GEE

**GEE Papers**

Number 94

**February 2018**

# Persistence in innovation and innovative behavior in unstable environments

**Joana Costa, Anabela Botelho and Aurora A.C. Teixeira**

GEE

# Persistence in innovation and innovative behavior in unstable environments [1]

Joana Costa [2], Anabela Botelho [3] and Aurora A.C. Teixeira [4]

**Abstract**

The analysis of persistence in innovation can improve the understanding of firm dynamics, anticipate the effects of the different policy actions, correct macroeconomic disequilibria, help in designing the correct policies to boost R&D and, consequently, generate prosperity.

Persistence of innovation is empirically explored mostly using the case of innovation leaders or followers, which may not apply to countries with poorer performances in terms of innovation. Studying the case of a moderate innovator may shed some light into the different conditions of firms and their attitude towards persistence, as well as the adoption of different policy actions to observe this heterogeneity. Additionally, the effect of firm size and industry has not yet been fully explored by the literature on innovation persistence.

The present paper analyses the persistence of innovation using a dynamic panel comprising 1099 firms operating in all economic sectors of a moderate innovator country, Portugal. Firms are observed in three waves of the Portuguese part of the Community Innovation Survey (CIS), from 2004 to 2010.

Using the random effects probit model, the persistence hypothesis fails to be corroborated. Such result suggest 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.

**JEL Classification:** D22; L20; O31; O32

***Keywords:*** *Persistence; Innovation; State dependence; Firms; Community Innovation Survey; Portugal*



[1] Premiado no âmbito da Call Inovação baseada em Conhecimento, realizada numa parceria entre o Gabinete de Estratégia e Estudos do Ministério da Economia (GEE) e a Agência Nacional de Inovação (ANI).

[2] Universidade de Aveiro

[3] Universidade de Aveiro

[4] CEF.UP, Faculdade de Economia, Universidade do Porto, ateixeira@fep.up.pt

## 1. Introduction

Fast changing technologies, which tend to rapidly erode the valuation in the market place of current products and associated services, have been driven the increasing competition in internal and external markets (Bower and Christensen 1995; Vecchiato, 2017). In this context, innovation, conceived as the transformation of ideas, information and knowledge to improved competitiveness and sustained competitive advantage, is a central piece of a firm's strategy (Karlsson and Tavassoli, 2016).

Given the pivotal role of innovation as driver of firm performance, it seems reasonable to assume that innovation persistence can help explain sustained competitive advantage and lasting inter firm performance differences (Cefis and Ciccarelli, 2005; Hecker and Ganter, 2014). Innovation persistence denotes "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 persistence in innovative activities and behaviors is an important topic in the innovation literature and applied industrial economics (Tavassoli and Karlsson, 2015; Córcoles et al., 2016), an emerging area of empirical research (Triguero et al., 2014), and a pertinent 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". Specifically, from the public policy perspective, innovation persistence suggests that intertemporal spillovers are important for designing, targeting, and evaluating innovation subsidies (Hecker and Ganter, 2014). Accordingly, the evidence of strong persistence effects would indicate that incumbent firms and creative accumulation are the chief drivers of innovation, which, to a certain extent, may downplay the 'creative destruction' potential of new entrants (Malerba and Orsenigo 1999; Aghion, 2017). Such an argumentation questions 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).

In the case of 'Moderate innovators' (EC, 2017),[5] understanding the links between past and present innovative behavior is critical. 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).

[5] 'Moderate Innovators' includes countries Member States where overall innovation performance is between 50% and 90% of the EU average. It is the category that includes the largest number of countries, 14. Beside Portugal, it includes Croatia, Cyprus, the Czech Republic, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Slovakia, and Spain (see EC, 2017).

Up to the present date, a reasonable amount of empirical evidence regarding innovation persistence has been gathered. However, such phenomenon is not yet fully comprehended (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 countries considered as '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).[6]

Additionally, with exception of Suárez (2014), who has analyzed a group of 800 Argentinean manufacturing firms over 3 periods involving 3 years spells (1998–2001, 2002–2004, and 2005–2006), the issue of innovation and innovative behavior persistence in unstable environments has been overlooked. Indeed, extant empirical literature on innovation persistence 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). They, thus, fail to account for the possibility of changes in firm innovative behavior.

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 percent in 2003, remained fragile until 2006. Productivity growth in the business sector fell to around 1 percent between 2004 and 2005. Unemployment also increased sharply, reaching 7.6 percent in 2005 and 8 percent in 2007, the highest rate in 20 years (IMF, 2009). Although there was a slight recovery in 2007, in 2009 real GDP per capita decreased by 3.1% and unemployment reach a socially problematic figure of 9.4%. Continuing fall of investment and gross saving and escalate public debt between 2006 and 2010 culminated in the Bailout programme, a Memorandum of understanding on financial assistance to the Portuguese Republic in order to cope with the 2010–14 Portuguese financial crisis (Costa et al., 2016). 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.

In the present paper, based on a balanced panel of 1099 firms located in a Moderate Innovator (Portugal), between 2004 and 2010 (involving 3 waves of the Community Innovation Survey: 2004-2006; 2006-2008; 2008-2010), we tested the hypothesis of 'true state dependence' (or true persistence in innovation), that is a causal behavioral effect where the decision to innovate in one period increases the likelihood to innovate in the subsequent period, assuming both that firms do not react to environmental fluctuations and that they do react by changing their innovative behavior (Continuous, New, Sporadically, and Non innovative firms).

[6] Two earlier studies (Malerba et al. 1997; Cefis and Orsenigo, 2001) address the case of Italian manufacturing firms but jointly with firms located in other countries (United States, Japan, United Kingdom, Germany, France).

Given that firms may exhibit certain characteristics that are unobserved but correlated over time, and that make them more likely to innovate (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). Thus, for overcoming this problem, we follow recent contributions by, among others, Peters (2009) and Hecker and Ganter (2014), in econometrically separating the influence of unobserved firm heterogeneity and initial conditions from causal effects of past innovation activity. Such procedure allowed to decompose observable innovation persistence into spurious and true state dependence. Furthermore, 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. In the next section we review the relevant literature and present the main hypotheses to be tested. Then in Section 3 we describe the database and present some exploratory results. Section 4 discusses the results of the econometric analysis. Finally, in Conclusions we summarize the main contributions and policy implications of the study, as well as main avenues for future research.

## 2. Literature review on persistence of innovative activities

### 2.1. Past and path dependence of the innovation process

The innovation process can be explained by to alternative properties: past dependence or path dependence. Past dependence means that the determinants of the innovative process and its results are fully determined by the initial conditions (Antonelli, 2011). Persistence will be conditional to the first innovation, and the generation of long-lasting innovative skills. Conversely, path dependence explains that, in a localized context in which knowledge is planted, an 'historical accident' occurs, followed by another in a random process. The success of innovation will depend on the ability of the firm to benefit from the 'accident'. Therefore, innovation will be strongly tied to existing competences and networking. In particular, persistence will be contingent to the exploitation of complementarities and interdependencies under the proper institutional environment (Collombelli and von Tunzelmann, 2011). The access to knowledge pools, reinforcement of networks, linkages among firms will therefore be strongly recommended.

The option for persistence innovations is part of the innovative process thus determining technological change (Cefis and Orsenigo, 2001). It is essential for firms to continue investing in these projects in order to respond to the changing economic environment. Hence, a strong cleavage is perceived among firms as persistence will be verified among 'great innovators' (Cefis, 2003). Managers may opt for pursuing innovation in a regular base, perceiving the fact that there is some inertia in the process, the innovative behaviour over time is not a random process, if the firm is targeted to the market (market drive) 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 to explain the sources of persistence of innovation

To assess the motivations of persistence of innovation four main complementary frameworks can be considered (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), innovation creates a temporary monopolist position which innovative firms desire to maintain. Consequently, when a firm becomes innovative and enjoys monopolist benefits, it has more incentive to further innovate. Since new entry firms will reduce monopolist benefits, the insider firm has more incentive to continue being a monopolist than the entrant's incentive to become a duopolist (Le Bas and Scellato, 2014). Therefore, incumbents tend to innovate persistently.

Regarding the 'success-breeds-success' (Mansfield, 1968; Stoneman, 1983) previous innovation success provides firms with additional technological opportunities, making future innovation success more feasible. Incomes and profits are 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 determining factor that is 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 forming 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 are very likely to generate 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 recuperate the cost of R&D investments, the conduct of 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. It argues that current knowledge is dependent on previous knowledge and the foundation upon which future knowledge rests. Knowledge, namely tacit knowledge, is accumulated in the people working in the organization; knowledge does not depreciate with time 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 ongoing 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. Main hypotheses to be tested

There is already a reasonable number of high quality studies on the persistence of innovation. Nevertheless, the results are not consensual. The extant evidence is mixed. Most works identify weak elements of persistency but do not provide a convincing consensus about its determinants and, most importantly, about the specific kind of dynamic process (see Antonelli et al., 2012).

Most of previous empirical studies have focussed 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 behaviour 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 behaviour to have no impact or even a detrimental impact on future innovative behaviour in contexts of changing (or uncertain) environments. As noted by Nelson and Winter (1982) this could happen if, for example, past successful innovative behaviour 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.

Strategic behaviour of firms, 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 cycle of innovation.

This leads to four possible innovation trajectories in each time threshold (see Table 1): non-innovative, if the firm decides not to innovate in the two time periods; sporadic innovator if the firm stops innovating from one moment to the other; new innovator if the firm commences the innovative process; or persistent innovator if the firm continues to innovate from one moment to the other. This analysis constitutes a further contribution to the persistence literature, discussing the different innovative strategies over time in the context of a moderate innovator.

In the first hypothesis [H1] pure time persistence will be tested ignoring other possibilities than being innovative in the former period of time. Under this assumption we will not consider the possibility of changing the innovative strategy over time due to eventual changes in the firm or in the economic environment. Therefore, past innovative achievements will influence the present (considering innovation inputs and structural controls).

According to existing literature, independent of the conceptual framework, having innovated in the past will positively influence the probability of innovating at present. Former continuous innovators will persist in their innovative strategies.

This construction aims at understanding if, for moderate innovators the framework of conventional persistence does hold. This hypothesis will be tested in the first model run to each innovation type.

The empirical evidence shows that frequently firms change their attitude towards innovation from one period to the 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. The strategic changes will be detailed in three alternative hypotheses:

**Table 1: Alternative innovative strategies**

| 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 |

*Source:* Own elaboration.

[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. In other words, if the firm did innovate two periods ago and was carry forward in the former period, 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. In other words, 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 that are ***new to innovation*** in t-1, so to say that they started innovation in the transition from t-2 to t-1, (non innovative in t-2 and innovative in t-1), have an ***increased probability*** to continue innovation at present. This means that the innovation wave started in t-1 will influence innovation in t.

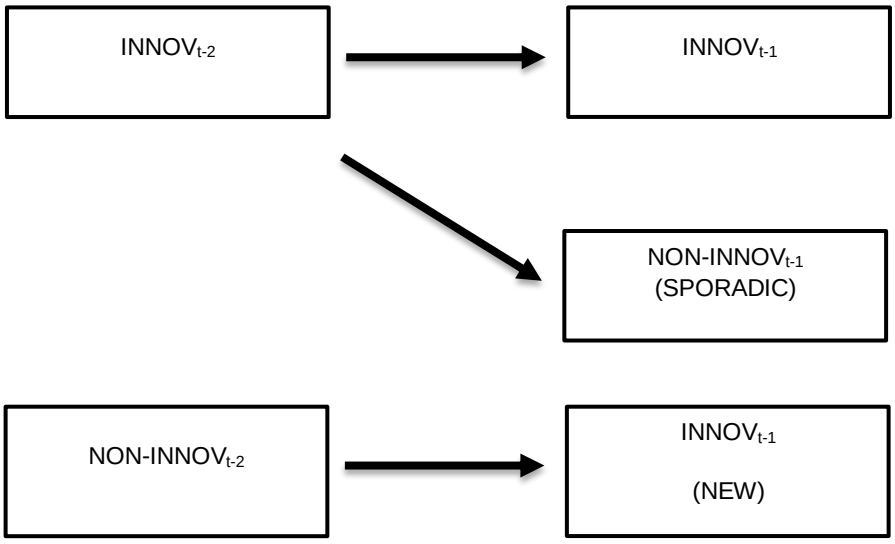
In analysing the previous hypothesis, the concepts connected to persistence, in both continuous and intermittent strategies will be tested along with the hypothesis of intermittence [H2] [H3] and [H4].

Summarising:

**CONVENTIONAL HYPOTHESIS - continuous innovation in the past will enhance present innovation**


**[H1]**

**(UN) CONVENTIONAL STRATEGIES – discontinuous innovation in the past and their effects in the present**




**[H2]**

**[H3]**

**[H4]**

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).

## 3. Database and descriptive results

### 3.1. Database and sample

The existing theoretical frameworks present persistence as a time connection between past innovative actions and the present. As a consequence, 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. This change in the strategic behaviour may be caused by subject to several constraints, either endogenous or exogenous. In this research we aim at understanding the underlying reasoning to change the innovative policy, and in particular, to explain the expected changes of firms to react to adverse environments such as a crisis.

To analyse the effective existence of pure time connection or the exploration of intermittence in innovative behaviour, a panel of firms was constructed considering several CIS waves as it is the most extensive in this field undergoing through the innovation details according to the recommendation of the European authorities. It comprises three biennia, the CIS 6, CIS 8 and CIS 10, which gather information between 2004 and 2010.

Despite the preliminary analysis of the entire sample of each CIS edition, a balanced panel was constructed to run the estimations, therefore, only firms that were present in the three inquiry moments were maintained, which leads to 1099 firms were observed during the three periods. Moreover, to establish the connection between past and present innovations the option was considering a dynamic panel.

The panel includes firms operating in all economic sectors along with structural characteristics believed affecting their innovative behaviour, such as the firm size, sector of activity, the use of public funds, the expenditures in R&D, and the openness to innovation sources.

In sum, the present innovative behaviour will be explained by past innovative actions, which consist in complex strategic decisions rather than on pure time dependence, along with the firm size, the resources devoted to R&D and the combination of internal and external efforts in these actions, the collection of connections with external sources of innovation, the reliance on public funds and belonging to an economic group.

The aim of the present research is to discuss the influence of the past managerial decisions regarding innovation in the present, as the idea of pure persistence seems to be scant to explain intermittence. The empirical evidence produced by the simple exploratory analysis avowals that firms start, stop or continue their innovative activities strategically and not by time inertia. Therefore, the past is insufficient to explain the present, and, policy actions must be designed bearing in mind the existence of these fluctuations.

When analysing the CIS waves in separate, one can observe that nearly two thirds of firms report performing some type of innovation during the period, this figure is somehow encouraging as Portugal is a moderate innovator and firms are expected to present poor performances in this field. When moving to the panel, persistence is observed in 56,8% of firms, which declared having continuously innovated during the six years. The rest, have opted for intermittent actions in their innovative policy. These preliminary results highlight the existence of persistence, so our aim is twofold: first, to understand the structural characteristics that explain persistence rather than accepting persistence as time dependence, and the second is to explain strategic intermittence and the role of public policy to leverage the success in innovation.

### 3.2. Exploratory analysis

#### 3.2.1 Structural traits of the panel

The analysis of persistence requires multiple time periods as it is a synonym of continuing innovative activities over time. Firms are considered as persistent if they report innovative actions without interruption. So, despite the existence of thousands of respondents in the CIS 6, the CIS 8 and the CIS 10, only those firms whose responses are available in the three biennia are kept, producing a balanced panel. This procedure allowed us to achieve 1099 responses, from firms with heterogeneous characteristics.

The panel is essentially composed by medium sized firms (44%); small firms represent 35% and large firms represent 21%. It seems an accurate representation of the Portuguese reality, even though the biasedness in favour of large firms exists due to an additional effort in collecting data from them due to methodological requirements. Firms in the secondary sector represent 62% (all industries), the primary sector reaches 2%, and services achieve 36% of the total. Concerning equity structure, half of the firms belong to an economic group the other half does not.

According to Pavitt's taxonomy (1984), half the firms in the panel belong to a high tech sector, one fifth to a low tech and one third to a mid tech. 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), achieves poor levels as 45% of firms do not perform any R&D activity at all, and, 41% of the firms present a 3% R&D intensity, which is considered as a good result.

The number of workers with undergraduates or educational titles is 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 between 75% and 100% of their workforce as being 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 reported not finding relevant any source of information for their innovative activities.

Three quarters of the firms have mentioned not relying on any type of external funds, the poor achievement in this indicator shown some disconnectedness between the innovation policy and the firms. As public funding seems to be important to support innovation, policy makers should be aware of this failure.

#### 3.2.2 Structural traits of the extreme groups

Firms can opt for innovation in a persistent basis, to solve specific problems in particular moments, or may opt not to innovate at all. Due to the differences in their managerial strategies it is expected to find cleavages in their structural traits. Results show that persistent innovators and non-innovators have different characteristics.

Most of our persistent innovators are part of an economic group. In terms of R&D intensity, persistent innovators present higher levels than non-innovators. Persistent innovators are open organisations while non-innovators are closed. The support from public funds is used by an important percentage of the persistent innovators, contrarily, non-innovators not to draw upon public finance. These results reinforce the theoretical outcomes. Concerning to size, economic sector and the education intensity no significant differences are found among the two sub-samples.

In sum, the general traits of the persistent innovators allow us to understand that these firms establish strong connections with other institutions, possibly enhanced by the human capital factors they seize, as well as a return of their expenditures in R&D. Their dynamism allows the use of public funding which is a handicap for the non-innovators.

### 3.3. Transition frequencies

In each period, firms face binary decisions: whether or not to invest in innovation. In dynamic terms it is transformed into stopping or starting/continuing innovative activities. The transition was operated over two moments, the first being from CIS 6 to the CIS 8 and the second from the CIS 8 to the CIS 10, so, having a three period panel one would have eight possible outcomes. Therefore, firms may adopt invariant strategies, meaning continuous in innovation, or continuous in non-innovation; or intermittent strategies, starting or stopping innovation in the different periods.

The innovative behaviour of firms in the transition from one period to the following had 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).

The transition frequencies allow us to understand the innovation trajectories over time. The panel of firms is observed over a six year period, allowing for an accurate design of the innovation strategies during the period of 2004-2010.

When analysing the innovation in general, in the CIS6, 857 firms have reported having performed at least one type of innovation, which is 78% of the panel. When moving to the second period, the CIS8, one could report as persistent innovators 725 firms, meaning that 132 firms failed to continue their innovative path. Continuing to the CIS10, the number of persistent innovators felt to 624 (see Table 2). Dissimilarly, 100 firms reported no innovation activities over the three consecutive periods.

No significant changes are found, from the first to the third period if we observe innovative firms at the aggregate level, 857 firms in the CIS6, and 817 in the CIS10. This preliminary analysis illustrates that when considering innovation in general (independent of the innovation type), no significant changes were reported even though, the type of innovation may have changed from one moment to the other.

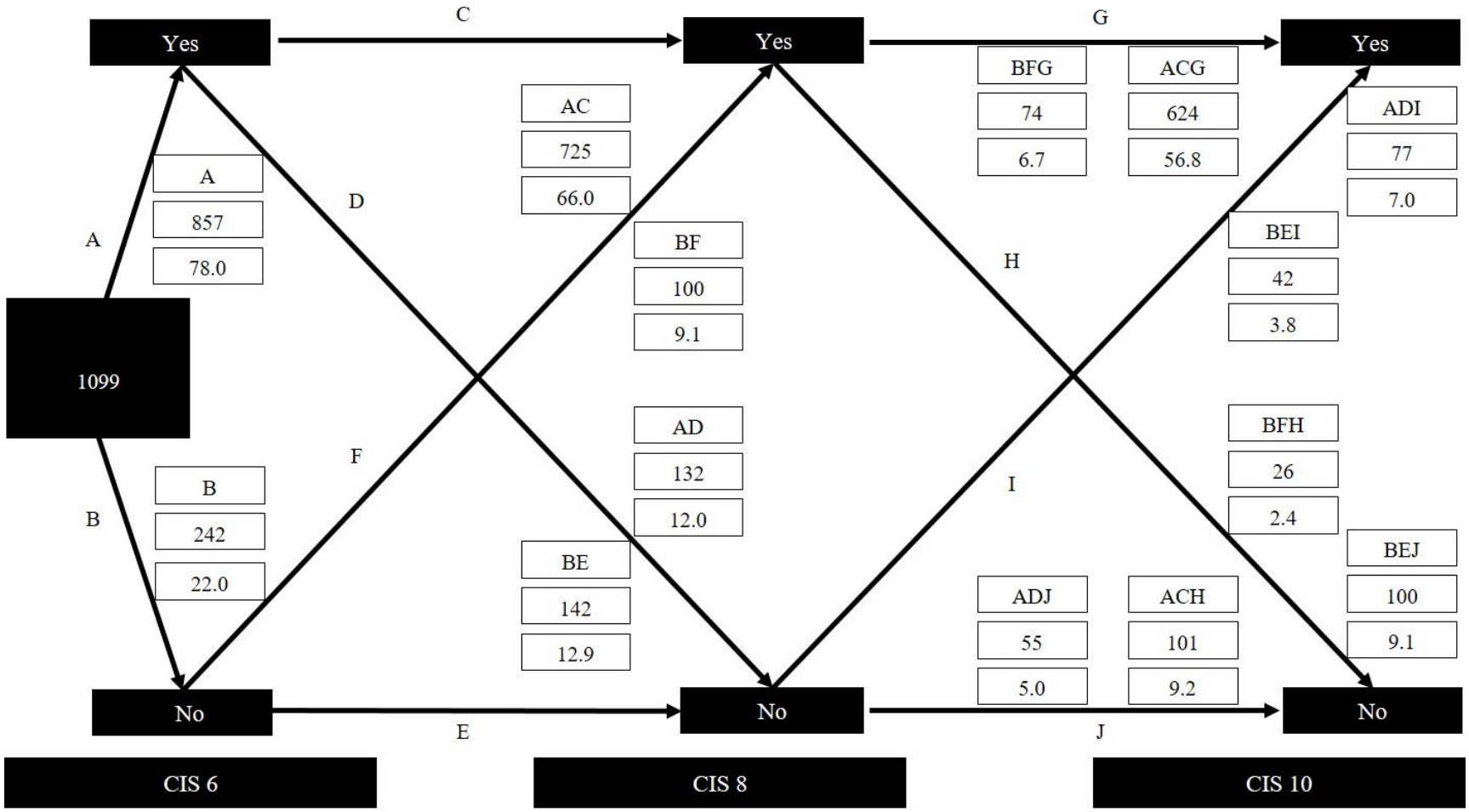
**Table 2: Aggregation of the innovative strategies in the period of analysis**

| **Innovative strategy (transition probability matrix path)** | | General |
|---|---|---|
| ACG | Continuous | 624 |
| ACH | Continuous - Sporadic | 101 |
| ADI | Sporadic - New | 77 |
| ADJ | Sporadic - Non innovative | 55 |
| BFG | New - Continuous | 74 |
| BFH | New - Sporadic | 26 |
| BEI | Non - innovative - New | 42 |
| BEJ | Non - Innovative | 100 |
| | **Total** | 1099 |

**Source:** Own computations based on the panel (CIS 6, CIS 8 and CIS 10)

The preliminary analysis of the transition probability matrix (see Figure 1) illustrates that most of the firms are continuous innovators, reinforcing our belief that there is continuity in innovation activities, which means, the conventional hypothesis of persistence.

**Figure 1 -** Transition frequencies: innovation in general




**Source:** Authors' computation based on CIS data

## 4. Econometric analysis

### 4.1. Proxies and methodology

In order to understand the probability of innovating in period t, we have included a set of variables indicating past innovative behaviour (continuing, sporadic and new) and a set of controls such as technological intensity, availability of skilled labour force, access to innovation sources, size, use of public funds, equity provenience and economic sector. The practicalities concerning variable construction are 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 |
| Education_intensity | Count | 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 relevant variables.

**Table 4: Descriptive statistics of the variables in analysis**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| SIC_code | 3297 | | | 7 | 74 |
| tech_intensity | 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 |
| innovation_in_general | 3297 | 0.758 | 0.428 | 0 | 1 |
| Funds_general | 3297 | 0.189 | 0.392 | 0 | 1 |
| Openess | 3297 | 4.914 | 4.081 | 0 | 10 |
| R&D_intensity | 3297 | 4.533 | 115.682 | 0 | 6615.23 |
| Education intensity | 3297 | 2.521 | 1.557 | 0 | 6 |

**Source:** Authors' own computation based on CIS 6, 8 and 10.

To answer the questions in appreciation, the econometric estimations were run using dynamic random effects probit estimations, still, conventional and unconventional hypotheses were separated as it was unfeasible to combine them in a single equation.

In consequence, model(s) 1 (see Table 5) test the conventional hypothesis of persistence as they do not include intermittent innovative behaviours; in these cases, being innovative in the past will influence the probability to innovate in the present. These models will depict pure past dependence.

The second set of model(s) 2 (see Table 5) include past innovative behaviours, allowing for strategic options. In the past, firms may have opted for continuing, starting, stopping or not innovating at all, according to the innovative strategy.

In all models, a set of explanatory variables are included, comprising the firm's structural traits and illustrating innovation efforts.

### 4.2. Econometric specification

Using either the conventional or the unconventional hypothesis 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 of these equations is binary: it takes the value of 1 if the firm i innovates at time t and the value of 0 otherwise. As is well-known, the nature of the dependent variable dictates that these models are best estimated using a probit (or logit) specification.

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:

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

Where firm *i* is innovative at time *t* by ($Innov_{it}$) depending on innovations at time *t-1*, a set of time-variant ($W_{it}$) and time-invariant ($V_i$) observable characteristics of the firm, and an unobservable firm-specific characteristic ($\alpha_i$).

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 behaviour. The group dissection was performed according to the proposal of the European Innovation Scoreboard (2004) and Sauréz (2014), creating four different sub-groups:

- Continuous innovators – firms that reported performing innovation in two consecutive time periods (Continuous_Innov);
- Sporadic innovators – firms that reported having performed innovation two periods ago, and stopped in the next period (Sporadic_Innov);
- New innovators – firms that reported not having performed innovation two periods ago and started innovation in the next period (New_Innov);
- 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:

$$INNOV_{it} = \beta_1 + \beta_2 CONTINUOUS\_INNOV_{it-1} + \beta_3 SPORADIC\_INNOV_{it-1} + \beta_4 NEW\_INNOV_{it-1} + \boldsymbol{\beta} W_{it} + \boldsymbol{\delta} V_i + \alpha_i + \varepsilon_{it} \qquad (2)$$

The second group of regressions allows for unconventional hypotheses of persistence, as it models intermittence. In this case, evidence in favour of persistence could come from a positive coefficient on Continuous_Innov$_{it-1}$ or New_Innov$_{it-1}$. Concerning Sporadic_Innov$_{it-1}$, 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 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 behaviour of moderate innovators.

### 4.3. Estimations and 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 being an innovator in the present. In the dynamic probit with random effects the propensity to be an innovator at present (binary) is explained by past innovative behaviours, 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 theoretical intuition 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. The splitting allowed understanding the existence of important differences in terms of the innovative behaviour 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 to be proved for innovation in general. Our empirical evidence, independent of the model being run does no support pure innovation persistence.

Our 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 have stopped innovation and 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: 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) |

## 5. Conclusion

Although a reasonable amount of empirical evidence regarding innovation persistence has been gathered, such phenomenon is not yet fully comprehended (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 countries considered as 'Innovation Leaders' or 'Strong Innovators'. The evidence focusing on 'Moderate Innovators' is almost exclusively concentrated on Spanish manufacturing firms. Additionally, with exception of Suárez (2014), the issue of innovation and innovative behavior persistence in unstable environments has been overlooked. The present study focused on a balanced panel of 1099 firms located in a Moderate Innovator (Portugal), between 2004 and 2010 and tested the hypothesis of 'true state dependence', assuming both that firms do not react to environmental fluctuations and that they do react by changing their innovative behavior (Continuous, New, Sporadically, and Non innovative firms).

The results obtained are only partially in line with Suárez's (2014) evidence 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, Cárcoles et al., 2016; Altuzarra, 2017). Two main results are worth highlighting.

First, although exploratory analysis, based on the transition probabilities matrix, uncover a very high degree of state dependence or innovation persistence, the econometric estimations (see Table 1) clarify 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 underlying 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).

Second, results suggest that in unstable environments (and when we account for the dynamics in firms' innovative behavior – Models A/…/F2), we cannot assume an automatic and linear relationship between past innovations, present innovative behavior, and future results. Specifically, we found that firms, particularly 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. 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.

## References

Aghion, P. (2017) 'Entrepreneurship and growth, lessons from an intellectual journey', Small Business Economics, 48 (1), 9-24.

Altuzarra, A. (2017) 'Are there differences in persistence across different innovation measures?', Innovation: Organization & Management, 19(3), 353-371.

Antonelli, C. (1997) 'The economics of path-dependence in industrial organization'. International Journal of Industrial Organization, 15, 643-675.

Antonelli, C. (2008) Localised Technological Change, Towards the Economics of Complexity. London, Routledge.

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

Antonelli, C., Crespi, F., and Scellato, G. (2012) 'Inside Innovation Persistence: New Evidence from Italian Micro-data'. Structural Change and Economic Dynamics, 23(4), 341-353.

Antonelli, C., Crespi, F., and Scellato, G. (2013) 'Internal and external factors in innovation persistence'. Economics of Innovation and New Technology, 3, 256-280.

Baraldi, A.L., Cantabene, C., and Perani, G. (2014) 'Reverse causality in the R&D-patents relationship: An interpretation of the innovation persistence', Economics of Innovation and New Technology, 23 (3), 304-326.

Bento, M. and Fontes M. (2015) 'The construction of a new technological innovation system in a follower country,wind energy in Portugal', Technological Forecasting and Social Change, 99,197–210

Bower, J.L., and Christensen, C.M. (1995) 'Disruptive technologies: Catching the wave' (pp. 506–520) Harvard Business Review Video.

Cefis, E. (2003) 'Is there persistence in innovative activities?'. International of Industrial Organization, 21, 489-515.

Cefis, E., and Ciccarelli, M. (2005) 'Profit differentials and innovation'. Economics of Innovation and New Technology 14 (1–2),43–61.

Cefis, E., and Orsenigo, L. (2001) 'The persistence of innovative activities. A cross-countries and cross-sectors comparative analysis'. Research Policy, 30, 1139-1158.

Chassagnon, V., and Haned, N. (2015) 'The relevance of innovation leadership for environmental benefits: A firm-level empirical analysis on French firms', Technological Forecasting and Social Change, 91,, 194-207.

Clausen, T., Pohjola, M., Sappraser, K., and Verspagen, B. (2012) 'Innovation strategies as a source of a persistence innovation'. Industrial and Corporate Changes, 21 (3) 553-585.

Colombelli, A., and von Tunzelmann, N. (2011) 'Persistence of innovation and path dependence'. In Handbook on the Economic Complexity of Technological Change, ed. C. Antonelli, 105-19. Cheltenham, Edward Elgar.

Córcoles, D., Triguero, A. and Cuerva, M.C. (2016) 'Comparing persistence of product and process innovation: a discrete-time duration analysis of innovation spells'. Economics. 10, http://dx.doi.org/10.5018/economics-ejournal.ja.2016-32.

Costa, L., Martins, N.O., and De Oliveira, F.G. (2016) 'Portugal's bailout and the crisis of the European Union from a capability perspective'. Cambridge Journal of Economics, 40 (6), 1479-1496.

Deschryvere, M. (2014) 'R&D, firm growth and the role of innovation persistence: an analysis of Finnish SMEs and large firms'. Small Business Economics. 43:767–785

Dosi, G. (1997) 'Opportunities, incentives and the collective patterns of technological change'. The Economic Journal, 107, 1530–1547.

Duflos, G. (2006) 'Persistence of innovation, technological change and quality-adjusted patents in the U.S. pharmaceutical industry'. Centre d'Economie de la Sorbonne, Cahier de la Maison des Sciences Économiques, n. 2006-29.

Duguet, E., and Monjon, S. (2004) 'Is innovation persistent at the firm level? An econometric examination comparing the the propensity score and regression methods'. Cahiers de la maison de sciences économiques. Université Panthéon-Sorbonne.

EC (2017) European Innovation Scoreboard 2017, European Union, ISBN 978-92-79-67685-7 I, in http://ec.europa.eu/DocsRoom/documents/24163.

Filippetti, A., and Archibugi, D. (2010) 'Innovation in Times of Crisis: The Uneven Effects of the Economic Downturn across Europe'. Munich Personal RePEc Archive, Working Paper n. 22084.

Freeman, C. (1982) The Economics of Industrial Innovation. London, Pinter.

Frenz, M., and Prevezer, M. (2012) 'What Can CIS Data Tell Us about Technological Regimes and Persistence of Innovation?'. Industry and Innovation, 19 (4) 285-306.

Geroski, P., Reenen, J., and Walters, C. F. (1997) 'How persistently do firms innovate?'. Research Policy, 26, 33-48.

Haned, N., Mothe, C. and Nguyen-Thi, T.U. (2014) 'Firm persistence in technological innovation: the relevance of organizational innovation', Economics of Innovation and New Technology, 23:5-6, 490-516,

Hecker, A., and Ganter, A. (2014) 'Path and past dependence of firm innovation'. Economics of Innovation and New Technology, 23, 563–583.

IMF (2009) World Economic Outlook, 2009, Washington D. C, International Monetary Fund.

Juliao-Rossi, J., and Schmutzler, J. (2016) 'Persistence in generating and adopting product innovations Evidence for manufacturing firms in a developing country'. Academia Revista Latino Americana de Administración, 29 (2),125 -146

Karlsson, C., and Tavassoli, S. (2016) 'Innovation strategies of firms: What strategies and why?', Journal of Technology Transfer, 41 (6), 1483-1506.

Kuratko, D. F., Hornsby, J. S., and Naffziger, D. W. (1997) 'An examination of owner's goals in sustaining entrepreneurship'. Journal of Small Business Management, 35, 24–33.

Le Bas, C., and Latham, W.R. (Eds.) (2006) The economics of persistent innovation: An evolutionary view. Berlin, Springer.

Le Bas, C., and Poussing, N. (2014) 'Is complex innovation more persistent than single? An Empirical Analysis of Innovation Persistence Drivers'. International Journal of Innovation Management, 18(1) 1–21.

Le Bas, C., and Scellato, G. (2014) 'Firm innovation persistence: A fresh look at the frameworks of analysis'. Economics of Innovation and New Technology, 23, 423–446.

Le Bas, C., Mothe, C., and Nguyen-Thi, T.U. (2015) 'The differentiated impacts of organizational innovation practices on technological innovation persistence', European Journal of Innovation Management, 18 (1), 110-127.

Lhuillery, S. (2014) 'Marketing and persistent innovation success', Economics of Innovation and New Technology, 23 (5-6), 517-543.

Lundvall, B.-Å. (1992) National System of Innovation: Towards a Theory of Innovation and Interactive Learning. London, Pinter.

Madsen, T.L., and Leiblein, M.J. (2015) 'What Factors Affect the Persistence of an Innovation Advantage?', Journal of Management Studies, 52 (8), 1097-1127.

Malerba, F., and Orsenigo, L. (1999) 'Technological Entry, exit and survival: an empirical analysis of patent data'. Research Policy 28 (6),643–660.

Malerba, F., Orsenigo, L., and Peretto, P. (1997) 'Persistence of innovative activities, sectoral patterns of innovation and international technological specialization'. International Journal of Industrial Organization, 15, 801-826.

Mansfield, E. (1961) Technical change and the rate of imitation. Econometrica, 29 (4) 741-766.

Mansfield, E. (1968) Industrial research and technological innovation: An econometric analysis. New York, NY, Norton.

Martínez-Ros, E., and Labeaga, J. (2009) 'Product and process innovation: Persistence and complementarities'. European Management Review, 6, 64–75.

Mohnen, P., Hall, B. (2013) Innovation and productivity: An update. Eurasian Business Review, 3 (1) 47-65.

Mohnen, P., Palm, F.C, Loeff, S., and Tiwari, A. (2008) 'Financial constraints and other obstacles: Are they a threat to innovation activity?'. De Economist, 156 (2) 201-214.

Nelson, R., and Winter, S. (1982) An evolutionary theory of economic change. The Belknap Press of Harvard University Press, Cambridge.

OECD, Eurostat. (2005) Oslo manual, Guidelines for collecting and interpreting innovation data – 3rd Edition. Paris, Organisation for Economic Co-operation and Development, Statistical Office of the European Communities.

Pavitt, K. (1984) 'Sectoral Patterns of technical change, towards a theory and a taxonomy'. Research Policy, 13, 343-373.

Peters, B. (2009) 'Persistence of innovation, stylised facts and panel data evidence'. The Journal of Technology Transfer, 34, 226-243.

Raymond, W., and Mairesse, J., Mohnen, P., Palm, F. (2013) Dynamic Models of R&D, Innovation and Productivity: Panel Data Evidence for Dutch and French Manufacturing. CESIFO, Working Paper n.4290.

Roper, S., Hewitt-Dundas, N. (2008) 'Innovation persistence: Survey and case-study evidence'. Research Policy, 37, 149-162.

Royo, S. (2010) 'Portugal and Spain in the EU, paths of economic divergence (2000-2007)'. Análise Social, XLV (195) 209-254.

Savignac, F. (2008) 'Impact of financial constraints on innovation, What can be learned from a direct measure?'. Economics of Innovation and New Technology, 17 (6) 553-569.

Schumpeter, J.A. (1934) The theory of economic development. Cambridge, Harvard University Press.

Schumpeter, J.A. (1942) Capitalism, socialism, and democracy. New York, Harper and Brothers.

Stoneman, P. (1983) The economic analysis of the technical change. Oxford, Oxford University Press.

Suaréz, D. (2014) 'Persistence of innovation in unstable environments, Continuity and change in the firm's innovative behavior'. Research Policy, 43, 726-736.

Sutton, J. (1991) Sunk costs and market structure. Cambridge MA, The MIT Press.

Tavassoli, S., and Karlsson, C. (2015) 'Persistence of various types of innovation analyzed and explained', Research Policy, 44 (10), 1887-1901.

Triguero, A. and Corcoles, D. (2013) 'Understanding innovation: An analysis of persistence for Spanish manufacturing firms'. Research Policy, 42, 340–352.

Vecchiato, R. (2017) 'Disruptive innovation, managerial cognition, and technology competition outcomes'. Technological Forecasting and Social Change, 116, 116-128.

Wooldrige, J. (2005) 'Simple solutions to the initial conditions problem in dynamic, nonlinear panel data models with unobserved heterogeneity'. Journal of Applied Econometrics, 20, 39-54.