Universidade de Aveiro Departamento de Economia, Gestão, Engenharia Industrial e Turismo

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DIANA CURA BRAGA

PADRÕES DE PERSISTÊNCIA DA INOVAÇÃO DE ACORDO COM OS TIPOS DE INOVAÇÃO

PERSISTENCE OF INNOVATION PATTERNS ACCORDING TO INNOVATION TYPES

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Economia, realizada sob a orientação científica da Doutora Joana Maria Costa Martins das Dores, Professora Auxiliar do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro.

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palavras-chave

Persistência da inovação, tipos de inovação, modelo probit dinâmico de efeitos aleatórios

resumo

O papel da inovação no crescimento económico está amplamente explorado, de tal forma que, nas últimas décadas aprofundou-se o tema da inovação e quais as suas interferências na sucessão de comportamentos inovadores ao longo do tempo. A análise dos detalhes da persistência da inovação ajuda a compreender a dinâmica das empresas, a eficácia das ações políticas, o aumento da produtividade e da prosperidade

A persistência da inovação é analisada empiricamente com base na inovação tecnológica e na continuidade de comportamentos inovadores no mesmo tipo de inovação. Contudo, os tipos de inovação não tecnológica são, de certa forma, negligenciados e a literatura existente pode não aplicar os tipos de inovação de uma forma generalizada. Para além disso, a persistência iterativa da inovação ainda não foi estuda de forma detalhada.

A compreensão das características específicas de cada tipo de inovação permitirá aos decisores de política ajustarem as suas decisões ao conjunto de particularidades. Além disso, o efeito da capacidade de absorção e da estratégia de inovação aberta não têm sido interligados com os tipos de inovação existentes na literatura.

A presente dissertação analisa a persistência da inovação através de um painel dinâmico composto por 2147 empresas Portuguesas de todos os setores económicos, observadas entre 2008 e 2014, abrangendo três edições do Inquérito Comunitário à Inovação (CIS).

Deste modo, utilizando o modelo *probit* de efeitos aleatórios, a hipótese convencional de persistência é apoiada para a inovação de processo iterativo, reforçando as características específicas de cada tipo de inovação. O facto de que apenas um pequeno número de empresas ser persistente nos tipos tecnológicos de inovação parece provar que os programas de políticas que financiam o mesmo tipo de inovação não conseguirão impulsionar a inovação futura.

Os resultados apontam para intermitência de comportamentos inovadores nos diferentes tipos de inovação, no entanto, a inovação de processo apresenta um padrão diferente de todos os outros. A estratégia de inovação aberta parece reforçar a intermitência e os fundos públicos são úteis apenas para as inovações tecnológicas.

Portanto, parece racional estimular políticas públicas diferenciadas visando os diferentes tipos de inovação, de forma a evitar uma visão única para todas as abordagens utilizadas atualmente.

keywords Innovation persistence, innovation types, random effects dynamic probit

abstract

The role of innovation in economic growth is widely explored, thus, in the last decades it has been understood that along with innovation *per se*, one must address the continuity of these behaviours over time. Analysing the details of innovation persistence helps in the understanding of firm dynamics, effectiveness of policy actions, raising productivity and prosperity generation.
Persistence of innovation is empirically explored using technological innovation, and continuity of innovative behaviours in the same innovation type; non-technological innovation types are somehow neglected and, the existing literature may not apply to the innovation types in a generalised manner and iterative persistence of innovation has not been detailed so far.
Understanding the specific characteristics of each innovation type will grant the design of fine tuning policy actions accommodating the array of particularities. Moreover, the effect of the absorptive capacity and the open innovation strategy has not been connected to the innovation types by the existing literature.
The present thesis analyses persistence of innovation using a dynamic panel comprising 2147 firms operating in all economic sectors in Portugal, observed from 2008 to 2014, covering three editions of the Portuguese Community Innovation Survey (CIS).
Using the random effects *probit* model, conventional hypothesis of persistence hypothesis is supported for interactive process innovation, reinforcing the specific characteristics of each innovation type. That fact that only a small number of firms are persistent in the technological types of innovation seems to prove that policy programs financing the same innovation type will fail to boost future innovation.
The results point to intermittence in innovative behaviors in the different innovation types, however, process innovation presents a different pattern from all others. The open innovation strategy seems to reinforce intermittence and public funds are helpful only for technological innovations; there is a scale effect reinforcing persistence.
Therefore, is seems rational to encourage differentiated public policies targeting the different innovation types avoiding the one size fits all approaches in use at present.

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Acronomys

CIS – Community Innovation Survey

R&D – Research and Development

TPM – Transition Probabilities Matrix

1. Introduction

The concept of innovation has been developed over time, based on multiple perspectives. Since the early proposal of Schumpeter (1934) innovation involves the introduction of new products, new methods of production, the opening of new markets, the acquisition of new supply sources and the adoption of new organization forms. However, Freeman (1982) considered essential to distinguish invention from innovation, the latter being an idea, model or design of a product or process, which assumes the role of innovation when validated by the market. Subsequently, Dosi (1988) stated that innovation is the search and discovery, experimentation, development, imitation and adoption of new products, production processes and new organizational structures.

Even though, in the recent years, the analysis of innovation has been considered under a different perspective, focusing on the continuity of these activities. 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. Given the central role of innovation as driver of firm performance, innovation persistence will help in the creation of competitive advantages at the firm and the country level (Hecker and Ganter, 2014). When a firm is persistent in its innovative activities, it accumulates feedbacks creating a relevant stock of knowledge. Firms with this ability will be more prone to proceed with new innovations, raising the probability to persist and succeed in innovation (Suárez, 2014).

The debate on persistence in innovation grasps the attention in different vectors such as industrial economics and firm dynamics (e.g.: Nelson and Winter, 1982; Tavassoli and Karlsson, 2015), evolutionary economics (e.g.: Nelson and Winter (1982)), virtuous accumulation cycles (e.g.: Mansfield (1968); Stoneman (1983)). The empirical research in persistence has strongly reinforced an originally purely theoretical framework (e.g.: Cefis (2003); Frenz and Prevezer (2012); Suárez (2014); Triguero and Córcoles (2013); Altuzarra (2017)), along with the development for public-policy design (e.g.: Hecker and Ganter (2014); Le Bas and Scellato (2014)).

Understanding the idiosyncrasy of persistence in innovation will help entrepreneurs, policy makers and the Academia to get a long run vision of the industry dynamics. These insights will help forecasting the long run industry progression and to anticipate the effect of public policies affecting R&D and innovative activities. In an ecosystem of scant public resources and the compelling need for efficiency, the existence of intertemporal innovation spill overs cannot be neglected when analysing public funding (Hecker and Ganter, 2014).

The existence of a knowledge legacy will put existing innovators in the forefront of recipients of new funds; the demonstration of this hypothesis should create some queries about

whose firms to support, and, in extreme in the rational of supporting non-innovative firms, being them start-ups or not (Aghion, 2017).

The thesis analyses persistence of innovation by means of a dynamic panel including 2147 firms from the different economic sectors. These firms are traced over three waves of the Portuguese Community Innovation Survey (CIS), covering the period between 2008 and 2014.

The data shows that nearly 35% of the firms in the panel are persistent in innovation. The empirical results reinforce the existence of different patterns according to the innovation types. Technological persistence has been more largely explored than the other types and it seems that service, organisational and marketing innovation must be approached differently. To empirically test persistence in the different types of innovation a random effects probit model is used, creating 12 alternative models to compare the (dis)similarities among them.

Firms do have characteristics which are time invariant, this problem is approached introducing in the panel the Wooldridge correction (2005), Furthermore, there is a probability identify time-correlated characteristics affecting the propensity to persist in innovation. The effect of unobserved time correlated effects is called in the literature as “spurious state dependency”, and as mentioned by Peters (2009) and Suárez (2014), must by corrected by means of the separation of the unobserved firm heterogeneity and initial conditions from causal effects of former innovation actions, in doing so we separate innovation persistence into spurious and effective state dependence, with the coefficients producing information about the later. The determinants of state dependence are discussed in the light of the competing paradigms of 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.

The rest of the thesis is structured as follows. The next section comprises a review the relevant literature and presents the main hypotheses in analysis. Section 3 describes the database and its structural traits concerning the variables potentially affecting persistence. Section 4 presents and discusses the econometric results. The final section presents the conclusions, opposing the present results with the existing literature and draws some policy recommendations.

2. Literature Review

2.1. Major concepts in analysis – Innovation and Innovation Persistence

Innovation, according to the Oslo Manual is defined as the introduction of a new or significantly improved good or service in terms of its characteristics or intended uses, or the implementation of production, marketing, or organizational issues (OECD, 2005). In this vein, Innovation is a determinant factor for the improvement of the overall performance of firms (Geroski, Van Reenen, and Walters, 1997), since when innovating, companies are involved in a learning process through which they generate and develop new ideas that should be intertwined with the already existent within the firm and applied in a more efficient way (Weitzman, 1998). Even though the relevance of Innovation *per se* and its importance as an engine of evolution of the societies, the major focus of the present research is not on innovation as a single phenomenon but its continuation over time, which is termed as Persistence in Innovation.

The issue of Persistence in Innovation goes back to the *Joseph Schumpeter*'s two structural conceptions of technological change: "creative destruction" and "cumulative creation", developed in *Theory of Economic Development in 1934* and *Capitalism, Socialism and Democracy in 1942*, respectively named by (Nelson and Winter, 1982) as Schumpeter Mark I and Schumpeter Mark II.

According to the Schumpeter Mark I, technological change is defined as a random process, driven by a group of homogeneous companies seeking a set of technological change opportunities available to all of them. Innovation promotes monopoly power, but only temporarily, as other companies will try to replicate these innovations. In this paradigm new companies replace those that were already established in a continuous race towards transitory monopoly power (Malerba, Orsenigo, and Peretto, 1997).

Under the Schumpeter Mark II conception, technical progress is associated with the existence of large companies competing in Oligopolistic markets. Innovations trigger new innovation processes by means of new investments resulting in accumulation processes, to ensure the company's perpetuation in the market, thus generating a virtuous cycle of accumulation and feedback (Suárez, 2014). Moreover, the existence of barriers to entry will foster high market power to the incumbent oligopolists which tend to become persistent innovators (Gilbert and Newbery, 1982; Le Bas and Scellato, 2014).

Peters (2009), argues that there is persistence in innovation when a firm which has innovated in one period continues to innovate in the following. According to Ganter and Hecker's, view (2013), persistence describes the influence that past innovation activities have on the behavior and success of current and future innovations. A positive relation between past innovations and the propensity to innovate at present is Suárez's view on the definition of persistence of innovation activities, being associated with investments in firms that allow them to achieve efficiency gains (Frenz and Prevezer, 2012; Suárez, 2014)

So, Innovation Persistence is defined as the degree of continuity of the innovative activity over time. The fact that innovations have been successful in the past increases the likelihood of their success in the present (Flaig and Stadler, 1994). Although firms' propensity to innovate depends on market structure in which they operate, the demand and the expected costs, the successes of past innovations provide a strong state dependence on the present innovation process (Triguero and Córcoles, 2013).

Persistence, considered as true state dependence is defined as a positive causal relationship between the decision to innovative in on period and the likelihood of innovating in the next (spurious state dependence occurs if unobserved attributes are correlated over time, and not properly controlled). In this way, past innovation seems to affect current innovation, because it captures the effects of unobserved persistent characteristics (Altuzarra, 2017). The distinction between spurious and true persistence is decisive for economic policy design since, as if the state dependence is spurious the performance of the firm is not likely to be influenced by economic policy in the long run. However, if state dependence is true, an accurate Policy design has long-term effects on firm performance (Peters, 2009).

In addition to the previously mentioned conceptions of innovation and market power (Schumpeter, 1934, 1942) three additional frameworks will provide a deeper help explanation to the existence of innovation activities that persist over time as identified in previous studies (e.g.: Le Bas and Scellato, 2014; Tavassoli and Karlsson, 2015).

2.2. Persistence Approaches

2.2.1. Success Breeds Success

The success breeds success hypothesis, firstly proposed by Mansfield (1968) and Stoneman (1983) argues that the success of previous innovations can increase the technological opportunities available to firms, increasing the probability of success in future innovations. The positive achievements of the past will encourage the development of new innovative cycles (e.g.: Mansfield, 1968; Scellato and Ughetto, 2010). This hypothesis relies on the fact that successful past innovators have an increased market power, benefiting from the results achieved by former innovations. Allying market power to abnormal profits, they reduce their financial constraints thereby being able to develop innovation cycles, fed by the results of the former. The success breeds success hypothesis reinforces the fact that innovation leads to profitability, and this will be the foundation of the future innovation processes. Under this concept and considering market power and positive finance it seems more likely that large companies will be persistent (Flaig and Stadler, 1994; Le Bas and Latham, 2006).

Additionally, firms succeeding in innovations can achieve profits otherwise impossible. These results reduce the aversion to these expenditures of either investors, shareholders or

borrowers expecting new innovations to be achieved. This leverages the capacity to continue investing in R&D activities that promote future innovations, moreover, there will be no need for external sources of finance, such as bank credit, as the equity will cover these costs. The availability of liquidity promotes trust and reinforces firm credibility in among investors (Tavassoli and Karlsson, 2015). So is past innovative success allows the existence of artificial monopoly profits, there is an interest in obtaining them for longer time span; aiming for new profits, shareholders will approve new R&D expenditures, and due to greater financial availability, there is a higher the possibility to increase the new innovation activities, often interrupted due to financial constraints or lack of external finance.

2.2.2. Sunk Costs

The concept of sunk costs is presented as an alternative hypothesis to explain persistence of innovation activities. It was firstly developed by Sutton in 1991. The author argues that investing in innovation activities is not an easy decision to make for firms, as they incur initial costs that are often high and unrecoverable (e.g. for the installation of R&D laboratories, for the recruitment of qualified people and for training of employees). In addition to the initial costs already mentioned, continuous funding is essential throughout the innovation process until the product is launched on the market (Sutton, 1991). Inside the firm there is risk aversion, and investors, seeking for the maximum return on investments will be reluctant to allow the directioning of finance to activities with uncertain outcomes. Once the investment is made, it seems irrational to stop those activities as the spending is small compared to the potential return. But, this irreversibility is considered as a barrier to take the first step.

Therefore, firms that decide to invest in R&D activities tend to invest continuously in the development of these activities creating a stock of physical and human capital that, in the long run, contributes to the existence of continuous innovation processes and efficiency gains with lower costs of production (Cohen and Klepper, 1996; Máñez, Rochina-Barrachina, Sanchis, and Sanchis, 2009). The fact that initial costs are high leads to barriers to entry for firms that are not innovative but want to start innovating. This approach reinforces the belief in virtuous cycles of accumulation as those firms which have entered the innovation process will not stop it as it seems irrational to waste the existing infrastructures and loose advantages compared to their competitors.

2.2.3. The Evolutionary Innovation Theory

The Evolutionary Theory of Innovation argues that experience in innovation activities is associated with increasing dynamic returns, either in the form of learning-by-doing or in learning-to-learn (Nelson and Winter, 1982). The technological knowledge recognized as an economic

good has characteristics of cumulativeness and non-exhaustiveness, which have great implications for the persistence of innovation, since the new knowledge acquired helps to improve the already existing inside the company and is the starting point for the future updates of new knowledge, thus creating a competitive advantage for innovators (e.g.: Teece, Pisano, and Shuen, 1997; Antonelli, Crespi, and Scellato, 2013; Le Bas and Scellato, 2014). Once more, the existing stock of knowledge develops an increased ability to capture new innovation opportunities inside the firm, with a prepared human capital whose absorptive capacity permits the acquisition of new information from the innovative milieu.

The different theories that seek to justify the existence of persistence of innovation activities are complementary to each other, since the interaction of the success breeds success hypothesis and the knowledge accumulation gives rise to a virtuous circle, where the financial profits achieved in R&D activities, allow the learning process to continue (Le Bas and Latham, 2006). Moreover, since successful innovations in international markets increase corporate profits and reduce the mistrust of banks and other financial institutions. The increase in external capacity occurs because successful past innovations are a positive sign for future innovation processes since the ability of the firm is boosted due to the accumulation of knowledge. Firms with past successful innovative processes will evolve to new innovations as they are intrinsically more capable as they have learnt from the past (Tavassoli and Karlsson, 2015).

With respect to the complementarity between the sunk costs and knowledge accumulation assumptions, it's clear that sunk costs are important in building the accumulation knowledge, since the existence of previous innovation processes will reduce the associated costs and will increase of knowledge necessary for the firm to continue to innovate and accumulate knowledge (Antonelli et al., 2012). Believing in the endogeneity is this process and its continuity over time should reinforce the importance and the desirability of these fields to absorb public finance, as, once the conditions are created by means of subsidization, the firm will continue this innovative cycle with no need to rely upon any other type of public funding.

As all perspective points to the continuity of those processes, it seems straightforward that policy makers should subsidize already existing innovators; innovators that succeeded in the past or the construction of infrastructures to support innovative activities such as R&D labs because once the virtuous cycle starts it is to some extent unstoppable.

2.3. Innovation Persistence and innovation types

The study of innovation traditionally unfolds in two dimensions: technological and non-technological. Most of the studies only cover product or process innovation (e.g.: (Flaig and Stadler, 1994; Raymond et al., 2010; Antonelli et al., 2012; Altuzarra, 2017); very few do cover non-technological innovation types (e.g.: Hecker and Ganter, 2014; Tavassoli and Karlsson,

2015), likewise, their aim is not to draw the specificities of the different innovation types neither to understand the iterations among them.

Besides, when analysing its persistence, there are substantial flaws, since the existing research focuses mostly on technological firms, where product and process innovations of are developed. While in the non-technological one can analyze service innovations, organizational and of marketing. The analysis of iterations and intermittences seems to fulfill an existing gap in the literature, as, persistence patterns are expected to differ among the innovation types and intermittences may be rational to certain innovation types contradicting the theoretical approach of state dependence.

2.3.1. Persistence in technological innovation

In the scope of technological innovation, product and process innovation are included. This hypothesis has been developed by several authors (e.g.: Flaig and Stadler, 1994; Cefis and Orsenigo, 2001; Cefis, 2003; Duguet and Monjon, 2004; Raymond et al., 2010; Antonelli et al., 2012). This typology was deepened with studies that focus on the analyzis of the existence of persistence in the innovation activities, relying on the previously developed frameworks. Flaig and Stadler (1994) have found evidence that innovating in the past causes a strong state dependence on the present for process innovation, based on a panel data set of manufacturing firms in Germany.

Cefis and Orsenigo, (2001), based on the results obtained by the transition probability matrices of manufacturing firms from six different countries, concluded that there is persistence in innovation activities, although not very high and decreasing over time. Again, Cefis (2003) has concluded that despite the existence of persistence in innovation activities, the proportion of firms that persist is reduced, yet great innovators present a high persistence rate. The results were obtained throughout the application of the transition probability matrices, in a group of 577 manufacturing firms of the United Kingdom. Duguet and Monjon (2004) analyzing 621 French manufacturing firms, argued that the persistence of innovation at firm level is strong. Raymond et al. (2010) based on a dynamic panel with the tobit type 2 model, found evidence that the persistence of innovation in Dutch firms is positive and highly significant in the innovation dynamics results. Antonelli et al. (2012), claim that the highest level of persistence is found in R&D-based innovation activities, thus verifying the presence of barriers to entry and exit. The authors have achieved more robust results for persistence in product innovation. These results are based on data from 451 Italian manufacturing companies and the application of the panel data model of discrete and dynamic options and by the transition probability matrices.

2.3.2. Persistence in non-technological innovation

Unconventional forms of innovation are gaining relevance in this field, namely organizational and marketing innovation, due to the development and consequent tertiarization of the economies and the post-selling activities of most of the industrial firms. The study of persistence in the field of non-technological innovation has, so far, been underdeveloped, but some empirical studies have shown that these types of innovation can complement the technological types of innovations (e.g.: Triguero and Córcoles, 2013; Ganter and Hecker, 2013; Hecker and Ganter, 2014; Tavassoli and Karlsson, 2015).

Most of the studies only address companies in the industrial sector, resultantly service innovation has been neglected for long in persistence of innovation studies. However, the tertiary sector has gained increasing importance in the society and consequently in the innovation dynamics. Thus, Bryson and Monnoyer (2004) sought to understand the relationship between services and innovation. In order to do this, they have analyzed several articles developed for various countries (e.g. Slovenia, Spain, Italy, Germany and France), concluding that the relationship between innovation and services is determined in a partial way by geography and, more specifically, by the scale of the national economy. In addition, they attest that although the concept of service innovation is controversial, it is already an area of study solidly established with theoretical and empirical literature in constant development. Peters (2009) introduced services, as a sector, in her database. Concluding that there is heterogeneity in terms of persistence in innovation between the industrial sector and the services. Firms in the industrial sector are more persistent than the companies in the services sector; despite neglecting process innovation and organizational innovation, and the potential existence of lagged results.

Recently, Gallego, Rubalcaba, and Hipp (2013) concluded that services are no longer a secondary tool in the value chain. In this way they are essential, and their involvement will generate comparative advantages. The empirical results demonstrate that service innovation is vital, in addition to the four types developed in line with Schumpeter (1934) as it allows to understand the firm intangibles and its connection to the consumer, generating solid connections thus reducing volatility in demand; moreover, service innovation will be determinant in the implementation of the circular economy frameworks.

***Table 1* - Innovation types used by authors**

Author	Innovation Types				
	Product	Process	Services	Organisational	Marketing
Altuzarra (2017)	✓	✓			
Antonelli, Crespi and Scellato (2012)	✓	✓			
Flaig and Stadler (1994)	✓	✓			
Ganter and Hecker (2013)	✓	✓		✓	
Hecker and Ganter (2014)	✓	✓		✓	
Marsili and Verspagen (2001)	✓	✓			
Peters (2009)	✓	✓	✓		
Raymond, Mohnen, Palm and Loef (2010)	✓	✓			
Tavassoli and Karlsson (2015)	✓	✓		✓	✓
Triguero and Córcoles (2013)	✓	✓			

Source: Self elaboration

2.3.3. Iterative / Heterodox Innovative behaviors

The existing studies about the persistence of innovation, based on the persistence patterns are orthodox in what concerns the proxy: a firm is said to be persistent if it does innovate in all the periods included in the time span of the panel (e.g.: a firm performing product innovation in t1, t2 and t3). Besides, all firms with discontinuities are considered as not persistent, and they are not analyzed in their intermittences. The non-persistent subset includes those firms who have never performed innovation and those who simply stopped temporarily their innovations for strategic reasons.

However, based on the "creative accumulation" developed by 1942, a product innovation developed inside the firm can cause a need for changes in the organizational structure of the same or even the market, pushing the firm towards the need to perform another type of innovation, with the goal of accommodating the product life cycle.

Therefore, it seems plausible to allow firms to move from one type of innovation to another and still being considered as persistent. Focusing on a certain type of innovation and seeking for its continuity over time may consist in a myopic approach to persistence. The seminal

conceptualizations of Schumpeter (1934) did mention the need for different types of innovation during the product lifecycle exploiting complementarities among them and still being persistent.

In this study, we aim to confirm that pure persistence does not imply the repetition of the same type of innovation, the firm needs do change over the product lifecycle, and the effective management of innovative activities forces the firms into swapping from one to the other.

Moreover, the public policy tends to subsidize technological innovators, which tend to be large firms. If the other types of innovation continue to be neglected, perhaps firms are forces to shorten product lifecycle. It is therefore believed that opening the possibility of moving between types of innovation will allow some of the moderate innovators and small and medium-sized enterprises to be included in the list of persistent innovators.

2.4. Innovation Persistence and Technological Regimes

Technological regimes are a determinant for the analysis of innovation, resulting from the Schumpeterian economy, they deepen the inherent differences between different technologies and consequently sector performance (Winter, 1984). For Marsili and Verspagen (2001) the study of technological regimes is important for the development of consistent economic theory differentiating the sectoral systems of innovation.

Nelson and Winter (1982); Dosi (1982); Winter (1984) stated that the description of the technological and operational environment, in which firms operate, is given by technological regimes. Later, Malerba and Orsenigo (1997) defined the technological regimes as the set of the main economic characteristics of the technologies and learning processes involved in technological activities, such as conditions of opportunity, appropriability and the cumulativeness of knowledge. They concluded that technological regimes are associated with the study of the persistence of innovation since it is expected that, at the firms' level, higher levels of technological cumulativeness are expected to be positively correlated with the existence of Innovation Persistence.

The existence of heterogeneity among firms is widely accepted in the literature, though, companies operating in the same sector share some operational characteristics, then, the possibility of heterogeneity does not stand or should be minimal (Dosi and Malerba, 1996). According to Frenz and Prevezer (2012), the technological regime should not be of major importance as other firm characteristics would be more important to assess persistence patterns. Still, weak persistence is more prone to be traced in low tech regimes and the opposite also stands.

The introduction of this determinant in the study is done through the use of Pavitt's (1984) taxonomy combined with Silva and Teixeira (2011), since it gives us information about the technological regimes in which to place the different industries, according to its technological intensity (moving from low to high). Likewise, it is expected that the persistence is conditional to

the activity being performed by the firm, which means that firms focusing on activities of high technological intensity are more likely to be innovative and succeed, thus presenting more conditions to be persistent in innovation. Conversely, firms operating in medium technological intensity sectors, that are expected to have lower levels of persistence; and in the low-tech sectors, whose probability to persist in innovation is very low.

2.5. Other determinants of persistence

So far, the discussion concerning persistence of innovation has been put in terms of, types of innovation and technological regimes. However, there are other characteristics inside the firm which justify its occurrence. Persistence in innovative behaviour may be explained by, firm size, sector of activity, absorptive capacity, use of public funds, membership in economic group, education of the workforce, combination of internal and external use of R&D, and the degree of firm openness to innovation sources do influence the probability of continuing innovative activities. Most of them are the widely cited literature, as presented below.

Firm size determines persistence, being the driver of R&D productivity in innovation studies (Cohen and Klepper, 1996). According to Schumpeter Mark II larger firms, will have an increased propensity to innovate and to continue in innovation over time. The size of the firm supports the, knowledge accumulation hypothesis since, an increased availability of internal funds, reinforces the probability of continuous innovation (Antonelli et al., 2013; Le Bas and Scellato, 2014).

However, the effect of size on persistence may be uncertain, as, on the one hand, large firms have a high market power and more capacity to innovate (Peters, 2009), and, due to the existence of conditions for innovation take off, the virtuous cycle will be retro-fed. Large firms will benefit from economies of scale in their innovative activities (Ganter and Hecker, 2013). Although, if the innovative efforts do fail, due to their larger efforts, the negative effects on finance will rise.

On the other hand, small firms have greater flexibility in the decision-making process, accelerating the adoption and dissemination of innovative activities, still they face many barriers to entry and many risks when innovating (Antonelli et al., 2012). In the aggregate, and considering the existent literature covering the different types of innovation, it is expected that the size of companies positively affects the persistence of innovation activities (e.g.: Pires, Sarkar, and Carvalho, 2008; Hecker and Ganter, 2014; Raymond et al., 2010; Peters, 2009; Triguero and Córcoles, 2013; Altuzarra, 2017; Teixeira and Santos, 2016).

In the study of persistence of innovative activities, the economic sector combined with the technological intensity is seen as a determining factor of analysis, since in a general way it is argued that persistence is higher in high technology sectors, since they are more prone to change and to constantly improvement their practices (Antonelli et al., 2012).

The firm's knowledge base and absorptive capacity can be defined as a set of five determinants: the training provided to employees; human capital (knowledge of human resources previously acquired through formal education); internal R&D activities; external R&D activities and the acquisition of machinery and other equipment (Teixeira and Santos, 2016).

The combination of the firm knowledge base and its absorptive capacity, can be considered as the most critical dimension to innovation; The combination of professional training and formal education of the labour force will also leverage the ability to innovate (Santos-Rodrigues, Dorrego, and Jardon, 2010). Continuous research and the acquisition of external R&D (Pires et al., 2008; Battisti, Gallego, Rubalcaba, and Windrum, 2014) and the acquisition of software (Carvalho, Costa, and Caiado, 2013).

Another determinant is the procurement of public funds by companies, since they encourage innovation as they do not need to invest from own funds to improve their productivity or to create organizational gain. Peters (2009) argues that the probability of persistent innovation is greater for companies receiving public funds moreover, the accurate use of public funds is compulsive to achieve targets (Altuzarra, 2017).

Belonging to a group of companies is another factor of analysis in this study given that these companies have a greater productive and organizational capacity as well as a simplified way to obtain support for innovation. Consequently, Raymond et al. (2010) claim that companies belonging to a group are more likely to be persistent in innovation.

Education is considered as an engine for firm development due to the expected productivity gains. The higher the level of education of its employees, the greater the ability to develop projects that promote new products, processes, forms of communication and of organization internal and external, and services. In other words, the greater the education of workers, the greater the propensity of firms to innovate persistently. For this reason, education is a strong determinant in the study of innovation (Pires et al., 2008; Dostie, 2018).

The expenditures in R&D are major innovation inputs. It is expected that performing R&D in different fields will help firms in innovation persistence. Even though, firms with different characteristics will experience opportunities and projects in different fields. Combined R&D strategies will enhance the opportunity to innovate and persist in this behaviour (Lazzarotti, Manzini, Nosella, and Pellegrini, 2016; Kennedy, Whiteman, and Van den Ende, 2017).

According to the concept primarily proposed by (Chersbrough, 2003), firms opting for an open innovative strategy will enhance their opportunities to innovate. Establishing collaborations with different innovation sources, inside and outside the value chain will generate innovation spill overs which positively influence the persistence in innovation activities. The degree of openness of the firm is another determinant for the persistence of innovation. Firms, by allowing the cooperation of external agents (such as customers, suppliers, competitors or universities) enable broadening their knowledge base, thus promoting the possibility of using new methods or products with higher efficiency levels (Varis and Littunen, 2010; Lazzarotti et al., 2016). For this reason, Battisti et al. (2014) argue that the greater the degree of openness of firms, the greater the propensity to persist in innovation activities.

2.6. Hypotheses in test

From the previous analysis, innovation types, technological regimes and firm characteristics do affect the propensity of firms to start and continue innovation activities. Likewise, the literature points towards the existence of different possibilities in terms of the innovation strategies.

The model about to be estimated allows for continuities and discontinuities along the time span (three-time periods). The conventional hypothesis concerning persistence in innovation points towards the interdependence of the past innovation strategies with the present, so, firms will continue in innovation due to their dependence to the past (state dependence) or will continue as non-innovative. Empirical evidence shows that firms have discontinuities in their innovative actions, but it is expected that firms which have performed innovation in the past continue to innovate at present, at least until they complete the innovation cycle or to approach the product lifecycle

Following the theoretical aspects discussed in the previous points, the empirical analysis will provide information to discuss the hypotheses listed in the table below.

Table 2– Hypotheses in test

Hypothesis Number	Description of Hypothesis
H1	Being persistent in innovation in the past will enhance the probabilities to continue innovating at present.
H2	Higher levels of absorptive capacity will enhance the probability of persistent innovative behaviour
H3	Higher levels of human capital will increment the probability to persist in innovation
H4	Firms with a larger size are more prone to continue in innovation
H5	The economic sector defines the persistence pattern

Source: Self elaboration

3. Data

3.1. Initial Considerations

The persistence of innovation according to the different frameworks already presented in the former sections depends on the success obtained in t-1, that is, the success obtained in the past will influence the continuation of innovation in the present. However, it is considered that in countries that are not frontrunners in innovation, firms are persistent if they carry out different types of innovations in different years.

The aim of this research is to show that in moderate and modest innovators there is no pure persistence of innovation activities, that is, companies do not practice the same type of innovation for years in a row, but there is already a persistence in the activities of innovation if we allow firms to change the types of innovation in different years.

To do so, data from three waves of the Community Innovation Survey (CIS), was put together, to obtain information on the characterization of the firms' innovation activities.

Analysing the persistence of innovation activities throughout the data collected in the CIS, requires the construction of a balanced panel. The option of using the balanced panel is relies in the fact that persistence requires that companies are to be observed in different periods of time, as persistence can only be measured when it is possible to monitor the same company for more than a period, this explains the fact that the panel has fewer companies (than those responding in each CIS wave), since they need to be present in all analysed time periods.

3.2. The database

Most of the firms in the panel are small (67%). Medium-sized companies account for 28% and the large firms only represent 5% of the sample. Regarding the Portuguese reality, it appears that the panel is in line with the reality given that there is a very high percentage of small businesses. These firms mainly work in the secondary sector (58%), 2% are in the primary sector and 40% in the tertiary. Only 29% of the panel companies belong to an economic group.

On the estimation panel, there are 336 firms that do not feature any highly educated workers. However, 162 companies have between 75% and 100% of workers with higher education. This measure is an important proxy for the intensity of education.

In order to verify the technological intensity of the balanced panel firms, the companies were divided into three categories: low, medium and high technology, according to Pavitt's taxonomy (1984). It is observed that 13% of companies are high technology and 46% are low-tech. Hopefully, high-tech companies will be more likely to innovate.

In the balanced panel, only 15% of the firms obtained public funds for the development of innovations. This may be due to the fact that many firms do not have all the necessary conditions to apply for these funds.

Regarding innovation activities, in the balanced panel composed of 2147 firms in total, 60% performed at least one type of innovation.

Since the objective was to observe the firms over several periods of time, all the observations concerning firms that were not observed during the three-time periods analyzed had to be dropped. In this way, when the firms that were not observed during the three required periods were withdrawn, the balanced panel used in this study has a total of 2147 firms.

3.3. Database Vs Entire sample

The database of this study is composed of three waves of the CIS, as already mentioned above. In total there are 20083 observations, 6160 of the CIS10, the CIS12 consists of 6840 observations and the CIS14 by 7083 observations.

Table 3 - Database overview

Edition	Period	Nº of firms
CIS 10	2008-2010	6160
CIS 12	2010-2012	6840
CIS 14	2012-2014	7083

Source: Self elaboration

By observing the three waves of CIS it is possible to characterize our database and to see if the panel that was balanced portrays or not the reality present in the complete database.

3.3.1. Innovation types

Regarding product innovation, there is a decrease in the number of companies that performed this type of innovation in CIS10 and CIS12, specifically in CIS10 product innovation made 1818 companies and in CIS12 the number decreased to 1694 firms. However, in CIS14 there is a slight increase in the number of firms that performed product innovation, with a total value of 1878 firms. However, it should be noted that throughout the three waves of the CIS, the total number of companies surveyed is increasing steadily.

In the period under analysis, there was a steady decrease in the number of firms that performed service innovation. In CIS10, 1422 firms made this type of innovation, in CIS12 the number of companies drops to 1378 and, finally, in CIS14 this figure stands for the 1309 firms.

When analyzing the data on Process Innovation, there is a decrease in the number of companies that innovate from the first to the second wave, but in the latter, there is an increase compared to the CIS12 wave.

In the period under review there is an increase in the number of firms that made marketing innovations from CIS10 to CIS12, with the number of firms increased from 2431 to 2554, respectively. However, from CIS12 to CIS14 there is a reduction in the number of companies that innovate from 2554 to 2259.

The number of firms that perform organizational innovations decreases continuously in the three CIS waves analysed. In CIS 10, 43,7% of the firms made organizational innovations, in the CIS 12 the percentage decreased to 38,8%. Finally, CIS 14 shows a sharp decrease, with 29,5% of the companies innovating at the level of the organization.

The analysis shows that in general, the panel portrays reality more than 2/3 of the CIS10 firms made at least one type and in CIS12 and CIS14 more than half performed at least one type of innovation. Therefore, it is expected that the balanced panel portrays reality, this is further reinforced since the panel even has a lower incidence rate of continuity than that which could be averaged.

Table 4 - Different innovation types are performed in the complete CIS 10, 12 and 14 databases

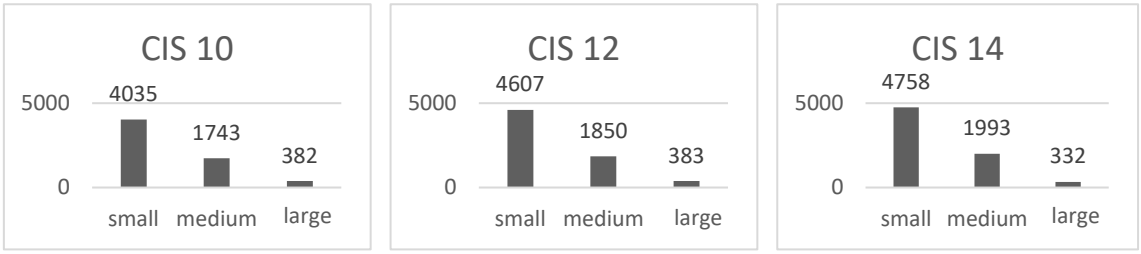
		Product innovation	Process innovation	Service innovation	Organisational innovation	Marketing innovation	Innovation in general
CIS 10	**Nº**	1818	2846	1422	2694	2431	4161
	%	29,51%	46,20%	23,08%	43,73%	39,46%	67,55%
CIS 12	**Nº**	1694	2712	1378	2658	2554	4175
	%	24,77%	39,65%	20,15%	38,86%	37,34%	61,04%
CIS 14	**Nº**	1878	2785	1309	2087	2259	4080
	%	26,51%	39,32%	18,48%	29,46%	31,89%	57,60%

Source: Self elaboration

3.3.2. Size

When looking at the firms of the three waves of the CIS, it can be seen that at least 65% of the firms are small and that the large firms represent only 6% for CIS10 and 12 and 5% for CIS14. These values go to of what is observed both in the Portuguese business structure and in the balanced panel structure this study. Thus, size is likely to be a variable that doesn't change over time, since to fluctuate in size in a short time.

Figure 1 - Size of firms in the complete CIS



Source: Self elaboration

3.3.3. Economic Sector

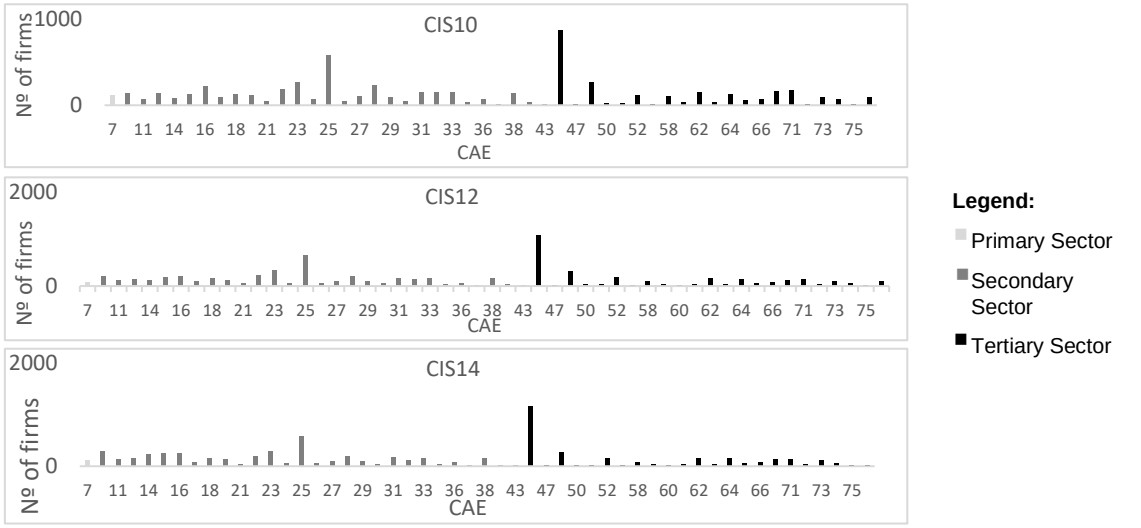
The analysis of the data collected in the three waves of the CIS, allows to conclude that the primary sector is the one that holds less companies with activities of innovation. The secondary sector is the one that has a greater number of firms that carry out innovation activities, the percentage varying between 57% and 58% of the total firms surveyed. Compared with the balanced panel, there is a diversity of activities by CAE's, with secondary sector also having the greatest weight with 69%. Regarding the primary sector, which generally represents between 1% and 2% of the data, 111 extraction and preparation of metal ores firms responded to the CIS10, in the CIS12 this number decreased to 73, in the CIS14 111 firms responded, and in the balanced panel 25 firms belong to this set.

In the food industry, 144 firms to the CIS10, 195 to the CIS12 and 299 to the CIS14. In the balanced panel 28 firms belong to this industry. As far as waste collection, treatment and disposal are concerned, there are firms that responded to the survey in the three CIS waves as well in the balanced panel.

The tertiary sector as a weight of 30% in the balanced panel and 40% to 42% in the CIS waves. However, the balanced panel also shows a diversity of activities within this sector that can be compared to the full CIS, as seen in the wholesale trade where 197 firms responded, and in CIS10 this number was 866 firms, CIS12 1072 firms and CIS14 1175.

In this way, my panel is composed of firms from all sectors of activity and although it is smaller, it covers a large part of the activities that the full CIS covers (see table of CAE's in the appendix 1).

Figure 2 - Economic Sector in the complete CIS

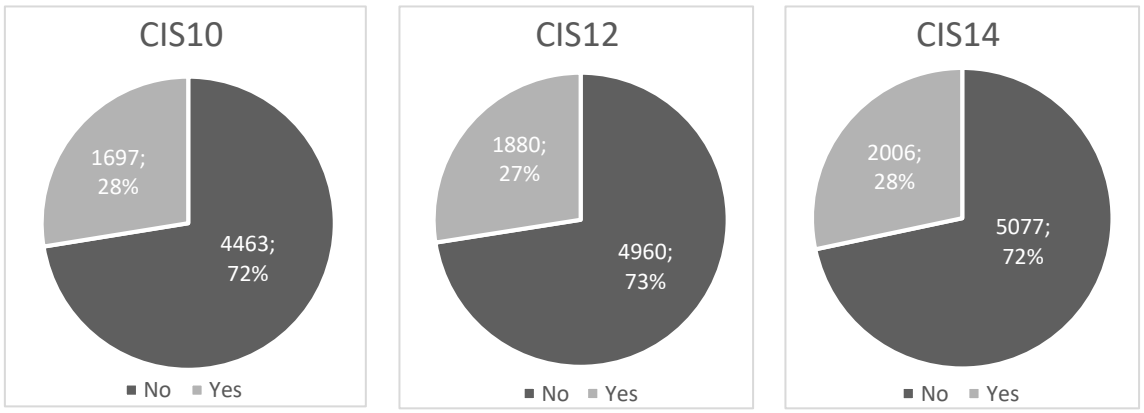


Source: Self elaboration

3.3.4. Group

Firms that are part of a group of companies are expected to be more likely to engage in more innovation activities, but what happens in the different waves of the CIS is that most firms do not belong to any economic group. It can be seen that the values between the CIS waves and the balanced panel for this point of the descriptive analysis are the same where the weight of the firms does not belong to an economic group is between 71% and 73%.

Figure 3 - Economic Group in the complete CIS

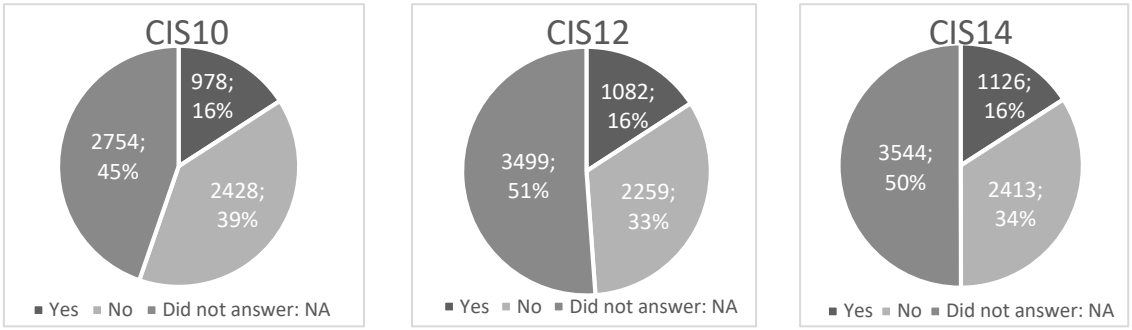


Source: Self elaboration

3.3.5. Public Funds

In general, most firms do not use any fund they think of in innovation activities. In CIS10 only 978 companies received funds, in CIS12 the number increased to 1082 and in CIS14 to 1126 firms. Compared to the balanced scorecard, it appears that there is an identical percentage of companies that use public funds, thus concluding that although the number of observations is smaller, they do not deviate from the overall reality of the data obtained in the CIS.

Figure 4- Public Funds in the complete CIS

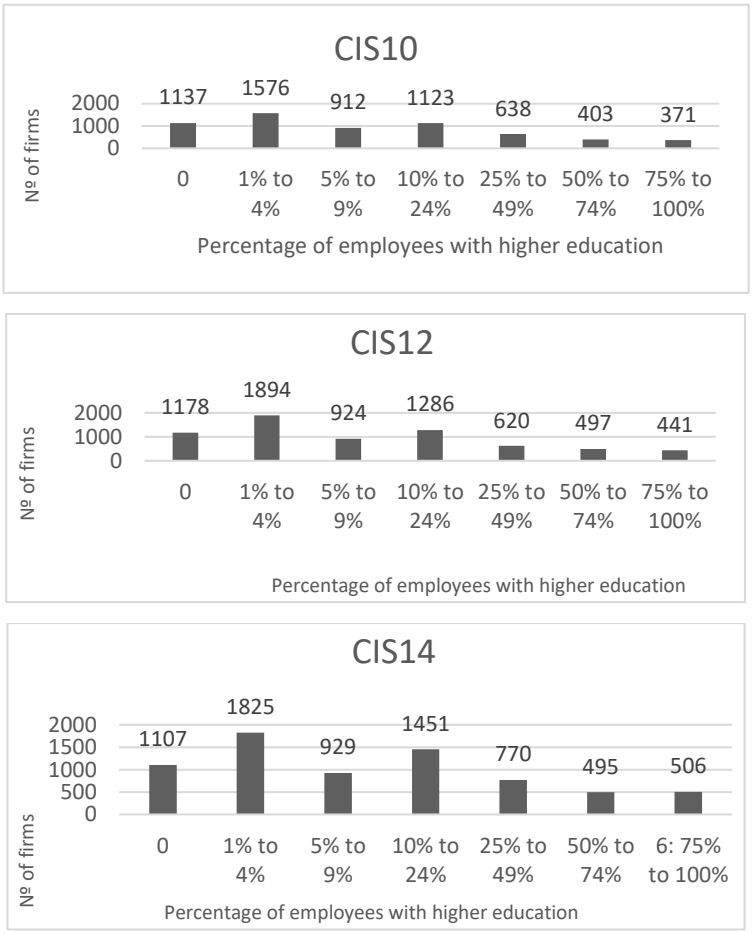


Source: Self elaboration

3.3.6. Human Capital

When analysing the Human Capital of the companies, it is concluded that there is a relevant percentage of companies that do not have employees with higher education. The number of companies with more than 25% of employees with higher education is very small. Thus, it is expected that one of the factors that can justify the lack of innovation is the low qualification of the employees.

Figure 5 - Human Capital in the complete CIS



Source: Self elaboration

4. Econometric Estimations and Results

4.1. Methodology

The analysis of persistence strategies and their (di)similarities according to the innovation types is the central objective of this study. To do so and using a balanced panel as previously described and including a set of variables that allow firms to be characterized and their innovative propensity.

The estimations were organised in 12 models, models 1 analyse pure persistence in innovation in general and all the innovation types. Models 2 follow the same procedure but allow for intermittences in innovations. The estimates are run based on the of dynamic random effects probit model.

4.1.1. Transition of Probability Matrices

It is essential to understand the behaviour of the firms concerning persistence during the period of analysis, firms are confronted with a binary decision in the beginning of each time period: whether or not to innovate. So, considering that scenario, the decision path is seen as a dummy that takes value 1 if the firm decides to invest in innovation activities and value 0 otherwise. The strategic decision is independent in each time period, though, the innovative path is conditional to former decisions.

To be considered as persistent, the firm must have conduced innovation in the three waves of the CIS (10, 12 and 14), Otherwise, it is not persistent, which means being intermittent or not innovative at all. The study also focuses on iterations among innovation types dividing the strategies in two major groups: pure (firms that persist in the same innovation type) and iterative (the type of innovation being performed changes over time.

Firms in making different decisions in the period of time promote different innovation strategies that may be: continuous innovative or not innovative and intermittent. The conceptualisation of innovation in general allows for iterations, which means that a firm is said to be innovative in general if it does persist in innovation independent of its type.

In order to able to understand all the strategic behaviours of firms in the three waves of the CIS, the transition of probability matrix was made, in the same line of previous studies was performed (e.g.: Cefis and Orsenigo, 2001; Cefis, 2003; Suárez, 2014; Tavassoli and Karlsson, 2015.

Given the existence of three binary decisions taken sequentially, it is provided a set of eight possible strategies for the time span (Table 5). Based on these eight strategies we will delineate generalised three behaviours related to innovation activities: firms that are persistent in innovation; intermittent and non-innovative.

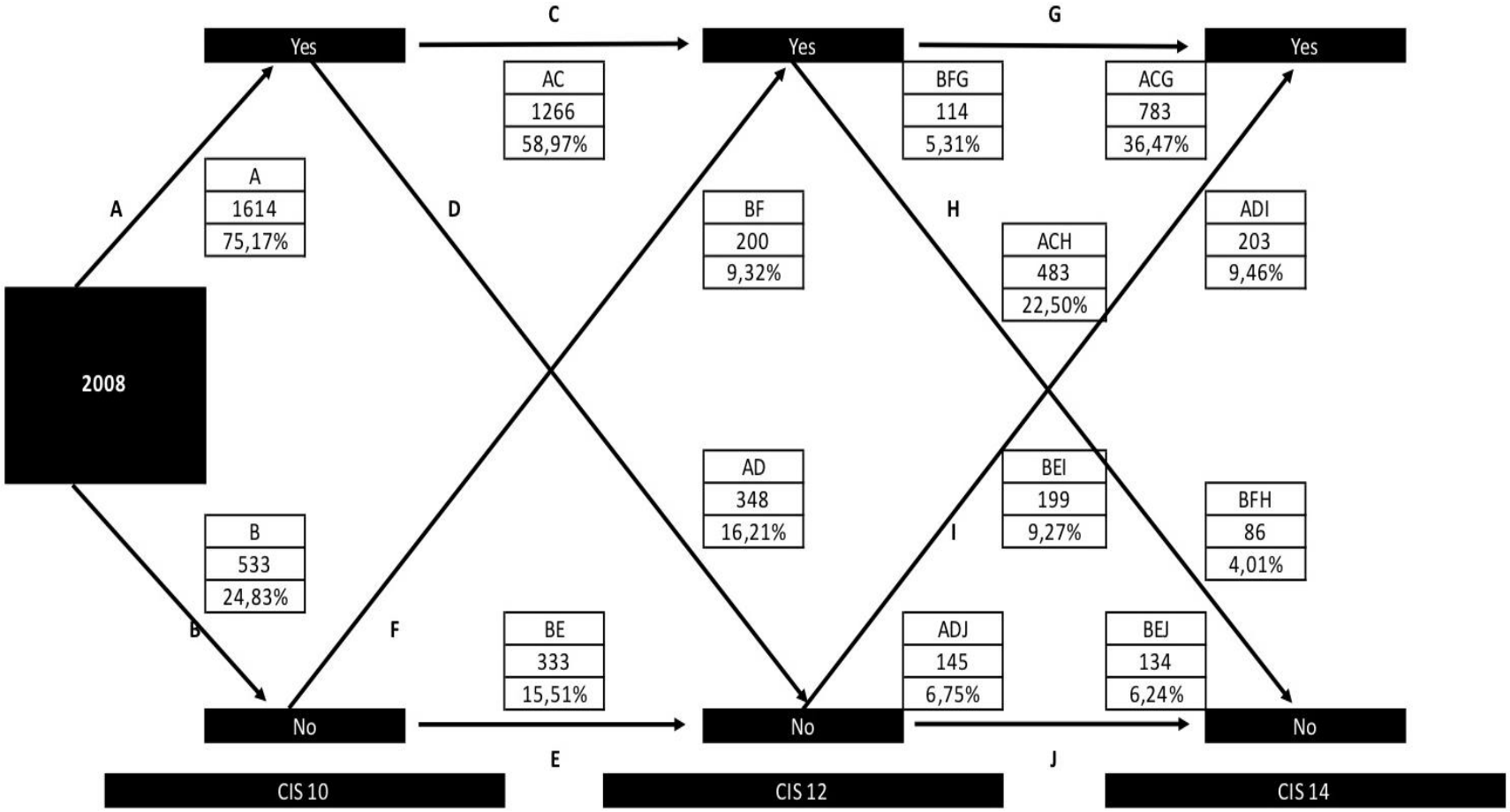
Table 5 – Innovation strategies

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: Self elaboration, following Costa et al., 2018

Another relevant vector of analysis was the design of the critical path pursued by the firm over the time span. Similar details can be traced for the other types on innovation persistence in appendix 1.

Figure 6 - Transition frequencies: innovation in general



Source: Self elaboration, following Costa et al., 2018

When analysing the transition probability matrix for general innovation, (this group includes all firms that have made innovations regardless of type), it's observed that there are 783 firms that are persistent in innovation activities, this value represents 36,47% of the sample (see table 6). The remaining 63,53% are include firms that aren't persistent in innovation activities, that is, having chosen any of the 7 remaining innovation strategies.

With regard to CIS10, 1614 firms performed at least one type of innovation, this figure decreased to 1266 firms in CIS12, this means a change between 75.17% and 36.47% in CIS10 for CIS14. Consequently, firms that did not carry out any type of innovation activity in the CIS10, represent 24.83% of the total firms in the balanced panel, which is reduced in CIS12 and CIS14 to 15.51% and 6.24%, respectively. This means that there is an increase in innovation activities over the period under review.

In terms of product innovation, 137 firms developed innovation activities in the three analysed periods and 810 which did not develop any innovation of this type. These values can be explained by the need for high financial capacity of firms to be able to innovate persistently in this type of innovation.

For firms that are persistent in innovation activities, the type with less relevance is that of services with only 2.93%. Process innovation is the type of innovation that holds fewer non-innovative companies with a percentage of 20.31%.

Table 6 - Aggregation of the innovative strategies in the balanced panel

Innovative Strategy		Types of Innovation (nº of firms and percentage)											
		General		Product		Process		Service		Organisational		Marketing	
		n	%	n	%	n	%	n	%	n	%	n	%
ACG	Continuous	783	36,47	137	6,38	340	15,84	63	2,93	230	10,71	219	10,20
ACH	Continuous-Sporadic	483	22,50	391	18,21	435	20,26	215	10,01	425	19,80	378	17,61
ADI	Sporadic-New	203	9,46	77	3,59	171	7,96	53	2,47	121	5,64	104	4,84
ADJ	Sporadic-Non-Innovative	145	6,75	229	10,67	241	11,22	225	10,48	299	13,93	226	10,53
BFG	New-Continuous	114	5,31	45	2,10	98	4,56	38	1,77	98	4,56	84	3,91
BFH	New-Sporadic	86	4,01	145	6,75	151	7,03	178	8,29	194	9,04	208	9,69
BEI	Non-Innovative-New	199	9,27	313	14,58	275	12,81	266	12,39	245	11,41	296	13,79
BEJ	Non-Innovative	134	6,24	810	37,72	436	20,31	1109	51,65	535	24,92	632	29,44
Total		**2147**		**2147**		**2147**		**2147**		**2147**		**2147**	

Source: Self elaboration

As it is considered that a firm is persistent when it performs an innovation regardless of type, it was interesting to find that 783 companies in the panel perform innovations persistently, making persistence a frequent behaviour. Even though, it was interesting to find typical patterns. To do so, we verified the types of innovation that each persistent innovator has performed in each wave of the CIS. It is of worth mentioning that if the firm performed more than one type of innovation, it was considered as complex.

The main conclusions drawn from this analysis are: 380 firms carried out in the three waves of the CIS more than a type of innovation, thus being determined as complex; 1 firm carried out in the 3 waves of the CIS only one type of innovation (product, marketing, process or organizational). It was not verified the existence of any firm to realize in the period in analysis only innovation of services. So, restrictive approaches not allowing for the transition between innovation types would decimate the percentage of the persistent.

Figure 7 - Number of firms pursuing pure or iterative strategies

Type of innovation over time					
Innovation strategy		CIS10	CIS12	CIS14	Total
	Pure	Product	Product	Product	1
		Process	Process	Process	1
		Organisational	Organisational	Organisational	1
		Marketing	Marketing	Marketing	1
		Complex	Complex	Complex	380
	Itteractive	Product	Complex	Complex	8
		Process	Complex	Complex	22
		Marketing	Complex	Complex	10
		Complex	Complex	Process	74
		Complex	Complex	Organisational	38
		Process	Process	Complex	9

Source: Self elaboration

4.1.2 Dynamic Random Effects Probit

The choice of the model to be used in the study was defined based on the dependent variable, innovation persistence. This choice is due to the fact that it can only be said that a firm is persistent innovative if the innovative past of the firm influences the present innovative, being therefore binary.

Therefore, the model chosen was a probit model of dynamic random effects, insofar as it has an autoregressive component (having done innovation in the past explains the fact of performing innovation in the present), that is, the variable when it is out of phase becomes explanatory.

However, there are characteristics of the firms that do not change over time and therefore, in the panel, they would not vary thus becoming constant (e.g. the firm's SIC Code). To solve this problem, Wooldridge (2005) developed a solution to include structural variables that do not change over time and to control individual heterogeneity.

This choice is fully consensual among the existing literature as previous studies have largely followed this procedure. The table 7 illustrates methodologies implemented in the former empirical research.

Table 7 - Estimation methods used in former studies

Author / Study	Country[1]	Period	Estimation Method
Antonelli, Crespi and Scellato (2013)	Italy (Lagging-behind)	1996-2005	Dynamic random effects probit model
Altuzarra (2017)	Spain (Lagging-behind)	1990-2013	Dynamic random effects probit model
Clausen, Pohjola, Sapprasert and Verspagen (2013)	Norway (Declining)	1995-2004	Dynamic random effects probit model
Peters (2009)	Germany (Frontrunner)	1994-2002	Dynamic random effects probit model
Ganter and Hecker (2013)	Germany (Frontrunner)	2002-2008	Dynamic random effects probit model
Suárez (2014)	Argentina (Catching-up)	1998-2006	Dynamic random effects probit model
Tavassoli and Karlsson (2015)	Sweden (Frontrunner)	2002-2012	Dynamic random effects probit model
Triguero and Córcoles (2013)	Spain (Lagging-behind)	1990-2008	Dynamic random effects probit model

Source: Self elaboration

4.2. Econometric Estimation

The persistence of innovation will be evaluated through two general models: model 1 that tests the conventional hypothesis of persistence and model 2 those that are unconventional. For each model, estimates will be made for all types of innovation and for innovation in general (at least one type of innovation).

Thus, as explained earlier, model 1 tests the conventional hypothesis of persistence, that is, it tests whether innovating in the past has affects the innovative activity in the present, not allowing for intermittences. For this, we used a probit model of dynamic random effects specified as follows:

[1] According Filippetti and Archibugi's taxonomy

Model 1

$$INNOV_{it} = \beta_1 + \beta_2 Innovation_{it-1} + \boldsymbol{\beta} W_{it} + \boldsymbol{\delta} V_i + \alpha_i + \varepsilon_{it}$$

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 (α_i).

Thus, in order to test the unconventional hypotheses of persistence, that is, to analyse the intermittence of innovation strategies, it was decided to use different innovative behaviours suggested by Suárez (2014) (continuous innovation, sporadic, new and non-innovative), thus modelling the second model:

Model 2

$$INNOV_{it} = \beta_1 + \beta_2 Continuing_{it-1} + \beta_3 Sporadic_{it-1} + \beta_4 New_{it-1} + \boldsymbol{\beta} W_{it} + \boldsymbol{\delta} V_i + \alpha_i + \varepsilon_{it}$$

The control variables that allow us to study persistence are the size of firms, the use of public funds or not, openness to different sources of innovation, the portion of skilled labour, the sector of activity, membership of a group of firms, a set of controls in relation to R&D activities. The specifications that led to the construction of each variable are presented in the table 8.

Table 8 - Variable Description

Variable	Type	Description
Acapacity	Count	Counts for the number of R&D types that firm uses
Internal Balance	Binary	1 if the firm use R&D extern and training
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 sector

Source: Self elaboration

The table 9 specifies the descriptive statistics of the control variables shown above.

Table 9 - Descriptive Statistics of the variables[2]

Variable	Number of Obs.	Mean	Std. Dev.	Min	Max
Sic_code	2147			7	86
Tech-intensity	2147	1.6726	0.6942	1	3
Sector	2147	2.3876	0.5225	1	3
Acapacity	2147	1.4846	2.0135	0	8
Internal Balance	2147	0.0797	0.2707	0	1
Education_intensity	2147	2.3253	1.7898	0	6
Openness	2147	0.2405	0.6503	0	2
Funds	2147	0.1547	0.3616	0	1
Group	2147	0.2865	0.4521	0	1
Size	2147	2.3845	0.5841	2	4

Source: Self elaboration

4.3. Estimation Results

The econometric estimation comprises 12 models, and, the purpose its twofold: model(s) 1 comprise pure persistence, which means that being innovative in the past affects the probability of innovation at present; model(s) 2 allow for unconventional persistence hypothesis (persistent, sporadic, new, non-innovative). Then, the estimation comprises innovation in general and all innovation types (product, process, service, organisation, and marketing).

The central point of the model is the analysis of the persistence strategy, discussing the effects of past innovative behaviours in the present. The second factor of analysis is the effect related to the R&D activities (measured by the absorptive capacity and the combination of R&D sources). The third connects human capital to innovation behaviour by means of education intensity. The forth connects innovation persistence to firm size. And, finally persistence is connected to the economic sector. Other controls are included such as innovative openness, reliance of public funds and, economic groups.

In models A we do consider innovation in general, meaning that a firm is considered as innovative because of performing innovation in any innovation type. Model A1 analyses pure persistence under a conventional formulation, and the results show that being innovative in the past does influence the present results at a 10% level. So, being innovative in the former period rises the probability to persist by 2,76 pp. This result appears with

[2] Results based on CIS14 for the balanced panel

particular interest as it accommodates the transition from one innovation type to another, reinforcing our belief that persistent innovators may change the innovation vector as suggested by the previous TPM's. The rest of model(s) 1, comprising pure persistence are only significant in the case of process innovation, failing to be significant in all others.

Model A2 which includes discontinuous innovation strategies presents divergent results. Under this framework, being innovative in the past decreases the probability to persist by 6,68pp compared to the non-innovative, emphasizing the existence of intermittences. Sporadic innovators in the former period will reduce their probability to innovate in the present.

Performing R&D activities does affect innovation persistence, even though the two proxies appear with a symmetric direction. In all models, the absorptive capacity positively influences innovation persistence, contrarily to the internal balance that shows a negative impact. Specifically, in relation to model B1 the higher the levels of the absorption capacity the higher the probability of persisting in innovation by 10.04 pp. This result is perhaps due to the fact that firms with high expenses in training and external R&D may find attractive to somehow stop their innovation activities and learn from the external agents. These results are consistent with the ones Peters (2009) achieved for German manufacturing and service companies.

Therefore, Hypothesis 2 - Higher levels of absorptive capacity will enhance the probability of persistent behaviour - it is widely validated.

As expected, firms that have higher levels of education among their staff are more prone to persist in innovation. This fact reinforces the evolutionary innovation theory, pointing to a higher capacity to learning-by-doing.

Also, concerning innovation in general, size does matter to explain persistence. Compared to small firms in the conventional hypothesis, medium firms have and increased probability to persist in innovation of 3,03 pp. Large firms strengthen the size effect with an increased probability to persist of 5,78pp compared to the small.

The economic sector is determining of innovation persistence, compared to the primary sector, the industry and the services rise the odds of persistence.

When analysing innovation according to its vectors, results are quite similar in what concerns the direction of the effect thus with different magnitudes. Being persistent in innovation in the former period decreases the probability to continue in innovation for product, service, organisational and marketing innovation. The magnitude of the effect is higher in marketing innovation, meaning that those firms that were persistent in marketing innovation in the past will have a decreased probability to persist of 15,82pp comparative to the non-innovative. This result reinforces the choice for intermittence in marketing innovation.

Sporadic innovators in the former period will have a reduced probability to persist in innovation at present; this result appear in all innovation types. The means that firms which have stopped their innovation in the former period are not very prone to restart in the present.

Firms that are new to innovation only present a statistically significant effect on persistence for process innovation. New innovators have and increased probability to persist of 5,55pp compared to the non-innovative. This result may enlighten the need for continuity of this innovation type.

Thus, Hypothesis 1 in the model 1- Being persistent in innovation in the past will enhance the probabilities to continue innovating at present - it is validated. These results are contrary to those of Suárez (2014) obtained for the Argentine firms.

The results clearly show that persistence will differ according to the innovation type, albeit similarities are found concerning intermittences. It deserves reinforcement the case of being new to innovation that only makes sense in the case of projects involving process innovation.

Human capital only presents significant values for the conventional and unconventional models in organizational and marketing innovation in addition to the innovation in general already analysed. In this case, for the conventional model of marketing innovation, the higher the levels of schooling of employees, the greater the probability of existence of innovation persistence at 1.36pp. These results may be due to the fact that Portugal is not a country at the frontrunner of innovation and therefore, companies do not have the capacity to innovate persistently in types of innovation that require cost or training workers as high machinery. In this way, firms may choose to strengthen the areas of innovation that are more financially accessible, such as organizational and marketing.

Tavassoli and Karlsson (2015) concluded that the human capital of firms is fundamental for the persistence of innovation activities. This conclusion is partially verified in this study since it is not significant for all types of innovation. However, if we allow the change of the types of persistence in innovation, the present results go along with those found by Tavassoli and Karlsson (2015).

Thus, Hypothesis 3 - Higher levels of human capital will increment the probability to persist in innovation - it is validated. The empirical results, show that the openness to the sources of innovation is not statistically significant in any model. These results contradict those obtained by Costa, Botelho and Teixeira (2018) in this case for Portuguese firms between 2004-2010.

In product and process innovation models (conventional and nonconventional), the use of public funds increases the likelihood that firms will persist in innovation. However, this factor is not statistically significant for the rest of the models. Altuzarra (2017) draws the same conclusions than this study, but it is important to note that it only analyses product and process innovations.

With regard to size, when compared to small firms, medium-sized enterprises are more likely to be persistent for process and service innovation. Large firms are more likely to persist for product and process innovation. The results of large firms may mean that they have more financial and organizational capacities to make themselves available to persist

in the more expensive types of innovation. Frenz and Prevezer (2012) concluded that one of the most important factors for the persistence of innovation is the size of firms.

Thus, Hypothesis 4 - Firms with a larger size are more prone to continue in innovation - is validated.

Finally, in comparison with the primary sector, the companies belonging to the industry in the conventional model of product innovation increase their chances of being persistent at 7.99 pp. The remaining models, except for innovation in general, are not statistically significant. Comparing the primary sector with the tertiary sector, firms belonging to the service sector increase the propensity to persist in service innovation and marketing models, in addition to innovation models in general.

In this way it is concluded that Hypothesis 5 - The economic sector defines the persistence pattern - it is validated.

The details of the econometric estimations can be found in the following table.

Table 10 - Estimations Results based on CIS 10, 12 and 14

		Innovation in general		Product Innovation		Process Innovation		Service Innovation		Organisational Innovation		Marketing Innovation	
		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$_{t-1}$**	**0.0276***		0.0532		**0.0496***		0.07670		0.0743		0.0908	
		(0.0150)		(0.1085)		(0.0289)		(0.0883)		(0.0488)		(0.1371)	
Dynamic innovative behaviour (default: not innovative)	**Continuing$_{t-1}$**		**-0.0668*****		**-0.1161 ***		-0.0021		**-0.0800*****		**-0.1216*****		**-0.1582*****
			(0.0150)		(0.0256)		(0.0240)		(0.0280)		(0.0271)		(0.0283)
	Sporadic$_{t-1}$		**-0.0693*****		**-0.1252*****		**-0.0448***		**-0.1300*****		**-0.1510*****		**-0.2207*****
			(0.0217)		(0.0254)		(0.0238)		(0.0225)		(0.0244)		(0.0277)
	New$_{t-1}$		0.0271		0.0156		**0.0555***		0.0327		0.0145		0.0059
			(0.0225)		(0.0378)		(0.0315)		(0.0369)		(0.0341)		(0.0393)
R&D activities	**Acapacity**	**0.2594*****	**0.2435*****	**0.1004*****	**0.0951*****	**0.1406*****	**0.1366*****	**0.0867*****	**0.0843*****	**0.0870*****	**0.0821*****	**0.1015*****	**0.0945*****
		(0,0176)	(0.0166)	(0.0043)	(0.0040)	(0.0051)	(0.0048)	(0.0041)	(0.0037)	(0.0056)	(0.0046)	(0.0122)	(0.0047)
	Internal Balance 1	**-0.3856*****	**-0.3731*****	**-0.1520*****	**-0.1537*****	**-0.2119*****	**-0.1987*****	**-0.1493*****	**-0.1470*****	**-0.0583****	**-0.0592****	**-0.1859*****	**-0.1847*****
		(0,0967)	(0.0849)	(0.0221)	(0.0208)	(0.0332)	(0.0309)	(0.0195)	(0.0180)	(0.0273)	(0.0254)	(0.0329)	(0.0246)
Education	**Education_intensity**	**0.0178*****	**0.0156*****	0.0063	0.0.0051	-0.0017	**-**0.0019	0.0055	0.0052	**0.0368*****	**0.0343*****	**0.0136****	**0.0102****
		(0.0041)	(0.0039)	(0.0045)	(0.0044)	(0.0045)	(0.0044)	(0.0040)	(0.0040)	(0.0051)	(0.0048)	(0.0054)	(0.0050)
Openness	**Openness**	0,0212	0.0112	0.0039	-0.0022	0.0046	0.0060	**0.0175***	0.0150	0.0090	0.0041	0.0176	0.0161
		(0.0255)	(0.0233)	(0.0110)	(0.0106)	(0.0139)	(0.0134)	(0.0097)	(0.0095)	(0.0130)	(0.0125)	(0.0135)	(0.0129)
Funds	**Public Funds**	0.0046	-0.0078	**0.0593*****	**0.0587*****	**0.0687*****	**0.0671*****	-0.0018	-0.0035	0.0189	0.0238	-0.0207	-0.0164
		(0.0353)	(0.0321)	(0.0159)	(0.0143)	(0.0196)	(0.0184)	(0.0149)	(0.0141)	(0.0186)	(0.0178)	(0.0205)	(0.0185)
Size (default: small)	**Medium_size**	**0.0303****	**0.0208***	-0.0071	- 0.0151	**0.0391*****	**0.0397*****	**-0.0475*****	**-0.0518*****	0.0101	**-**0.0025	-0.0096	**-0.0245***
		(0,0124)	(0.0121)	(0.0122)	(0.0120)	(0.0129)	(0.0125)	(0.0112)	(0.0113)	(0.0144)	(0.0138)	(0.0150)	(0.0142)
	Large_size	**0.0578***	**0.0507***	**-0.0593*****	**-0.0734*****	**0.0558****	**0.0480***	-0.0196	**-0.0333***	0.0423	0.0235	-0.0073	-0.0412
		(0.0295)	(0.0280)	(0.0207)	(0.0196)	(0.0276)	(0.0275)	(0.0197)	(0.0189)	(0.0261)	(0.0248)	(0.0261)	(0.0251)
Group	**Group**	-0.0084	-0.0082	0.0198	0.0204	**-**0.0007	0.0005	0.0009	0.0016	0.0248	0.0199	-0.0204	-0.0227
		(0.0143)	(0.0140)	(0.0134)	(0.0127)	(0.0139)	(0.0136)	(0.0119)	(0.0116)	(0.0153)	(0.0147)	(0.0153)	(0.0149)
Initial endogeneity and individual heterogeneity	**Innov_geral_initial**	**0.0421*****	**0.1022*****	0.0832	**0.1852*****	**0.0509****	**0.1150*****	0.0430	**0.1664*****	0.0326	**0.1604*****	0.0837	**0.2504*****
		(0,0151)	(0.0158)	(0.0788)	(0.0132)	(0.0208)	(0.0154)	(0.0605)	(0.0126)	(0.0342)	(0.0157)	(0.1081)	(0.0149)
	Mean_Acapacity	-0.0034	0.0030	**-0.0172****	**-**0.0100	**-0.0162****	**-0.0187*****	**-0.0160*****	**-0.0155*****	-0.0055	0.0005	-0.0088	-0.0028
		(0.0053)	(0.0055)	(0.0072)	(0.0063)	(0.0065)	(0.0071)	(0.0057)	(0.0053)	(0.0073)	(0.0073)	(0.0079)	(0.0067)
	Mean_education_intensity	**-0.0007***	**-0.0006***	**-0.0009****	**-0.0010****	**-0.0009****	- **0.0009****	0.0003	0.0004	-0.0007	-0.0005	**-0.0011****	**-0.0009****
		(0,0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
	Mean_openess	0,0107	0.0177	-0.0090	**-** 0.0047	0.0072	0.0099	-0.0219	-0.0175	-0.0152	-0.0051	-0.0152	-0.0085
		(0.0157)	(0.0153)	(0.0155)	(0.0153)	(0.0164)	(0.0162)	(0.0142)	(0.0142)	(0.0189)	(0.0187)	(0.0191)	(0.0188)
Sector (default: primary)	**Industry**	**0,0708***	**0.0668***	**0.0799***	0.0710	0.0505	0.0509	-0.0365	-0.0388	0.0101	0.0091	0.0449	0.0420
		(0,0379)	(0.0371)	(0.0483)	(0.0459)	(0.0438)	(0.0430)	(0.0515)	(0.0522)	(0.0499)	(0.0493)	(0.0600)	(0.0579)
	Services	**0,1075*****	**0.1056*****	-0.0031	-0.0025	0.0334	0.0328	**0.0988***	**0.0951***	0.0550	0.0583	**0.1304****	**0.1314****
		(0.0386)	(0.0378)	(0.0481)	(0.0469)	(0.0445)	(0.0437)	(0.0519)	(0.0522)	(0.0506)	(0.0501)	(0.0615)	(0.0584)
	Nº of observations	4294	4446	4294	4446	4294	4446	4294	4446	4294	4446	4294	4446
	Nº of groups	2147	2147	2147	2147	2147	2147	2147	2147	2147	2147	2147	2147
	Wald-Test (P-value)	231.74 (0.0000)	281.09 (0.0000)	450.48 (0.0000)	586.86 (0.0000)	391.09 (0.0000)	436.25 (0.0000)	396.86 (0.0000)	544.15 (0.0000)	621.71 (0.0000)	774.40 (0.000)	622.57 (0.0000)	762.82 (0.0000)

Source: Self elaboration

5. Conclusions and Policy Recommendations

Despite the large extent of empirical evidence covering the topic on innovation persistence, phenomenon is not yet fully understood. (Cefis, 2003, Clausen et al., 2012, Juliao-Rossi and Schmutzler, 2016; Altuzarra, 2017). Most of the studies focus on firms operating in the industrial sector, in Innovation leaders and conventional persistence hypothesis. Albeit, the analysis of innovation persistence seems to have far more peculiarities than those traditionally exploited in the literature. The conventional hypothesis reinforcing the virtuous cycles of accumulation neglect the natural intermittences in the innovative proves. Moreover, the determinants of innovation differ according to the innovation type.

The empirical results support Schumpeter's idea of different innovation types to accommodate product lifecycle. These findings are quite new and should deserve the attention of policy makers.

The present study focused on a balanced panel of 2147 firms located Portugal, covering the time span of 2008 and 2014 and tested the hypothesis of 'true state dependence', assuming both that firms do not react to exogenous fluctuations and that they may change their innovative behaviour (Continuous, New, Sporadically, and Non innovative firms) (Suaréz, 2014; Costa et al, 2018). Several results should be underlined:

Concerning the innovative strategy, the results only partially go along with those found in Suárez's (2014) concerning non-conventional persistence hypothesis, Past persistent innovators have a reduced propensity to continue in innovation, such as sporadic and, being new to innovation does not affect the probability to continue, driving out the hypothesis of persistence. In the aggregate level, the effects of past innovative strategies do not differ from one innovation type to another.

Additionally, the exploratory analysis, provided by the transition probability matrices, unveil a very high degree of state dependence or pure innovation persistence, nevertheless the econometric estimations reported in models 1 fail to provide statistical support for this belief. It seems that the pattern of persistence traced in this model is spurious rather than pure, which means that the factors explaining persistence are closer to the firm characteristics rather than past innovative behaviour. Among firm characteristics it determinant the effect of the firm absorptive capacity, its open innovation strategy (combine internal and external investments in intangible assets) and punctually the skills of the labour force and the public funds. Contrarily to the previous Portuguese analysis (Costa et al., 2018), reliance on innovation sources fails to affect innovation persistence.

Another surprising result is the effect of size, as one can observe a scale effect when focusing on innovation in general, and process or service innovation. In addition, concerning product innovation large firms have a reduced likelihood to persist in innovation.

The different types of innovation are transversally affected by the firms' absorptive capacity and open innovation strategies. However, when it comes to the reliance on public funds, the only innovation types affected by this determinant are product and process innovation. Surprisingly, the

skills of the labour force fail to affect persistence on what concerns product, process and service innovation.

The specificities of these results have important implications in terms of the public policy. As innovation persistence is not verified in our panel, it seems that the innovation policy programs fail to achieve their targets, being incapable of generating virtuous cycles of accumulation. Firms, when on themselves, do not persist in innovation, forcing policy makers to create the accurate mechanism to overcome the failures in continuity. Perhaps the innovation policy should focus on the factors forcing the firms to interrupt their innovative paths. So, the reliance on subsidies should not be singular, nor persistent, it should help firms in staring the innovation cycles and supporting them in punctual moments when they are forced to stop.

It seems evident that innovation policy requires commitment; it should not change in the short run according to short run fluctuations, economic or electoral cycles. It persistence fails to be achieved firm's virtuous cycles will be broken and intertemporal spill overs are unlikely to be created.

According to the results, there might be a rational to encourage public policies targeting small firms with high absorptive capacity, with open innovation strategies being either in the secondary or tertiary sectors if the funding goal is to promote innovation in a persistent scheme.

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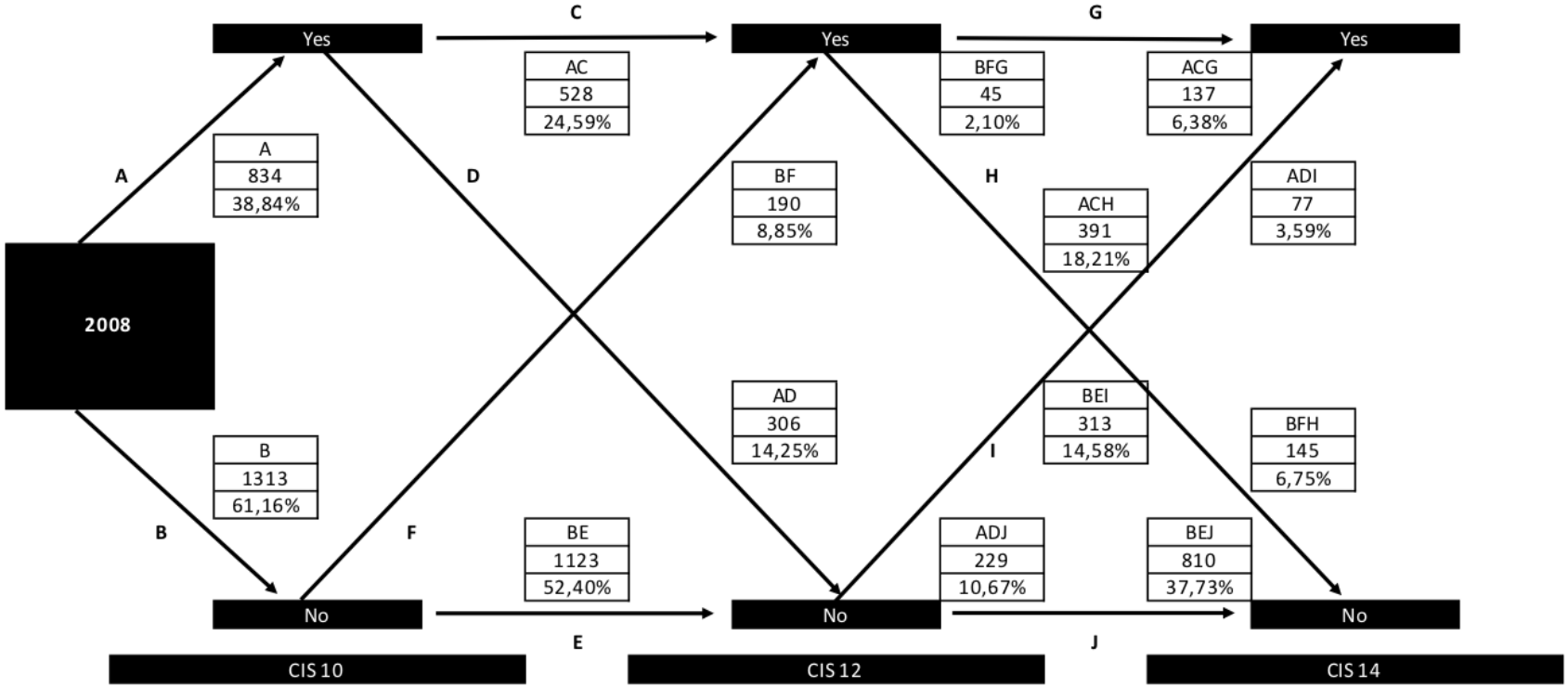
Appendices

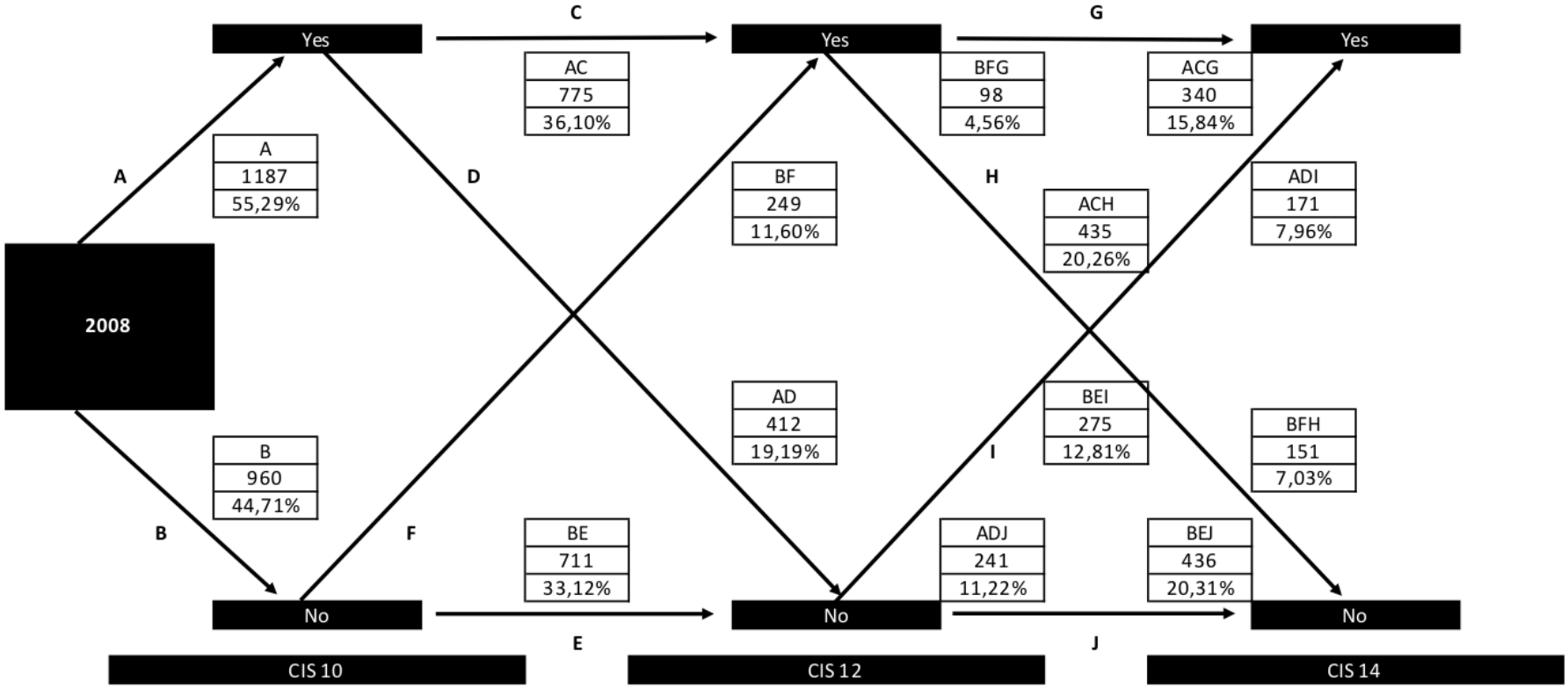
Appendix 1

Figure 8 -Transition frequencies: product innovation



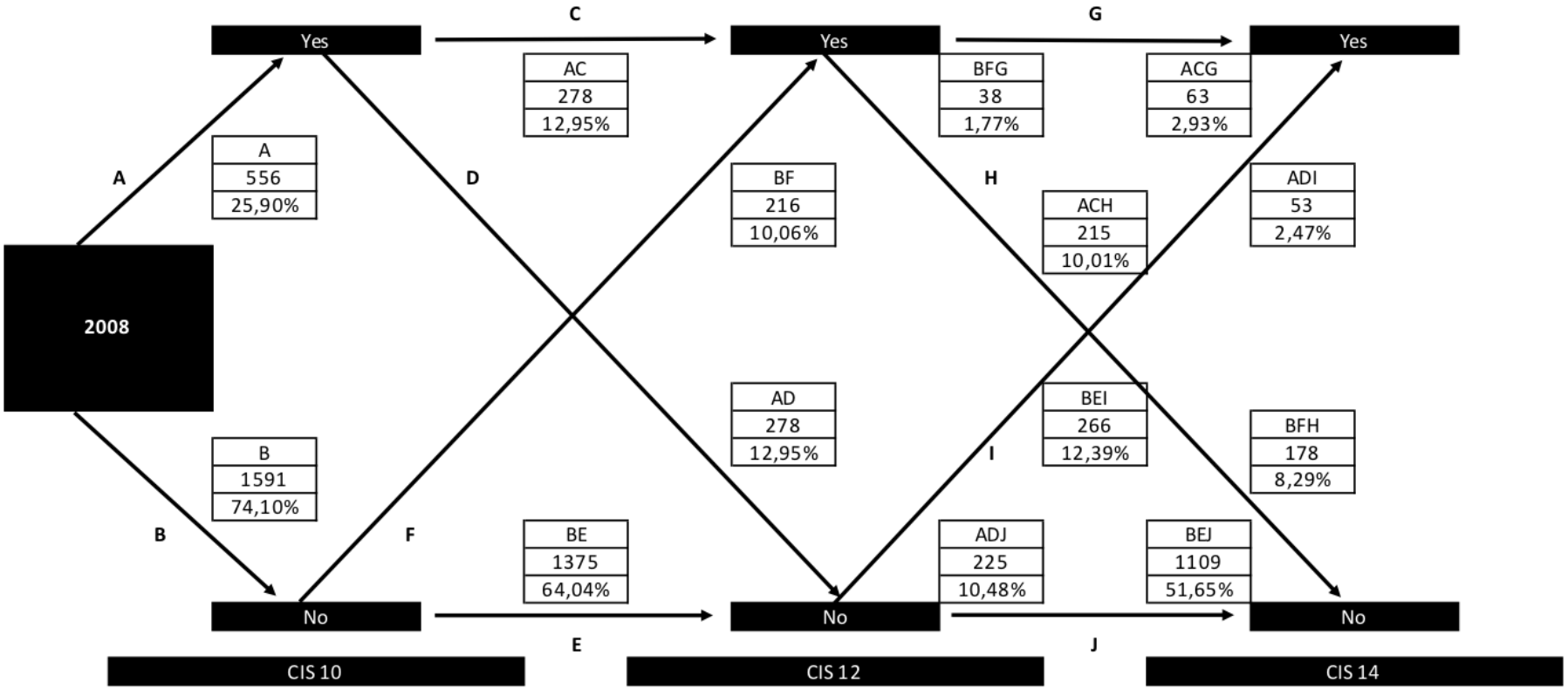
Source: Self elaboration

Figure 9 -Transition frequencies: process innovation



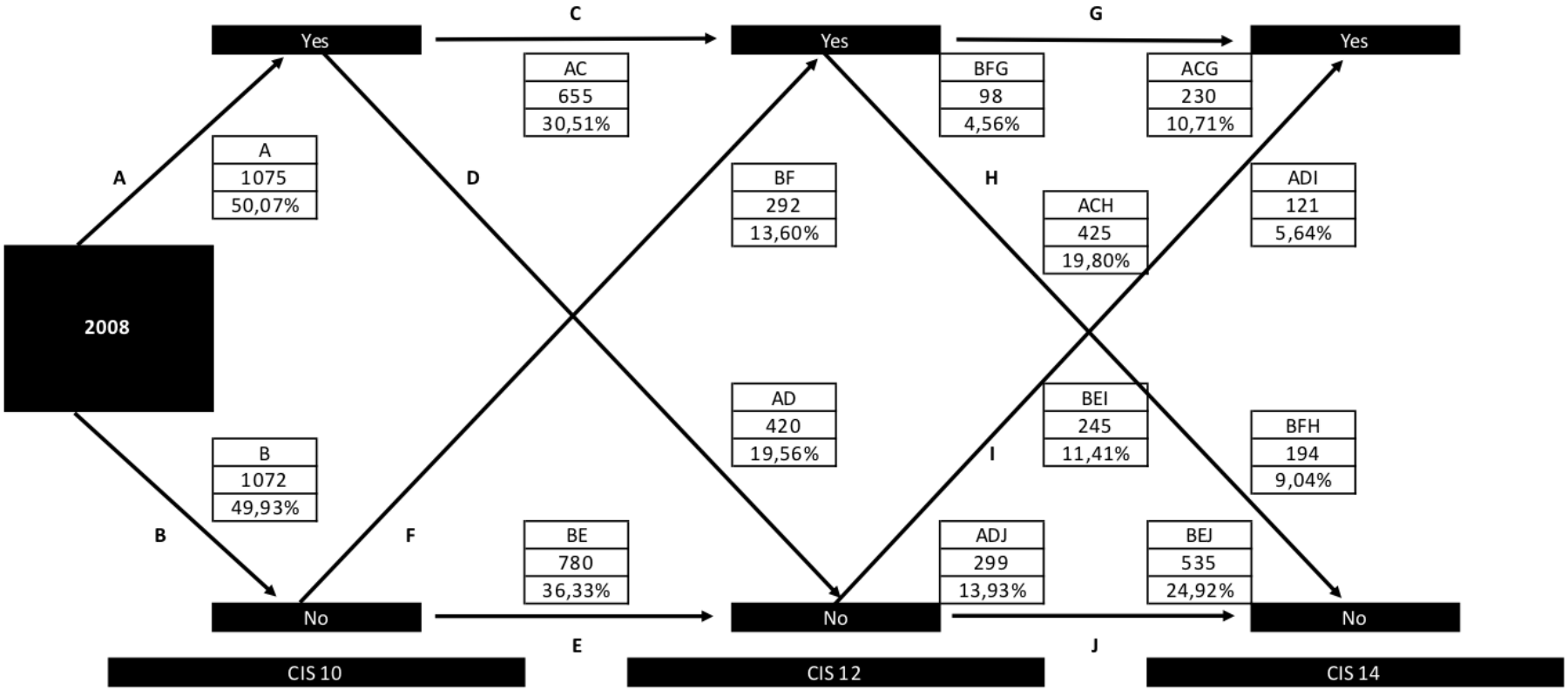
Source: Self elaboration

Figure 10 - Transition frequencies: services innovation



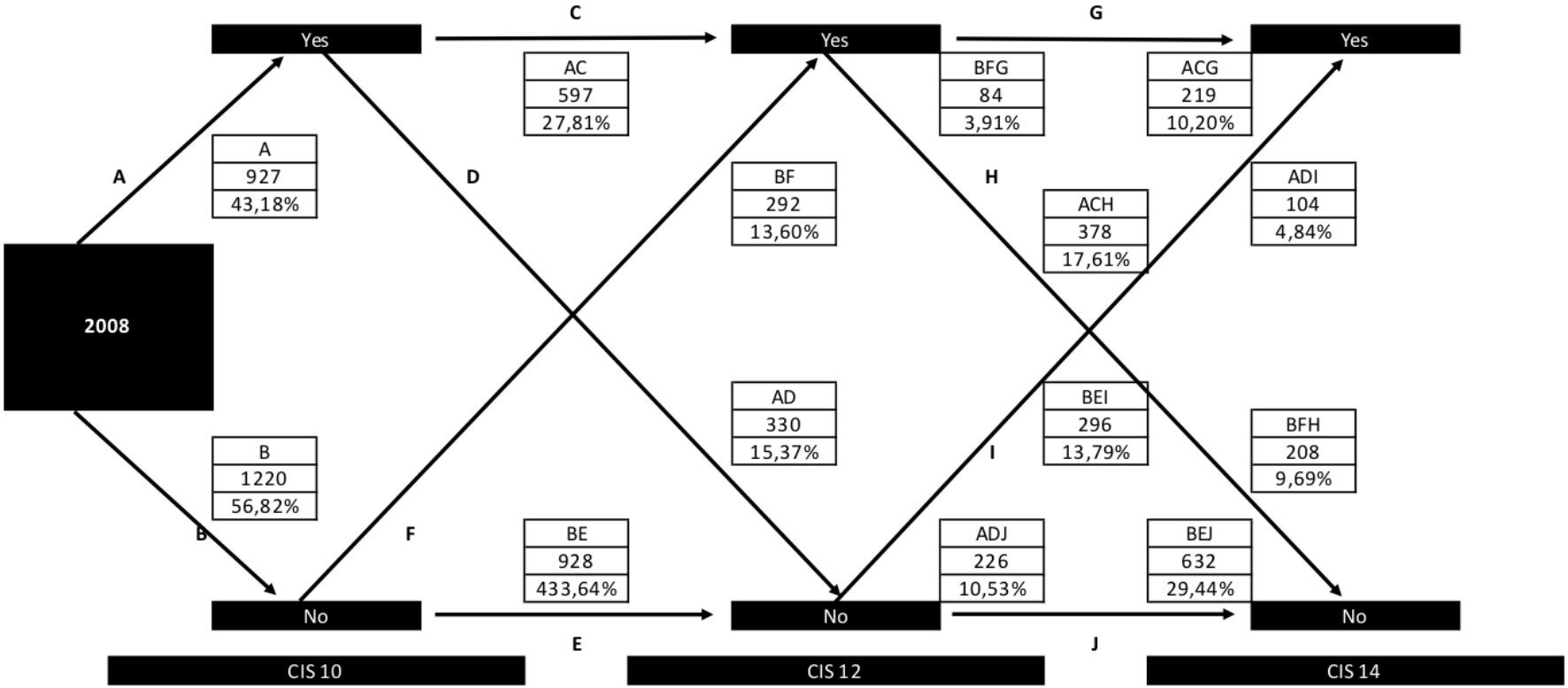
Source: Self elaboration

Figure 11 - transition frequencies: organisational innovation



Source: Self elaboration

Figure 12 - Transition frequencies: marketing innovation



Source: Self elaboration

Appendix 2

Table 11 - Distribution of Sic-Code by technological regimes

Technological Regimes	CAE (Rev3)	CAE Designation	Number of firms CIS10	Number of firms CIS12	Number of firms CIS14	Number of firms Panel
Very Low Tech	13	Manufacture of textiles	134	132	162	39
	14	Clothing industry	82	114	232	16
	15	Industry of leather and leather products	133	188	253	50
	16	Manufacture of wood and of products of wood and cork, except furniture; Manufacture of basketware and wickerwork	220	203	250	77
Low Tech	10	Food industry	144	195	299	29
	11	Drink industry	73	128	129	41
	22	Manufacture of rubber and plastic products	184	221	196	93
	23	Manufacture of other non-metallic mineral products	264	333	299	86
	24	Basic metallurgical industries	68	66	64	41
	25	Manufacture of metal products, except machinery and equipment	584	654	583	210
	31	Manufacture of furniture and mattresses	154	154	167	42
	32	Other manufacturing	151	137	124	73
	33	Repair, maintenance and installation of machinery and equipment	147	157	146	62
	42	Civil Engineering	30	25	16	14
	43	Specialized construction activities	17	11	13	8
	49	Land transport and transport by pipeline	266	313	268	66
	50	Water transport	23	25	25	14
Medium Tech	7	Extraction and preparation of metal ores	111	73	111	27
	17	Manufacture of pulp, paper and paperboard	95	89	80	36
	18	Printing and reproduction of recorded media	127	163	160	50
	19	Manufacture of coke, refined petroleum products and agglomerates of fuels	111	116	140	54
	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	47	46	41	25
	26	Manufacture of computer equipment, communication equipment and electronic and optical products	49	53	48	28
	27	Manufacture of electrical equipment	99	91	90	42
	28	Manufacture of machinery and equipment, n. e	232	203	200	110
	29	Manufacture of motor vehicles, trailers, semi-trailers and components for motor vehicles	90	107	105	39
	30	Manufacture of other transport equipment	46	50	42	28
	35	Electricity, gas, steam, hot and cold water and cold air	38	42	41	22
	36	Water collection, treatment and distribution	70	66	74	46

	37	Collection, drainage and treatment of waste water	17	18	14	12
	38	Collection, treatment and disposal of waste; valuation of materials	143	158	149	86
	46	Wholesale trade (including agents) other than motor vehicles and motorcycles	866	1072	1175	192
	47	Retail trade, except of motor vehicles and motorcycles	16	15	16	10
	51	Air transport	21	27	27	17
	52	Warehousing and auxiliary transport activities (including handling)	113	175	162	33
	53	Postal and courier activities	15	15	13	5
	60	Radio and television activities		15	15	
	61	Telecommunications	37	32	29	12
	65	Insurance, reinsurance and pension funds, except compulsory social security	54	55	53	38
	66	Activities auxiliary to financial services and insurance	74	78	85	27
	75	Veterinary activities	10	20	17	4
	86	Human health activities	92	94	18	11
High Tech	58	Editing activities	104	107	82	46
	59	Cinematographic, video, television program production, sound recording and music publishing activities		31	38	
	62	Computer consulting and programming and related activities	146	161	152	38
	63	Information services activities	30	30	31	17
	64	Financial services activities, except insurance and pension funds	129	146	162	52
	69	Legal and accounting activities	157	112	136	25
	71	Architectural, engineering and related technical activities; testing and technical analysis activities	171	141	134	12
	72	Scientific and development research activities	14	30	43	7
	73	Advertising, market research and opinion polls	91	96	109	20
	74	Other consulting, scientific, technical and similar activities	71	57	65	15
		Total number of firms	**6160**	**6840**	**7083**	**2147**