovation ecosystems. Innovation persistence was empirically analyzed for innovation leaders or even followers; still the literature fails to provide evidence for moderate innovators. The present article appraises the innovative strategy of firms operating in this context and their attitudes towards persistence, controlling for firm characteristics such as size, sector, R&D expenditures and human capital intensity. To do so, a balanced panel was built, encompassing three waves of the Portuguese Community Innovation Survey (CIS), (2004 to 2010) including 1099 firms from different areas. The estimation of the random effects probit model, evidenced that persistence hypothesis fails to be corroborated, evidencing no time dependent innovation strategies. Such result suggests that innovation policy programs do not have long-lasting effect on innovative behavior of firms and it is unlikely that incumbent past innovators be the drivers of creative accumulation and future innovation. There is, however, some evidence that new, smaller, innovators might lead the creative wave. In this vein, there might be a rational to encourage public policies targeting start-up firms and new market entrants when innovation is the main primary funding goal.

Keywords: CIS, dynamic random effects probit, moderate innovators, persistence in innovation

1. Introduction

The rapid erosion of value in goods and services caused by highly perishable technologies have been driven the increasing competition in internal and external markets (Bower and Christensen 1995; Vecchiato, 2017). Innovation, conceived as the transformation of ideas, information and knowledge to improved competitiveness and sustained competitive advantage, is a central in firm survival (Karlsson and Tavassoli, 2016).

As a driver of firm performance, innovation and its persistence can help explain sustained competitive advantage and lasting inter firm performance differences (Cefis and Ciccarelli, 2005; Hecker and Ganter, 2014). Innovation persistence relates “the feedbacks, accumulation, and lock-in effects that arise from innovations and put the firm in a better position to seek new innovations, with the consequent increase in the odds of continuing to achieve these” (Suárez, 2014: 726).

The continuous innovative activity is of high interest in areas such as economics of innovation and applied industrial economics (Tavassoli and Karlsson, 2015; Córcoles et al., 2016), an emerging area of empirical research (Triguero et al., 2014), and a central issue for public policy (Hecker and Ganter, 2014). As Le Bas and Scellato (2014: 423) content “[t]he analysis of the drivers and the underlying mechanisms of persistency in innovation performance of firms can relevantly improve our understanding of both the long-run industry dynamics and the expected effects of policies to sustain R&D and innovation”. From the public policy angle, analyzing intertemporal effects is important for the effectiveness of innovation funding (Hecker and Ganter, 2014).

The existence of time dependence indicates that incumbent firms and creative accumulation are central drivers of innovation, which, to a certain extent, may downplay the ‘creative destruction’ potential of new entrants (Malerba and Orsenigo 1999; Aghion, 2017). Such evidence may force rethinking the conventional policy practice of subsidizing start-up firms and new market entrants when innovation promotion is the primary funding goal (Hecker and Ganter, 2014).

Understanding the links between past and present innovative behavior is critical in ‘Moderate innovators’ (EC, 2017). Indeed, these countries present low innovative profiles with the production of new technologies seldom being the result of radical advances and the processes of R&D and innovation being influenced by a myriad of factors, most notably technological opportunities, market structure, demand conditions, firms’ capabilities, organizational arrangements, and appropriability conditions (Le Bas and Latham, 2006; Altuzarra, 2017).

Up to the present date, a reasonable amount of empirical evidence regarding innovation persistence has been gathered, however, it is not yet fully understood (Juliao-Rossi and Schmutzler, 2016; Altuzarra, 2017). Most of extant research focus on the innovation persistence of firms, mainly from the manufacturing sector, located in ‘Innovation Leaders’ (e.g., Finland - Deschryvere (2014); Germany - Hecker and Ganter (2014), Peters (2009); Sweden - Karlsson and Tavassoli (2016), Tavassoli and Karlsson (2015)) or ‘Strong Innovators’ (France - Cefis and Orsenigo (2001), Malerba et al. (1997), Haned et al. (2014); Ireland- Roper and Hewitt-Dundas (2008); Luxembourg - Le Bas and Poussing (2014); UK - Geroski et al. (1997), Cefis (2003), Frenz and Prevezer (2012)). Despite being the most numerous group (14 countries), the evidence focusing on ‘Moderate Innovators’ is almost exclusively concentrated on Spanish manufacturing firms (Martinez-Ros and Labeaga, 2009; Triguero et al., 2014, Córcoles et al., 2016; Altuzarra, 2017).

Additionally, with exception of Suárez (2014), who has analyzed a group of 800 Argentinean manufacturing firms over 3 periods (1998–2001, 2002–2004, and 2005–2006), innovative persistence in unstable environments has been overlooked. Indeed, extant empirical literature implicitly assume that environmental conditions do not change and "what the firm did in the past is useful for the things the firm has to deal with in the present" (Suárez, 2014: 726), neglecting the possible changes in the innovative strategy.

From 2004 to 2006, Portugal faced high political instability with 3 distinct governments. Additionally, the economic performance which started to deteriorate markedly after 2000 (see Royo, 2010), with real GDP growth averaged less than 1 percent between 2000 and 2005, having contracted 0.8% in 2003, remained fragile until 2006. Productivity growth in the business sector fell to around 1% between 2004 and 2005. Unemployment rose to highest rate in 20 years: 7.6% in 2005 and 8% in 2007 (IMF, 2009). Although there was a slight recovery in 2007, in 2009 real GDP per capita fell by 3.1% and unemployment reach a socially problematic figure of 9.4%. Continuing fall of investment and gross saving along with escalate public debt between 2006 and 2010 culminated in the Bailout programme. Given all these fluctuations and uncertainties in the macroeconomic and political environments, it is reasonable to expect that firms have reacted by changing their innovative behavior.

Based on a balanced panel of 1099 firms located in Portugal and covering the 2004-2010 period (CIS 6, CIS 8 and CIS 10), the empirical analysis is twofold: firstly, we test 'true state dependence' (or true persistence), in which past innovative behavior, per se explains the present and therefore firms do not react to environmental fluctuations or iterative. Secondly, iterative strategies (new, sporadic, non-innovative) are considered as a response to exogenous changes.

Due to unobservable time correlated firm characteristics raising innovative propensity (e.g. strategic orientation, innovation capabilities development or R&D investments), the problem of 'spurious state dependency' might arise (see Peters, 2009; Juliao-Rossi and Schmutzler, 2016). To overcome this problem, we follow, Peters (2009) and Hecker and Ganter (2014) econometrically separating the influence of unobserved firm heterogeneity and initial conditions from causal effects of past innovative activity. Such procedure decomposes observable innovation persistence into spurious and true state dependence. We assess the determinants of the latter by comparatively evaluating alternative theoretical accounts (the market power and innovation – Schumpeter, 1934, 1942; the success-breeds-success - Mansfield, 1968; Stoneman, 1983; the sunk costs - Sutton, 1991; the evolutionary - Nelson and Winter, 1982) against the empirically determined patterns of persistence.

This paper is structured as follows. Section 2 presents the literature review and the hypotheses in test; section 3 provides a database description and the exploratory results. Section 4 presents the econometric estimations and the results; section 5 concludes and puts some policy measures to consideration.

2. Literature Review

2.1 Past and path dependence of the innovation process

Either past dependence or path dependence explains the Innovation process. The first underlies that the determinants of the innovative process and its results fully determined by the initial conditions (Antonelli, 2011). Persistence depends on the first innovation, along with long-lasting innovative skills. Conversely, path dependence explains that, throughout a random process, knowledge is planted in a localized context ('historical accident'). The success of innovation will depend on the ability of the firm to benefit from the 'accident'. So it is strongly tied to existing competences and networking.

Persistence will be contingent to the exploitation of complementarities and interdependencies under the proper institutional environment (Collombelli and von Tunzelmann, 2011). Accessing knowledge pools, reinforcement of networks, linkages among firms is thus recommended.

Opting to persist in innovation is part of the innovative strategy thus determining technological change (Cefis and Orsenigo, 2001). It is essential for firms to continue investing in these projects to accommodate the changes in economic environment. Hence, there will be a strong cleavage among firms and persistence will occur among 'great innovators' (Cefis, 2003). Managers may opt for pursuing innovation in a regular base, perceiving some inertia in the process. Innovative behaviour over time is not a random process, if the firm is market oriented the propensity to become a persistent innovator will raise, as well as if it is R&D intensive or science based (Clausen et al., 2012).

2.2 Complementary approaches of persistence in innovation

Four complementary frameworks can be considered concerning persistence of innovation (Le Bas and Scellato, 2014; Altuzarra, 2017): market power and innovation (Schumpeter, 1934, 1942); success-breeds-success (Mansfield, 1968; Stoneman, 1983); sunk costs (Sutton 1991); and the evolutionary innovation theory (Nelson and Winter, 1982).

According to the 'market power and innovation' approach (Schumpeter, 1934, 1942), innovators are temporary monopolists, benefiting from abnormal profits; as this is a fleeting position, the firm will move the next innovation, thus raising the propensity to persist. New entrants will decrease the monopoly profits, therefore incumbents will persist in innovation as a way to create barriers to entry (Le Bas and Scellato, 2014).

The 'success-breeds-success' approach (Mansfield, 1968; Stoneman, 1983) states that previous innovation reinforces technological opportunities, leveraging future innovation success. Income and profit is generated by the subsequent commercial success of innovators which allows firms to increase their internal funds, making it possible to finance future innovation projects (Le Bas and Latham, 2006; Le Bas and Scellato, 2014). In the presence of asymmetric information between the innovator and the lender, the accessibility to internal funds is a key factor directly related to innovative activity. Firms achieving innovations will be considered as successful, standing out from their competitors due to their abnormal profits which will be reinvested in the development of new innovative activities, hereby creating a virtuous cycle (Nelson and Winter, 1982). When a firm reaches innovation, it conquers market power, achieves higher profit levels, thus creating an advantage from its competitors. Past innovations will generate the finance to support present innovative activities which raise the likelihood of future innovations.

The large upfront costs of R&D activity, as well as continuous funding to move a product through the various stages of the R&D process until the product comes to market (installation of laboratories, recruitment of researchers or training of employees), entails considerable 'sunk costs' (Sutton, 1991). Because firms need to recover the cost of R&D investments, conducting R&D activities require both persistent commitment and a long-term horizon (Kuratko et al., 1997). Additionally, once firms have engaged in R&D, the continuation of this activity becomes increasingly less costly, which encourages firms to carry on performing R&D.

Finally, the evolutionary innovation theory (Nelson and Winter, 1982) put forwards the hypothesis of dynamic increasing returns in innovation. Arguing that current knowledge is dependent on previous knowledge and the foundation upon which future knowledge rests.

Knowledge, namely tacit knowledge, is accumulated in people working in the organization; knowledge is not perishable and is likely to be used in multiple ways. Knowledge is cumulative and non-extinguishable generating a permanent advantage enhancing the probability of persistence. The systematic interaction between the knowledge stock and the productive routines converts innovation in a competitive advantage (Antonelli et al., 2013). Former innovations generate financial availability for the future, as past success will raise profitability and credibility towards external sources (Latham and Le Bas, 2006).

These approaches act as complementary and self-reinforcing; virtuous cycles will emerge from the dynamic interaction between the "knowledge accumulation" and the "success breeds success" in which, the returns from present R&D will retro-feed new ones (Latham and Le Bas, 2006). Due to strategic options, firms decide to invest in R&D, this cost is considered as sunk, and therefore, it will rationally be supported in the long-run. Innovative firms create a certain stock of knowledge, this process enhances the success-breeds-success hypothesis, and the profits generated with the on-going innovative process will retro-feed the system, financing new R&D activities enabling the system to continue working. This setting portraits a virtuous cycle in which the learning process will indefinitely continue.

2.3 Hypotheses in test

Albeit the existence of a reasonable number of high quality studies on the persistence of innovation results are not consensual. The extant evidence is mixed; most works identify weak elements of persistence and do not provide a convincing consensus about its determinants and, most importantly, about the specificities of the dynamic process (see Antonelli et al., 2012).

Most of previous empirical studies have focused on patenting activity finding limited evidence of persistence (see, for instance, Geroski et al., 1997; Cefis and Orsenigo, 2001; Cefis, 2003; Latham and Le Bas, 2006). the Resorting to the innovative history of UK firms in the period 1969–1988 using the patent records and the introduction of 'major' innovations, Geroski et al. (1997) show that only a minority of firms (those introducing 'major' innovations) is persistently innovative. Using 1400 manufacturing firms in five European countries in the years 1978–1993, Cefis and Orsenigo (2001) find weak persistence of patenting activity. They show that both low-innovators and great-innovators tend to remain in their classes and that much of the persistence in innovation activities seems to be determined by the 'economic' persistency of the firms themselves. In a later study, Cefis (2003) focused on 577 UK patenting firms in the period 1978–1991, and again found evidence of overall little persistence (only great innovators have a stronger probability to keep innovating). Focusing on French and US patents, Latham and Le Bas (2006) confirm that the persistence of innovation takes place, but only and mainly in a limited time span.

In contrast to patent-based studies, empirical analyses based on survey data find stronger evidence of innovation persistence (see Córcoles et al., 2016; Altuzarra, 2017), namely when dealing with product innovation (Tavassoli and Karlsson, 2015) and complex products (Fontana and Vezzulli, 2016). Early studies on innovation persistence using survey data by König et al. (1994) and Flaig and Stadler (1994) found evidence of state dependence in innovative outcomes on a panel of manufacturing firms in West Germany. More recently Raymond et al. (2010), albeit failing to find true state persistence in introducing product or process innovations by Dutch manufacturing firms for the years 1994–2000, show that within the group of continuous innovators there was persistence in innovation (i.e., the market success of previous innovation positively influenced the success of subsequent innovations).

The above mentioned studies have generally tested innovation persistence in stable contexts. In volatile environments, continuity in innovative activities will be an expression of deliberate strategic behavior rather than sheer time correlation. Persistence generates feedback and accumulation but they are indeed the outcome of continuous innovative strategies. The framework of persistence will be designed by the managerial strategy as well as the dynamic interaction of the firm and its environment (Suárez, 2014). Thus, in contrast to what one would expect in the context of stable environments, one might find past successful innovative behavior to have no impact or even a detrimental impact on future innovative behavior in contexts of changing (or uncertain) environments. As noted by Nelson and Winter (1982) this could happen if, for example, past successful innovative behavior generated from specific problem-solving processes that are not necessarily useful for the new environment. On the other hand, the new environment may create opportunities for previously non-innovative firms. These innovative firms may therefore be more likely to innovate in the future if their innovation process is adapted, from the start, to the new environment.

Firm Strategic behavior, in some cases, points to non-innovative strategies as being the more effective; conversely, in other cases, the most efficient option is to invest in innovation. The empirical evidence points to the fact that some innovative actions generate new innovative actions; albeit others fail to boost the virtuous innovation cycles.

The assumption that changing the environment conditions may change the innovation strategy in each period, poses a binary decision in each moment: whether or not to innovate independent of what has been done in the past. Consequently, considering one time transition the firm can be: a) non-innovative, if deciding not to innovate in the two time periods; b) sporadic innovator if the firm stops innovating from one moment to the other; c) new innovator if the firm commences the innovative process; d) persistent innovator if the firm continues to innovate from one moment to the other. Combined trajectories will appear if more time periods are added (see Table 1). Discussing iterative innovative strategies over time in the context of a moderate innovator is a further contribution to the persistence literature.

Independent of the conceptual framework, the literature highlights the existence of persistence, which means that past innovations will positively influence the probability of new ones. Therefore, [H1], states that former persistent innovators will continue in innovation. Pure time persistence will be tested ignoring other possibilities, focusing on the influence of past innovation on the present, along with other innovation inputs and structural controls (Models A). The objective is to address the existence of conventional persistence in moderate innovators.

The empirical evidence shows that, frequently, firms change their attitude towards innovation from one period to other; most of the works unveil persistence given certain characteristics, or non-innovativeness, but, very few explain the transition from one to another. The following hypotheses will depict the managerial strategies that comprise changes along the period. Strategic changes are described by three alternative hypotheses:

Table 1 Innovative strategies pursued

Innovative strategies(3 time periods)	DESCRIPTION
Continuous	The firm reports having performed innovative activities in all periods of analysis
Continuous - Sporadic	The firm reports having performed innovative activities in the first and the second period of analysis, and stopped innovating in the third
Sporadic - New	The firm has innovated in the first period, stopped innovating in the second and started innovating in the third
Sporadic - Non innovative	The firm has performed innovative activities in the first period of analysis and stopped in the next two
New-Continuous	The firm did not perform innovative activities in the first period, commenced in the second and continued in the third
New - Sporadic	The firm did not innovate in the first period, has innovated in the second, immediately stopping in the third
Non - innovative - New	The firm did not innovate in either the first and the second period and started innovating in the third
Non - Innovative	The firm did not innovate at all in all periods of analysis

[H2] – Being a continuous innovator in the transition from t-2 to t-1, will enhance the probability to continue innovation in the transition to t. So, if the firm did innovate in the two periods before it is more likely to be an innovator at present as well.

[H3] – Sporadic innovators in t-1 will have a decreased probability to pursuit innovation in t. Firms that did innovate in t-2, but which have stopped innovation in t-1, will have fewer chances to innovate in t.

[H4] – Firms which are new to innovation in t-1, so to say that they started innovation in the transition from t-2 to t-1, have an increased probability to continue innovation at present. This means that the innovation wave started in t-1 will leverage innovation in t.

In analyzing the previous hypothesis, the concepts connected to persistence, in both continuous and intermittent strategies will be tested along with the hypothesis of intermittence [H2] [H3] and [H4].

In sum figure 1 summarizes what will be tested.

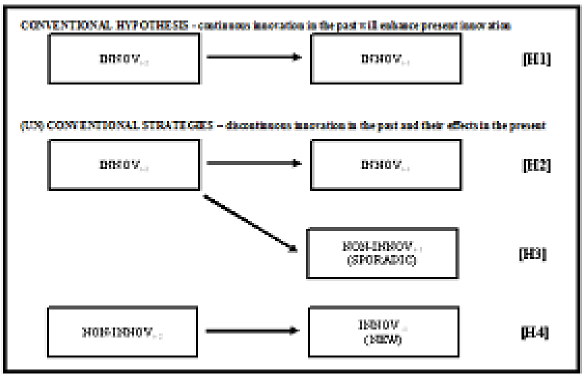

Fig. 1 Summary of the Hypotheses

Under the conventional persistence hypothesis, present innovation outcomes are explained by past innovation achievements, subject to the extension of investments in resources and capabilities (investments in R&D and machinery, skilled human resources) and firm's structural characteristics (size, sector, age, capital ownership) (Le Bas and Scellato, 2014; Altuzarra, 2017). The iterative hypothesis allows for changes in the innovative strategy caused by exogenous changes in the economic environment, despite the innovative heritage.

3. Database and descriptive results

3.1. Database and sample

The literature frameworks describe persistence as a time connection between past innovative actions and the present. Therefore, past managerial decisions will influence the present is a continuous way. Still, the empirical evidence shows that firms stop and initiate innovative actions for more than pure past dependence. Strategic behaviour changes due to several constraints, either endogenous or exogenous. We aim at identify the motivations for intermittences in innovation and explain the expectable changes under adverse economic environments.

Empirical support will rely on a panel of firms comprising several CIS waves, as it is the most extensive survey in this field undergoing through the recommendation of the European authorities. It comprises three biennia (CIS 6, CIS 8 and CIS 10), covering the period between 2004 and 2010. The appraisal of time span effects is made throughout balanced data, leading to a sample of 1099 firms observed over the entire period; intertemporal connections are made throughout dynamic panel estimations. Therefore, present innovative behaviour is explained by past innovative actions (allowing for complex strategies rather than pure time dependence) along with firm size, use of internal and external sources to perform R&D, connections with external sources of Knowledge, the reliance on public funds and belonging to an economic group.

Empirical evidence relying on exploratory analysis avowals that firms start, stop or continue in innovation strategically rather than by time inertia. Therefore, the past is insufficient to explain the present, and, policy actions encompass these fluctuations.

When analyzing the entire sample of the CIS in separate, and nearly two thirds of firms report performing some type of innovation; this figure is somehow encouraging as Portugal is a moderate innovator. The panel evidences persistence in 56,8% of firms; the rest has opted for intermittent actions in their innovative strategy. Here our aim is twofold: understand the structural characteristics that explain persistence rather than accepting persistence as time dependence and explain strategic intermittence and the role of public policy to leverage the success in innovation.

3.2. Exploratory analysis - Panel Characteristics

Persistence implies multiple time periods as it is a synonym of continuing innovative activities, so, only firms traceable in the period are kept, producing a balanced panel with 1099 heterogeneous firms.

Despite the dispersion in terms of dimension, it is essentially composed by medium sized firms (44%); which seem an accurate representation of the Portuguese reality, despite the biasedness in favor of large firms due to an additional effort in data collection from them due to methodological requirements of the survey. The secondary sector represents 62% (all industries), the primary 2%, and services 36%. Concerning equity, half of the firms belong to an economic group. Half the firms belong to a high tech sector, one fifth to a low tech and one third to a mid tech (according to Pavitt's taxonomy, 1984). High tech firms are naturally expected to be more innovative than others.

The R&D intensity (measured by the amount of resources devoted to innovative activities compared to the total turnover), is poor as 45% of firms do not perform any R&D activity at all, and, 41% of the firms present a 3% R&D intensity. Undergraduates or educational titles in the workforce are often used as a proxy for education intensity.   In the panel, 86 firms have no workers with top education, being the workforce classified as unskilled. Conversely, 53 firms report more than three quarters of their workforce highly skilled. Almost 9% of the firms in the panel have reported performing innovative activities in the innovation types considered on the survey; contrarily, one quarter of the firms declared not performing any innovative activity during the period of analysis. There were 371 firms not finding relevant the use of any source of information for their innovative activities.

Three quarters of the firms have mentioned not relying on any type of external funds, showing some disconnectedness with the innovation policy. As public funding seems to be important to support innovation, policy makers should be aware of this failure.

3.3. Transition frequencies

In each period, firms face binary decisions: whether or not to invest in innovation. In dynamic terms, it means stopping or starting/continuing innovative activities. The transition is appraised twice: from CIS 6 to the CIS 8 and from the CIS 8 to the CIS 10 with eight possible paths. Firms may adopt invariant strategies, (continuous in (non-)innovation), or intermittent strategies (starting or stopping innovation) in the different periods. The transition frequencies allow us to understand the innovation trajectories over time.

When moving from one period to the following there are four possibilities: persistent (a double yes to the performance of innovative activities), non-innovative (a double no to the performance of innovative activities), sporadic (a yes/no sequence) and a new innovator (no/yes sequence).

Independent of the innovation type, in the CIS6, 857 firms reported having performed somehow innovation (78% of the panel). Moving to the CIS8 725 remained in innovation, considered as persistent. Carrying to the CIS10, persistent innovators felt to 624. Dissimilarly, 100 firms reported no innovation activities over the three consecutive periods.

Table 2 Aggregation of the innovative strategies in the period of analysis

PATH	INNOV STRAT (TPM=3)	N	%
ACG	Continuous	624	56,8
ACH	Continuous - Sporadic	101	9,2
ADI	Sporadic - New	77	7
ADJ	Sporadic - Non innov	55	5
BFG	New - Continuous	74	6,7
BFH	New - Sporadic	26	2,4
BEI	Non - innovative - New	42	3,8
BEJ	Non – Innovative	100	9,1
	TOTAL	1099	100

The analysis of the transition probability matrix (Figure 2) illustrates that most of the firms are continuous innovators, reinforcing the conventional hypothesis of persistence. On the contrary, 100 firms never innovate during the period and 375 evidenced intermittent strategies.

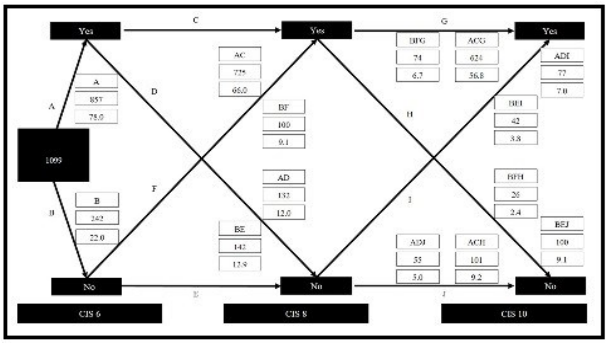

Fig. 2 Transition frequencies: innovation in general

4. Econometric analysis

4.1. Proxies and methodology

In order to understand the probability of innovating in period t, the regression includes a set of explanatory variables relating to past innovative behavior (continuing, sporadic and new) and a set of controls such as technological intensity, availability of skilled labor force, access to innovation sources, size, use of public funds, equity provenience and economic sector. Variable description detailed in Table 3.

Table 3 Variable description

Variable	Type	Description
RD_intensity	Count	Ratio comparing the expenditures in R&D compared to the total turnover
Mid_tech	Binary	1 if the firm belongs to a SIC code classified as being mid tech [1]
High_tech	Binary	1 if the firm belongs to a SIC code classified as being high tech [1]
Balance	Binary	1 if the firm combines investments in endogenous and exogenous knowledge
Educ_intensity	Connt	Ratio comparing the number of top educated workers to the total
Openness	Count	Counts for the number of sources of innovation the firm uses
Funds	Binary	1 if the firm uses public funds
Medium_size	Binary	1 if the firm in medium
Large_size	Binary	1 if the firm in large
Group	Binary	1 if the firm belongs to an economic group
Industry	Binary	1 if the firm belongs to the industrial sector
Services	Binary	1 if the firm belongs to the services

[1] Technological intensity defined according to the Pavitt taxonomy in what concerns the manufacturing sector and extended to the other activities as seen in diffused literature from the OECD and the European Commission

Table 4 presents the descriptive statistics of the variables in use.

Table 4 Descriptive statistics of the variables in analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
SIC_code	3297			7	74
tech_int	3297	2.298	0.778	1	3
sector	3297	2.329	0.517	1	3
size	3297	2.868	0.748	2	4
group	3297	0.485	0.500	0	1
Innov g	3297	0.758	0.428	0	1
Funds g	3297	0.189	0.392	0	1
Openess	3297	4.914	4.081	0	10
R&D_int	3297	4.533	115.682	0	6615.23
Educ int	3297	2.521	1.557	0	6

The econometric estimations were run using dynamic random effects probit, still, conventional and unconventional hypotheses were separated as it was unfeasible to combine them in a single equation (see Table 5). Model(s) 1 test the conventional hypothesis of persistence, as they do not consider intermittent innovative behaviors; in these cases, pure past dependence is estimated posing that being innovative in the past will influence the probability to innovate in the present. Model(s) 2 include strategic options concerning past innovative behaviors (firms may have opted for continuing, starting, stopping or not innovating at all). In all models, a set of explanatory variables is included, comprising the firm's structural traits and illustrating innovation efforts.

4.2. Econometric specification

Using either the conventional or the unconventional hypotheses of persistence, the aim of the present research is to determine the probability of being an innovator in period t subject to what has been done by the firm in the past. Therefore, the dependent variable in both equations is binary: it takes the value of 1 if the firm i innovates at time t and the value of 0 otherwise. Due to the nature of the dependent variable the best suiting models are the probit (or logit).

The estimation of the panel can be addressed through fixed-effects or random-effects, even though, some of the explanatory variables of interest are time-invariant making the use of fixed effects unfeasible, forcing the choice to random-effects. However, the use of random effects is only valid if the unobserved time invariant firm effects are uncorrelated to the explanatory variables, which is impossible given that the lagged value of the dependent variable is an explanatory variable. Wooldridge (2005) developed a solution to relax the "independence assumption" in random effects dynamic probit models. This solution consists in replacing the αi in the equations below by a linear function of the firm's observable characteristic's (i.e. the average values of the time-variant exogenous characteristics) added to the value of the so-called "initial condition", i.e., the innovative or non-innovative state of the firm at the starting period in observation.

Therefore, the estimation of either the model presented in the following equations (equation (1) and equation (2)) will be completed using a dynamic random effects probit model.

The conventional hypothesis of persistence, presented in model(s)1 will consist of a dynamic random effects probit specified as follows:

$$INNOV_{it} = \beta_1 + \beta_2\, INNOV_{it-1} + \boldsymbol{\beta} W_{it} + \boldsymbol{\delta} V_i + \alpha_i + \varepsilon_{it} \quad (1)$$

Where firm i is innovative at time t by (Innovit) depending on innovations at time t-1, a set of time-variant (Wit) and time-invariant (Vi) observable characteristics of the firm, and an unobservable firm-specific characteristic (αi).

This model only allows for the assessment of the traditional hypothesis of persistence, modelling the effect that past innovations have on present innovations without any discontinuity or variability added to a vector of explanatory variables. In all regressions ran this coefficient fails to be statistically significant, this result may present some evidence supporting the failure of pure persistence.

The analysis of intermittence in innovative strategies requires the construction of subgroups according to the past innovative behavior. The group dissection was performed according to the proposal of the European Innovation Scoreboard (2004) and Sauréz (2014), creating four different sub-groups:

a) Continuous innovators – firms that reported performing innovation in two consecutive time periods (Continuous_Innov);

b) Sporadic innovators – firms that reported having performed innovation two periods ago, and stopped in the next period (Sporadic_Innov);

c) New innovators – firms that reported not having performed innovation two periods ago and started innovation in the next period (New_Innov);

d) Non-innovative - firms which did not perform innovation in any of the periods (Non-innov), this category is considered as default in our estimation.

In this context, the model previously presented (equation (1)) is restructured as follows:

$$\begin{aligned} INNOV_{it} = {} & \beta_1 + \beta_2 CONTINUOUS_{INNOV\ it-1} \\ & + \beta_3 SPORADIC_{INNOV\ it-1} \\ & + \beta_4 NEW_{INNOV\ it-1} + \boldsymbol{\beta}_{it} + W\boldsymbol{\delta}_i \quad V \\ & + \alpha_i + \varepsilon_{it} \end{aligned} \quad (2)$$

The second group of regressions allows for unconventional hypotheses of persistence, as it models intermittence. In this case, evidence in favor of persistence could come from a positive coefficient on Continuous_Innovit-1 or New_Innovit-1. Concerning Sporadic_Innovit-1, if the hypothesis of persistence is confirmed one would expect a negative effect in the probability of innovating at present.

When the intermittence regressions are run, the coefficients of past innovative strategy variables appear as statistically significant. Albeit, in this case, the results provide a different perspective, which may reinforce the heterogeneity in terms of innovative strategic behavior of moderate innovators.

4.3. Estimation Results

The objective of analysis is the understanding of persistency in innovative activities, which means, the relation between being an innovator in former time periods and continuing in innovation in the present. In the dynamic probit with random effects, the propensity to be an innovator at present (binary) is explained by past innovative behaviors, and a set of controls corresponding to the firm structural characteristics. Namely firm characteristics such as size, economic group, economic sector, use of funds, R&D intensity, technological intensity, intra and extramural R&D activities [this vector of variables is chosen according to the findings of former studies (e.g. Peters, 2009; Raymond et al. 2010; Frenz and Pevezer 2012; Ganter and Hecker 2013; Le Bas and Poussing, 2014)].

The complete set of firms, regardless the sector of activity or the size is presented in models A (1 and 2). Given the previous belief that firms operating in industry should present a different pattern than those in services, models B(1 and 2) only include firms from industrial sectors and models C(1 and 2) contain firms from services. Significant differences are found in terms of the effect of past innovative strategies in present innovation along with some structural characteristics. Models D, E and F (1 and 2) separate firms according their size, following the CIS's taxonomy; this segmentation allowed understanding the existence of important differences in terms of the innovative behavior of small, medium and large firms.

Concerning the traditional hypothesis of persistence (illustrated in model(s)1) being innovative in the past does not influence the probability of being innovative in the present. In other words, the hypothesis fails being proved for innovation in general. Our empirical evidence, independent of the model being run does no support pure innovation persistence.

The present results cannot be directly compared the existing literature, as to us, being an innovator means having performed innovation independent of the type. Pure persistence should hold, still, the result is not statistically significant. The statistical insignificance of the conventional hypothesis of persistence occurs in all models, independent of the segmentation operated. It is of worth underlying that increases in R&D intensity raise the probability of innovation along with openness highlighting the importance of the sources of innovation to develop different innovative strategies and adapt to the changing environment. Here the empirical evidence for Portugal differs from the German, as Peters (2009) has found that German firms are persistent innovators in terms of product innovation.

When considering intermittent strategies different results appear, being a persistent innovator in the past reduces the probability of innovating at present by 8.17 percentage points compared to the non-innovative firms. This result is contrary to the expectation about pure persistence, indicating that firms deliberately discontinue their innovation activities. Past sporadic innovators also have a reduced probability to innovate at present; those firms that stopped innovation will be less prone to restart it. On the contrary, firms that are new to innovation will have an increased probability to continue their innovations, perhaps closing their innovation cycle.

So far, most of the works have only considered firms operating on the industrial sector, albeit the increasing importance of the services impelled to the estimation of both groups in separate. In the case of the industry similar results from the entire group appear, but, in the tertiary sector either conventional or unconventional persistence fails to be statistically significant, this result deserves further reflection as policy makers cannot reach these sectors of activity with the present policy design.

Peters (2009), when analysing conventional persistence in product innovation for German firms did find statistical significance for size, with larger firms being more prone to persist in innovation. Frenz and Prevezer (2012), exploring the British evidence confirm the conventional persistence hypothesis, also supporting the significance of size and sector. In this vein, the division of firms according to their size was operated to understand if there is a similar pattern of innovative strategy among them. In the Portuguese case, either in small, medium and large firms pure persistence fails to be significant (models D1, E1 and F1).

The models that include intermittence bring up differences across firm sizes. In the case of small and medium sized firms, being persistent in the past does not influence the probability of innovating at present. This effect is only evident in the case of large firms. Being a sporadic innovator in the past reduces the probability of innovation in the present for small and medium sized firms, and does not produce any effect in the case of large firms. New innovators have an increased probability to innovate in the present, in all firm sizes, reinforcing the idea of innovation cycles.

Concerning the controls, and in parallel with the Dutch case explored by Raymond et al. (2010), exists persistence among mid-high and high tech firms; our results go in a similar direction as the marginal effects of technological intensity punctually appears as positive.

The existing literature did not proxy the influence of innovation sources in the probability to innovate, even though, to us, this effect cannot be neglected, and, it appears as significant in the models run. More open firms have an increased probability to innovate, which reinforces the need to establish strong connections among the actors operating inside and outside the production chain to leverage innovation. Table 5 (in Appendix) evidences the estimation results for the different models in discussion.

5. Conclusion and Policy Recommendations

Despite the extant works in innovation persistence, there is no comprehensive understanding about the leitmotif of continuity or intermittence in innovation (Juliao-Rossi and Schmutzler, 2016; Altuzarra, 2017). Additionally, analysts focus on Leaders or Strong Innovators rather than on Moderate countries, whose difficulties are of worth more attention given the convergence targets. The firm strategy is appraised in a ceteris paribus assumption towards the economic environment, removing realism from the findings; unstable economic environments are overlooked in both theoretical and empirical terms.

Focusing on a balanced panel of 1099 firms located in Portugal and analyzing the three biennia 2004 and 2010 the hypothesis of 'true state dependence' failed to be proved throughout the conventional models in which no intermittences were allowed. Even though, when the estimation encompasses reaction to exogenous changes, former persistence disincentives present innovations. This result holds in either the entire sample or the industrial sub-sample.

Results obtained are only partially in line with Suárez's (2014) regarding Argentinian firms, and contrast significantly with extant literature on European countries, namely that analyzing other 'Moderate Innovator', Spain (Martinez-Ros and Labeaga, 2009; Triguero et al., 2014, Córcoles et al., 2016; Altuzarra, 2017). Two main results are worth highlighting.

First, although exploratory analysis, based on the transition probability matrices, uncover a very high degree of state dependence or innovation persistence (in Table 1), the econometric estimations (in Table 5) evidence that, when changes in innovative behavior are not accounted for (Models A/…/F1), such innovation persistence is mainly spurious rather than true innovation persistence. In other words, the observed persistence is the result of other factors such as firms' characteristics, most notably openness (number of distinct external sources of information for innovation the firm uses) and the capability to effectively combine internal and external investments in intangible assets (more precisely, R&D activities). Additionally, heterogeneity was found between industrial firms and services, requiring fine tuning adjustments in policy design.

Second, results suggest that in unstable environments (and when we account for dynamics in firms' innovative behavior – Models A/…/F2), we cannot assume an intertemporal relationship between past innovations, present innovative behavior, and future results. Specifically, empirical evidence suggests, particularly in large manufacturing firms that are 'Continuing innovators' in the past have a decreased odds of innovating in the future. In contrast, 'New innovators', and to large extent those of small and medium size, observe an increased odds of innovation. Thus, the persistent levels among 'New innovative' firms evidence path independence rather than path dependency and cast doubts on the capacity of firms, particularly large incumbent firms, to respond swiftly to changes in the environment.

These results have important policy implications. First, because innovation persistence does not hold in our sample, it is likely that innovation policy programs do not have long-lasting effect on innovative behavior of firms. As firms do not tend to persist on engaging in innovation themselves if policy makers have a strong reason to stimulate innovation, then innovation policies must be prepared to do such stimulation as a longer term commitment and not change policies in the short and medium run. Moreover, attention should be paid to the importance of external sources of knowledge in enhancing the probability to innovate. Second, in the absence of evidence of innovation persistence, potential intertemporal spillovers are unlikely to emerge, in order words, it is unlikely that incumbent past innovators be the drivers of creative accumulation and future innovation. There is, however, some evidence that new, smaller, innovators might lead the creative wave. In this vein, there might be a rational to encourage public policies targeting start-up firms and new market entrants when innovation is the main primary funding goal.

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Table 5: Dynamic random effect probit estimations with endogenous initial conditions (average marginal effects) [dependent variable: the firm innovates in the current period)]

		All		Industry		Services		Small		Medium		Large	
		Model A1	Model A2	Model B1	Model B2	Model C1	Model C2	Model D1	Model D2	Model E1	Model E2	Model F1	Model F2
Persistence	Innovation $_{t-1}$	0.0250 (0.2594)		0.0250 (0.0259)		0.0113 (0.0560)		0.0365 (0.0470)		0.0222 (0.0348)		-0.1173 (0.5388)	
Dynamic innovative behavior (default: 'never innovates')	Continuing $_{t-1}$		**-0.0817***** (0.0202)		**-0.0816***** (0.0195)		-0.0937 (0.5210)		-0.0576 (0.0381)		-0.8664 (0.5852)		**-0.0532***** (0.0172)
	Sporadic $_{t-1}$		**-0.0997***** (0.0434)		**-0.0996**** (0.0410)		-0.0707 (1.1421)		**-0.1091**** (0.0477)		**-1.0390*** (0.5428)		0.0154 (0.0944)
	New $_{t-1}$		**0.1209***** (0.0278)		**0.1210***** (0.0273)		0.1442 (0.3595)		**0.1791***** (0.0391)		**0.5957*** (0.3701)		**0.0920**** (0.0457)
R&D activities	R&D intensity	**0.0129**** (0.0060)	-0.0001 (0.0002)	**0.0128**** (0.0060)	-0.0001 (0.0002)	0.0167 (0.0178)	-0.0009 (0.0006)	0.0208 (0.0184)	0.0242 (0.0227)	**0.0092*** (0.0055)	-0.0053 (0.0050)	0.7322 (3.3620)	**0.2074***** (0.0600)
	R&D balance (Perform both internal and external R&D activities)	0.0356 (0.0600)	0.0346 (0.0476)	0.0357 (0.0600)	0.0344 (0.0475)	**0.8458***** (0.2392)	6.4971 (20.876)	**0.6798***** (0.1297)	**0.6875***** (0.0890)	0.0141 (0.0596)	0.2136 (0.4043)	0.5927 (2.1524)	0.3218 (0.2662)
Education	Education intensity	0.0118 (0.0101)	0.0015 (0.0074)	0.0119 (0.0101)	0.0016 (0.0074)	0.0082 (0.0158)	-0.0036 (0.0389)	0.0009 (0.0149)	-0.0169 (0.0113)	**0.0377*** (0.0195)	**0.2775*** (0.1628)		
Openness	Openness (Number of distinct sources of information for innovation)	**0.0559***** (0.0040)	**0.0465***** (0.0039)	**0.0559***** (0.0040)	**0.0465***** (0.0038)	**0.0595***** (0.0081)	0.0515 (0.1184)	**0.0998***** (0.0189)	**0.0860***** (0.0190)	**0.0483***** (0.0044)	**0.3244**** (0.1613)	0.0430 (0.1521)	**0.0194***** (0.0030)
Funds	Public funds	-0.0380 (0.0397)	-0.0077 (0.0304)	-0.0395 (0.0391)	-0.0083 (0.0301)	**-0.2313***** (0.0684)	-0.1491 (0.3276)	0.0110 (0.1555)	**-0.0187** (0.1417)	-0.0371 (0.0441)	-0.0943 (0.2672)	-0.1412 (0.8275)	-0.0597 (0.0520)
Size (default: Small)	Medium	-0.0130 (0.0141)	-0.0077 (0.0097)	-0.0135 (0.0141)	-0.0079 (0.0097)	0.0048 (0.0232)	0.0059 (0.0358)						
	Large	0.0319 (0.0223)	**0.0268*** (0.0139)	0.0320 (0.0223)	**0.0267*** (0.0139)	0.0353 (0.0332)	0.0304 (0.0646)						
Group	Group (1 if the firm belongs to a Group)	-0.0001 (0.0157)	-0.0063 (0.0108)	0.0008 (0.0156)	-0.0057 (0.0108)	-0.0309 (0.0232)	-0.0244 (0.1554)	-0.0000 (0.0325)	-0.0067 (0.0226)	-0.0004 (0.0211)	-0.0338 (0.1222)	0.0098 (0.0746)	-0.0116 (0.0140)
Sector (default: Primary)	Industry (1 if the firm operates in Industry)	-0.0061 (0.0347)	-0.0059 (0.0247)					-0.0955 (0.0608)	**-0.0601*** (0.0349)	0.0593 (0.0530)	0.2295 (0.4434)		
	Services (1 if the firm operates in Services)	0.0026 (0.0364)	-0.0015 (0.0254)					-0.0766 (0.0635)	-0.0496 (0.0371)	0.0770 (0.0553)	0.3687 (0.4866)	-0.0203 (0.1441)	-0.0044 (0.0173)
Initial endogeneity and individual heterogeneity	$Inno_0$	**0.0671***** (0.0215)	**0.2137***** (0.0096)	**0.0673***** (0.0216)	**0.2137***** (0.0096)	0.0454 (0.0402)	0.2074 (0.1458)	0.0436 (0.0362)	**0.2400***** (0.0150)	0.0454 (0.0323)	**1.6300***** (0.5820)	0.2094 (0.9613)	**0.1403***** (0.0201)
	mean_rd_intensity	0.0006 (0.0009)	0.0004 (0.0007)	0.0006 (0.0009)	0.0004 (0.0007)	**0.0002***** (0.0001)	0.0002 (0.0007)	0.0042 (0.0033)	0.00176 (0.0016)	-0.0007 (0.0006)	-0.0020 (0.0040)	0.0164 (0.0755)	0.0050 (0.0060)
	mean_educ_intensity	-0.0100 (0.0114)	0.0004 (0.0081)	-0.0092 (0.0113)	0.0008 (0.0080)	-0.0062 (0.0169)	0.0057 (0.0324)	0.0011 (0.0184)	0.0192 (0.0129)	**-0.0348*** (0.0203)	-0.2661 (0.1998)	0.0024 (0.0612)	0.0008 (0.0006)
	mean_openness	0.0003 (0.0050)	-0.0016 (0.0028)	0.0001 (0.0050)	-0.0017 (0.0028)	0.0015 (0.0078)	-0.0016 (0.0249)	0.0112 (0.0107)	0.0006 (0.0056)	-0.0022 (0.0070)	-0.0154 (0.0338)	-0.0063 (0.0161)	-0.0022 (0.0039)
	No. observations	2198	3297	2198	3297	780	1170	756	1134	969	1456	468	702
	No. of groups	1099	1099	1099	1099	390	390	378	378	485	487	234	234
	Wald test (p-value)	188.44 (0.000)	781.48 (0.000)	188.48 (0.000)	781.68 (0.000)	60.81 (0.000)	222.74 (0.000)	61.08 (0.000)	231.48 (0.000)	85.33 (0.000)	366.50 (0.000)	18.90 (0.063)	78.21 (0.000)