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THE IMPACT OF THE GLOBAL FINANCIAL CRISIS ON OPEN INNOVATION STRATEGIES AND INNOVATION PERFORMANCE OF PORTUGUESE COMPANIES

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Bio

Luís Carlos Couto Moreira was born in March 18th of 1995 in Vila Nova de Famalicão. He completed his bachelor in Management at Faculdade de Economia do Porto (FEP) in 2017. In September of that year, he enrolled in the Master in Management in FEP, which he is currently attending.

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To all my friends who aided me through this journey.

Abstract

The global financial and economic crisis entailed many mutations in the business environment and businesses behavior. Companies worldwide faced an all-new business environment, where business opportunities were less certain and riskier. Although some contend that such increased business uncertainty tends to make companies less willing in making long-term investments in innovation, new economic cycles can also bring structural changes in worldwide economies and be an occasion for companies to reorganize procedures to explore new opportunities.

The empirical literature on the impact of the global financial crisis on companies' innovation behavior is scarce and did not produced clear-cut or consensual results. The limited amount of studies that address the impact of crisis on the innovative behavior and performance of firms focused the issue of collaboration or reliance in distinct types of knowledge sources. No study has yet addressed how economic crisis affect the distinct open innovation strategies, most notably the importance attributed to the reliance on scientific (e.g., universities) versus market related sources (e.g., clients or suppliers), and the external R&D collaboration activities on companies' non-radical and radical innovation performance.

To overcome this literature gap, the present study resorts to a balanced panel of 920 companies located in Portugal, which answered the Community Innovation Survey in three set of waves, encompassing the periods 'before the crisis' (2006 and 2010), 'during the crisis' (2010 - 2014), and 'after the crisis' (2014-2016).

Resorting to logistics panel data techniques, we found three main results: 1) Non-radical technological innovation increased during crisis (and kept increasing after crisis), however radical technological innovation was only spurt after crisis, observing a very slight decrease during the crisis period; 2) During the period of economic crisis, companies that rely more extensively on OI strategies, most specially related to the importance attributed to market sources of knowledge and R&D collaboration, tended to outperform the other companies in terms of non-radical and/or radical innovation; and 3) During the crisis period human capital endowments, training, and the acquisition of machinery, equipment and software, fostered companies' radical technological innovation, whereas continuous intramural R&D activities and the acquisition of machinery, equipment and software enhanced non-radical innovation performance.

Keywords: Economic crisis; innovation; companies; Portugal

Resumo

A crise financeira e económica de 2008 criou muitas alterações nas relações comerciais e no comportamento das empresas. Empresas de todo o mundo enfrentaram um novo paradigma, onde as oportunidades de negócios são mais incertas e arriscadas. Embora alguns afirmem que esse aumento da incerteza nos negócios tende a tornar as empresas menos dispostas a investimentos de longo prazo em inovação, novos ciclos económicos podem trazer mudanças estruturais nas economias mundiais e revelar-se uma oportunidade para reorganizar procedimentos e explorar novas alternativas.

A literatura empírica sobre o impacto da crise financeira de 2008 nos comportamentos de inovação das empresas é escassa e não produziu resultados claros ou consensuais. A quantidade limitada de estudos que abordam o impacto da crise sobre o comportamento inovador e o desempenho das empresas focou a questão da colaboração e a dependência de certas fontes de conhecimento. Nenhum estudo abordou ainda como a crise afeta as diferentes estratégias de inovação, principalmente a importância atribuída à colaboração com fontes científicas (por exemplo, universitárias), de mercado (por exemplo, clientes ou fornecedores) ou a colaboração no âmbito de atividades externas de I&D no desempenho inovador radical e não radical das empresas.

Para colmatar esta lacuna, a presente dissertação recorre a um painel de 920 empresas localizadas em Portugal, que responderam ao Inquérito Comunitário à Inovação em três conjuntos de ondas, abrangendo os períodos "antes da crise" (2006 e 2010), "durante a crise" (2010 - 2014) e "depois da crise" (2014-2016). Recorrendo a técnicas de dados em painel logístico, encontramos três resultados principais: 1) Inovação tecnológica não radical aumentou durante a crise (continuando a aumentar após a crise), porém a inovação tecnológica radical só foi impulsionada após a crise, observando uma ligeira queda durante o período de crise; 2) Durante o período de crise económica, as empresas que dependem mais das estratégias de "Open Innovation", especialmente relacionadas com a importância atribuída às fontes de conhecimento do mercado e à colaboração em I&D, tenderam a superar as outras empresas em termos de inovação não-radical e / ou radical; e 3) Durante o período de crise, o capital humano, formação e aquisição de máquinas, equipamentos e software fomentaram a inovação tecnológica radical das empresas, enquanto as atividades contínuas de I&D intramurais e a aquisição de máquinas, equipamentos e software aumentaram o desempenho da inovação não radical.

Palavras-chave: Crise económica; inovação; empresas; Portugal

Index

Index of Tables

Index of Figures

1. Introduction

Considered by many as the worst financial crisis since the Great Depression of the 1930s, the financial crisis of 2007–2008, also called global financial crisis/ 2008 financial crisis, involved increased uncertain financial conditions which constrained companies' activities, namely those related with innovation (Zouaghi et al., 2018).

This global financial and economic crisis entailed many mutations in the business environment and businesses behavior (Teplykh, 2018). Companies worldwide faced an all-new business environment, where business opportunities were less certain and riskier, market demand was declining, distress within the financial markets and macroeconomic uncertainty increased (Ignatov, 2018). Such increased business uncertainty tended to make companies less willing in making long-term investments in innovation (Filippetti and Archibugi, 2011). However, some content (e.g., D'Agostino and Moreno, 2018; Ignatov, 2018) that new economic cycles can also bring structural changes in worldwide economies and be an occasion for companies to reorganize procedures to explore new opportunities.

The empirical literature on the impact of the global financial crisis on companies' innovation behavior is scarce and did not produced clear-cut or consensual results (Archibugi et al., 2013a; D'Agostino and Moreno, 2018).

The relation between business cycles and innovation is far from consensus. The countercyclical approach proposes that during recessions innovation increases as, with low demand, the opportunity costs of doing innovation is lower than in periods of growth (Schumpeter, 1942; Archibugi et al., 2013b). Otherwise, the procyclical approach points out that financial constraints might prohibit the companies to maintain or increase their R&D budget and that companies postpone innovation to periods of expansions to maximize the returns (Ignatov, 2018).

Some literature has pointed out the idea that learning is a crucial capacity of the company and under changing external environment companies react by adapting their learning process (Chesbrough and Garman, 2009; D'Agostino and Moreno, 2018).

In particular, in turbulent times companies might decide for an exploration strategy such as more research or experimentation of which cooperation in innovation activities is a possible alternative (Chesbrough and Garman, 2009). Therefore, cooperation could offer learning

opportunities even during a turbulent time such as an economic recession and can constitute a specific strategy to face economic crises (D'Agostino and Moreno, 2018).

Moreover, from the limited amount of studies that address the impact of crisis on the innovative behavior and performance of firms, only three have focused the issue of collaboration (Martinez et al., 2018; D'Agostino and Moreno, 2018) or reliance in distinct types of knowledge sources (Archibugi et al., 2013). These latter studies, however, analyzed very restricted contexts: Spain (D'Agostino and Moreno, 2018; Zouaghi et al., 2018) or the 27 EU member states, plus Norway and Switzerland all together (Filippetti and Archibugi, 2011). Specifically, D'Agostino and Moreno (2018) explored how cooperation in innovation activities had a stronger relation with radical innovation performance during the economic recession than before, whereas Zouaghi et al. (2018) assessed the differential effects of external knowledge sources on the firms' innovative performance. Filippetti and Archibugi (2011) explored the effects of the economic downturn in terms of firms' innovation across European countries. They conclude that those effects differ from country to country due to the different competences and quality of the human resources, the specialization in the high-technology sector and the level of development of the financial system. These characteristics seem to be the structural factors which are able to offset the effect of the economic downturn on innovation investments of companies across Europe (Filippetti and Archibugi, 2011).

No study has yet addressed how economic crisis affect the distinct open innovation strategies, namely the importance attributed to external sources of knowledge such as science (e.g., universities), market (clients, suppliers, competitors), or the collaboration in R&D through the acquisition of extramural Research and Development (R&D).

The present dissertation aims at exploring this literature gap and improve our knowledge about how the economic slowdowns affect companies' innovative performance and how the economic/ financial crisis mediate the impact of OI strategies on companies' technological (product and process) innovative performance by studying the impact of the 2008 financial crisis on the innovation propensity of multi-sector companies of a moderate innovator country, Portugal.

To reach this goal, we resort to data from the Community Innovation Survey (CIS) for Portugal involving three set of waves, the CIS08 and CIS10, which covers the firms' innovation strategies between 2006 and 2010 ('before the crisis'), and the CIS12 and CI14, which com-

prise those same strategies between 2010 and 2014 ('during the crisis'), and the CIS16, covering the most recent available period, 2014-2016 ('after the crisis'). Each CIS encompasses, on average, around 7000 companies operating in all sectors of activities. We merged these 3 waves to obtain the 920 companies that were operating throughout this 10-year period, which permit to analyse, resorting to panel data logistic regressions, how companies' OI strategies evolved and how they impacted innovative performance before, during and after the crisis.

The present dissertation is structured as follows. Next section reviews the literature on the relevant area: economic crisis, firms' innovation strategies and innovation performance. Then, in Section 3, the methodology is described. In Section 4, we present the empirical results of the study. Finally, Section 5 concludes the study, synthetizing the main outcomes, limitations and paths for future research.

2. The impact of crisis on innovation strategies and performance of companies: the theoretical framework

Global economic downturns differ in terms of how they originate and spread across countries and industries, as well as in their after-effects (Teplykh, 2018).

Several theoretical approaches permit to explain, directly or indirectly, how companies behave during and after economic downturns in terms of innovation strategies and performance. These include, the innovation-based approaches (Schumpterian approach of creative destruction and cummulativess, and the Open innovation approach), and the resource and competencies-based approaches (Penrose's theory of the firm; Resource based view, and Teece's dynamic capabilities).

2.1. Innovation-based approaches

2.1.1. Schumpeter's contribution

Joseph Schumpeter is among the first authors who present the concept of innovation. His views on the topic, however, changed over time. In his 1912's book *The Theory of Economic Development* Schumpeter looked at innovation as an event that could revolutionize economic life by bringing into the market new entrepreneurs or new companies and creating new industries. Schumpeter argued that the occurrence of discontinuous and revolutionary changes was at the core of economic development which breaks the economy out of its static mode and that innovation was an essential driver of firms' and countries' competitiveness. Accordingly, innovation was the "creative destruction" that develops the economy while the entrepreneur performs the function of the change creator (Schumpeter, 1912). The term "creative destruction" describes the process of innovation as a result of an economy characterized by low cumulativeness and high technological opportunities, which leads to an environment with greater dynamism in terms of technological ease of entry and exit, as well as a major role played by entrepreneurs and fierce competition.

Later, in his work *Capitalism, Socialism, and Democracy* (1942), Schumpeter observed and described that the dynamics of capitalism was bound to fail and the entrepreneur to disappear because very efficient corporations would lead to monopolistic structures by being able to perform R&D and innovation as a routine, building on their previous competences. Schumpeter (1942) stated that the "creative accumulation" process is associated with an

economy characterized by high cumulativeness and low technological opportunities, bringing about more stable environments in which the bulk of innovation is carried out incrementally by large and established firms, leading to a market structure with high entry barriers and oligopolistic competition.

According to the Schumpeterian approach, economic downturns can constitute an opportunity to invest in innovation for getting competitive advantage in times of economic growth.

2.1.2. The open innovation approach

In the line of Schumpeterian vision, the open innovation approach contends that companies that keep investing in their innovative capabilities during economic downturns are those more suited to perform better when growth returns (Chesbrough and Garman, 2009).

Notwithstanding, the proponents of the OI approach recognize that increased business uncertainty tend to make companies less willing in making long-term investments in innovation (Filippetti and Archibugi, 2011). As such, companies prioritize, give attention and resources to those projects that are most likely to generate near-term profits (Chesbrough and Garman, 2009). This type of strategy is likely to freeze many potentially promising projects at an early stage in their development and leave them stranded inside the company compromising company's ability to grow beyond its core business (Chesbrough and Garman, 2009). In this context, Chesbrough (2003) argues that open innovation strategies can play an important part to overcome companies' constrains in time of crisis.

Open innovation can be described as the use of inflows of knowledge to accelerate internal innovation, and the use of outflows of knowledge to expand the markets for external use of innovation (Chesbrough, 2003). The new imperative for innovating companies is that they can and should use external as well as internal ideas, and both internal and external paths to market, when they seek to maximize returns from their innovation activities (Chesbrough and Garman, 2009).

Inter-organizational alliances are increasingly recognized in the innovation management literature as 'access relationships' that enable partners to acquire non-redundant knowledge and capabilities residing outside their organizational and technological boundaries (Chesbrough, 2003; Chesbrough and Garman, 2009). Strategic alliances facilitate access to

diverse markets and technological knowledge and boost innovation by enhancing combinatory search (Jiang, et al., 2010; Lahiri and Narayanan, 2013). Such open strategies depend on contributions from across a network of partners ranging from suppliers of raw materials, equipment, research institutes to consumers, and customers that create value for the end consumer (West and Lakhani, 2008)

Cooperation with suppliers is found to increase efficiency and complement the technological base of the company (Belderbos et al., 2004). Collaboration with universities and research institutes, can provide access to tailor made, cutting edge technologies (Tsai et al., 2009); nevertheless, it may require companies to collaborate with other actors in order to implement the technology (Berg-Jensen et al., 2007). Horizontal alliances are more likely to be strategically motivated to improve long-term product technology development whereas vertical alliances tend to be more concerned with cost reduction (Kotabe, 1990). Collaboration with competitors enables firms' rapid market penetration and access to technological abilities that can be difficult, time-consuming, and costly to develop alone within their boundaries (Van Beers and Zand, 2014).

In order to face new business challenges, due to economic downturns, companies could use these open innovation strategies, namely collaborate with external partners, in order to overcome the perceived high risks involved in technological innovation and financial constraints and get competitive advantages in the market (Abramovsky et al., 2005).

2.2. Resource and competencies-based approaches

2.2.1. Penrose's theory of the firm

Penrose (1959) argued that a company is a collection of productive resources (human and non-human) under administrative coordination and authoritative communication that can be combined in different ways to produce/create goods and services for sale in the market for a profit and the combination of resources is what makes the company unique. She further added that the company creates a learning environment for all those involved, which leads to new resources that can be used for further expansion, with material resources being of great importance.

Unused resources, lack of managerial skills, and lack of specialised knowledge constitute, according to Penrose (1959), internal limits on expansion of firms. Unused productive resources are, at the same time, a challenge to innovate, an incentive to expand, and a source of competitive advantage.

In times of financial constraints, the amount of resources within the companies decreases, which is likely to lead companies to cut expenditures that are allocated to innovation, and thus innovation performance is likely to diminish.

2.2.2. The resource-based view (RBV)

The resource-based view (RBV) theory is inspired in the work of Penrose (1959) and establishes that a company should be considered both as a bundle of products as well as a bundle of resources (Wernerfelt, 1984).

This theory argue that competing companies have different resources and that the main focus is on what the company can do with these resources (Davidsson and Wiklund, 2006). Wernerfelt (1984) defines resources as anything which can provide the company with a strength or weakness, while Barney and Arikan (2001) define them as tangible and intangible assets which are used by the company to create and implement strategies.

Resources are a source of competitive advantage and have a major influence in firm's performance (Hoopes et al., 2003). A company can have different types of resources, including tangible such as finance and physical capital and intangible such as human capital (Barney and Arikan, 2001). Riley and Robinson (2011) and Dal Borgo et al (2013) consider that intangible resources are vital to many knowledge-based companies and that because of the rise of the knowledge-based economies these resources are determinants for companies to achieve and sustain growth.

During economic recessions, companies face low demand, uncertainty about future market opportunities and financial constraints which lead to decrease the amount of resources available. Under these conditions most companies are forced to reduce their investments in innovation.

2.2.3. Teece's dynamic capability approach

According to Teece et al. (1997), dynamic capability is the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. The basic assumption of this framework is that core competencies should be used to modify short-term competitive positions in order to build longer-term competitive advantage (Helfat et al., 2007). Companies and their employees need to be able to learn quickly and to build and integrate within the company new strategic assets such as capability, technology, and customer feedback (Teece et al., 1997). Teece et al. (1997) argue that what matters for business is corporate agility: the capacity to sense and shape opportunities and threats, seize opportunities, and maintain competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the firms' intangible and tangible assets.

According to this approach, economic downturns can constitute an opportunity reframe firms' internal and external innovation processes in order to address the new reality of the markets and get competitive advantage.

2.3. Synthetizing the theoretical approaches: crisis and innovation performance

Both the RBV and Penrose theories focus on resources (Penrose, 1959; Wernerfelt, 1984) and an analysis of both perspectives highlight that the resources they focus upon includes management, products, knowledge and finance. Both approaches argue that resources are distributed heterogeneously amongst companies (Penrose, 1959; Hoopes et al., 2003) and that resources can be used differently to create different products and services. Resources are not enough by themselves to enable company growth and managers should deploy resources while developing new ones (Penrose, 1959).

In times of crisis or economic downturns companies face financial constraints. Wunsch-Vincent and Guellec (2009) show these constraints are the main factor explaining the decline in Business Research and Development Expenditure (BERD). Specifically, cash flows decrease and creditors and investors became more risk-averse.

Indeed, an economic crisis is often associated with high levels of environmental uncertainty and significant downward shifts in demand levels in many sectors, which force some companies to reduce their production or go bankrupt (Cerrato et al., 2016; Ignatov, 2018). Under

such economic conditions, it can be argued that investments in R&D activities become increasingly risky for companies due to uncertainties in the commercialization of new products and services and the fact that they could fail to bring sufficiently high payoffs to recover production costs (Cruz-Castro and Sanz-Menéndez, 2016; Fernandes and Paunov, 2015)

Most investments in knowledge are irreversible, compared to tangible assets. Thus, higher uncertainty about the future reduces incentives for risk-adverse investors (Filippetti and Archibugi, 2011). Increased risks and high distrust among investors reduced investment opportunities and external sources of funding such as long-term credits, equity and debt issuing became quite expensive, leading to the consequent cutting of long-term R&D programs (Ignatov, 2018).

Moreover, financial crisis tends to difficult the access by companies to the financial markets. Thus, many companies are obliged to change their businesses strategies and/or use their available and unused resources more efficiently (Archibugi et al., 2013). Regarding innovation strategies, some companies are forced to postpone ongoing R&D and innovation projects (Cincera et al., 2012; Filippetti and Archibugi, 2011; Paunov, 2012). According to OECD (2012), the 2008 crisis had a strong negative influence on innovations worldwide with companies stopping or reducing their R&D projects.

In line with innovation-based approaches, although some companies react to a short- or medium- term adverse macroeconomic environment by downsizing expenditures, including expenditures on investment and innovation, economic crises may provide an opportunity for companies to restructure productive facilities and to explore new opportunities (Archibugi et al., 2013; Teplykh, 2018).

It is a fact that the 2008-09 crisis, in spite of its financial origins, led to a strong and permanent structural shifts in economies, deconstructing old business models and forcing the implementation of new schemes of functioning (Filippetti and Archibugi, 2011). In an environment of heightened competition, innovations may enhance market position and reduce the risk of bankruptcy (Sidorkin and Srholec, 2014; Fernandes and Paunov, 2015), which may motivate companies to spend more on R&D and innovation related expenditures. Consequently, financial position, size and age appeared to enhance the importance of R&D activity in the post-crisis time (Teplykh, 2018).

Wernerfelt (1984), Penrose (1959), and Teece et al. (1997) established that the growth and decisions of investment in assets by companies are dependent on their (dynamic) resources.

In times of crisis, companies tend to see their resources bases shrinking. Thus, it is expected that economic crisis reduces companies' investments in innovation. However, the new economic cycle that follows a recession inevitably brings structural changes in the composition of output and demand (Archibugi et al., 2013b). Thus, in order to reap the opportunities of the new cycle, successful companies need to be prepared by providing new and improved goods and services (Teplykh, 2018). As such, and according to Teplykh (2018), companies tend to make radical changes when they encounter a crisis, with their management teams rethinking economic strategies and reassessing how to allocate money to their operations.

In this context, economic downturns can be seen has an opportunity for companies to invest and gain competitive advantage in the future economic growth periods (Schumpeter, 1942; Teplykh, 2018).

Based on the above, and more in line with innovation-based approaches, we conjecture that

H1: Economic crisis fosters companies' innovation performance.

Additionally, in times of crisis companies are likely to adopt more open innovation strategies, by taking advantage of R&D collaboration/ alliances with multiple partners, in order to create and develop new products and processes (Chesbrough and Garman, 2009). Even though the fact that the choice of each type of partner depends on the strategy and resources of the firms, it has been found that having multiple types of partners has a positive relation with innovation performance (Becker and Dietz, 2004; Nieto and Santamaría, 2007).

R&D collaborations with both suppliers and clients can provide vital information on technologies, markets, and user's needs (Zeng et al., 2010). Nieto and Santamaría (2007) stated that R&D collaborations with institutions usually involve low risk of knowledge leakage and it has increasingly become a crucial means to access to new scientific, basic and precompetitive knowledge.

Companies that rely on multiple types of cooperation partners increase their capacities to create innovative products (D'Agostino and Moreno, 2018). However, in time of economic turmoil, companies might avoid having a broad network of partners, since too much openness could become costly and inefficient for the company (Laursen and Salter, 2006). Indeed, it has been observed that companies which innovate mainly through collaboration with others tend to have fewer variety of partners because some benefits arise from focusing on a

single type of partner, such as the development of certain routines that facilitate knowledge exchange (Belderbos et al., 2015).

But, the benefits of relying on a variety of sources could be higher than the ones from having a single type of partner, especially during a crisis because a higher diversity of external knowledge increases the chances to find channels allowing companies to broaden the pool of technological opportunities (Belderbos et al., 2015). Thus, in periods of economic downturns, using a wide range of external actors may allow companies to have a large variety of experiences with multiple partners that in some cases can be living the crisis differently, allowing for wider knowledge than collaboration with only one type of partner (D'Agostino and Moreno, 2018).

So, the diversity in the type of partners is associated to innovation performance more intensively during economic crises. In addition, if these partners are international, the combination of organizational and geographical diversity should reinforce the relations with innovation performance (D'Agostino and Moreno, 2018). More specifically, collaboration with Universities and R&D Institutions may motivate the creation of radical innovations by providing a very important source of state-of-the-art, technological knowledge (Belderbos et al., 2015). Such collaboration can lead to the development of new applications of already existing technology and/or of radically new technology (Archibugi and Coco, 2004). Engaging in university/R&D institutions collaboration can be attractive for companies since it allows inexpensive and low-risk access to specialist knowledge (Woerter, 2012), which can be very importance since in times of financial constraints, the amount of resources within the companies decreases.

Taking the above arguments into account, we conjecture that

H2: During periods of economic crisis, companies that rely more extensively on open innovation related strategies tend to outperform the other companies in terms of non-radical and/or radical innovation.

H2a: Companies that attribute higher importance to science-based external knowledge sources, such as Universities and R&D Institutions, tend to outperform their counterparts in terms of radical innovation, particularly during periods of crisis.

H2b: Companies that attribute higher importance to market-based external knowledge sources, such as clients, suppliers and competitors, tend to outperform their counterparts in terms of (non-radical and radical) innovation, particularly during periods of crisis.

H2c: Companies that rely more on external R&D activities tend to outperform their counterparts in terms of (non-radical and radical) innovation, particularly during periods of crisis.

Beside the macroeconomic context and the open innovation strategies, the innovative capacity and innovation performance depend on a wide range of factors (D'Agostino and Moreno, 2018). Innovation is associated with organizational and structural determinants, such as size, capital intensity, export capacity, ownership and technical knowledge, but also the determinants of the environment such as competition and concentration of firms, technological opportunities, and demand growth, and finally, context determinants, related to the type of industry, the degree of innovation in the sector, the stage of development of products and company life cycle (Hasan and Tucci, 2010)

Figure 1 illustrates and summarizes our main hypotheses and considers that the innovative performance of companies in periods of economic downturns, is linked to the capacity to absorb knowledge and its openness dimension, which includes tendency of companies to cooperate with external entities.

The ability to absorb and apply new knowledge is crucial to the innovative capacity of companies (D'Agostino and Moreno, 2018). Cohen and Levinthal (1990) concept of 'absorptive capacity' emphasize the relevance of developing a company's knowledge base, through in-house R&D and innovation activities, in order to understand and benefit from the technological progresses that are realized in their external environment. For example, the degree of qualification of the staff, internal R&D, training activities and acquisition of machinery, equipment and software.

In-house R&D and innovative activities contribute to the ability to recognize the value of external information and knowledge, and must of all, to absorb, explore and apply it internally (Escribano et al., 2009).

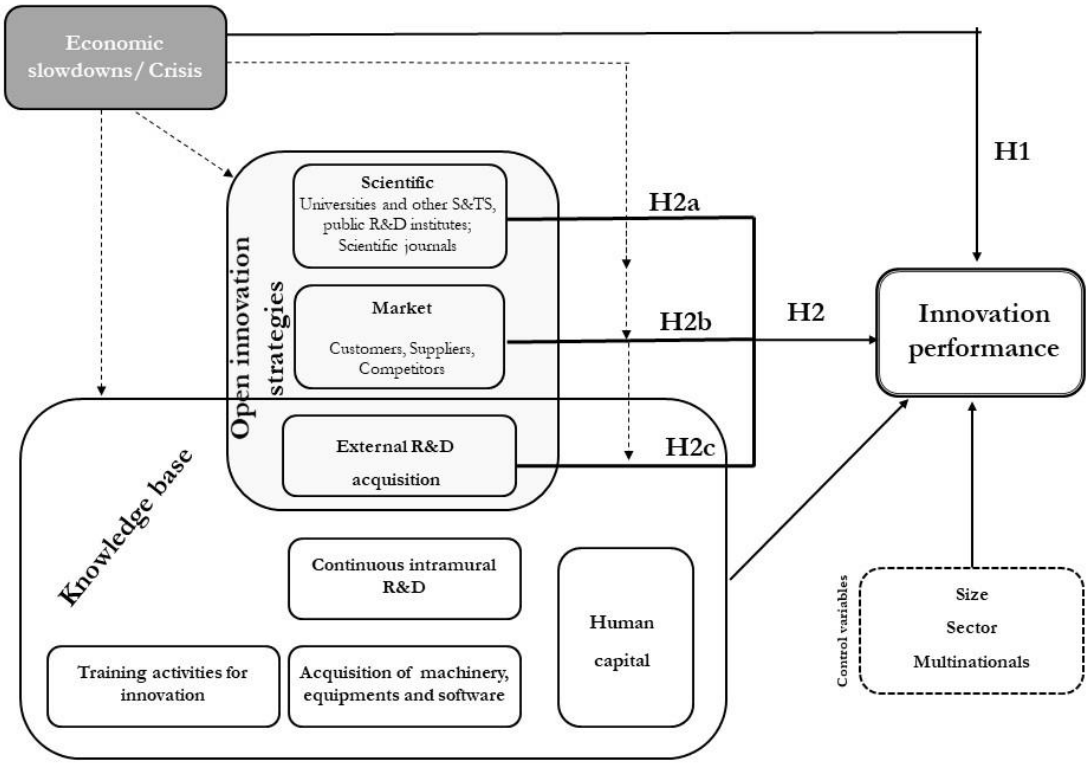

Figure 1: Theoretical framework

Source: Own elaboration.

2.4. Empirical evidence of the impact of crisis on firms' innovative performance

The empirical assessment on how economic crisis affect the distinct open innovation strategies (e.g., higher reliance on scientific related sources, such as universities, versus higher reliance on market related sources, such as clients or suppliers) of companies and the influence on their innovation performance is a rather overlooked issue. Notwithstanding, some evidence exist on how economic crisis have impacted companies' innovative efforts / capabilities in different context, namely moderate innovators countries (Spain - D'Agostino and Moreno, 2018; Zouaghi, Sánchez, and Martínez, 2018), strong innovators (France and Germamny – Teplykh, 2018), and innovation leaders (UK – Archibugi et al., 2013a; Teplykh, 2018). Two other studies - Archibugi et al. (2013b) and Cincera et al. (2012) – involve the analysis of companies located in a wider set of European countries. Table 1 summarises this empirical evidence.

Focusing on the case of companies located in a moderate innovator country, Spain, both D'Agostino and Moreno (2018) and Zouaghi et al. (2018) explored, the impact of the crisis on two groups of 'sectors': manufacturing and services companies (D'Agostino and Moreno, 2018) and low vs high tech industries (Zouaghi et al., 2018).

Specifically, D'Agostino and Moreno (2018), using data from 5955 manufacturing and services firms, explored the relation between cooperation in innovation activities and innovation before and during the last economic recession. The authors concluded that, in general, companies were less willing to invest in innovation during the recent economic recession. However, they also observe that cooperation in innovation activities were successfully associated to innovation performance, as part of companies' strategy aiming at accessing knowledge they did not have. Zouaghi et al. (2018) studied the role of internal and external knowledge capabilities as dynamic capabilities to overcome adverse economic conditions. The authors focused their study on the impact of the financial crisis in high and low-tech industries. To do so, they used a sample of 13507 observations for high tech industry and 15404 for low tech industries. This study also concluded that the crisis had a negative impact on companies' innovative performance, observed by the overall decrease in sales from innovations. Zouaghi et al. (2018) stated that in order to mitigate the effects of the financial crisis companies should maintain strong internal and external knowledge capabilities, such as qualified human capital assets, high investment in R&D (in the case of high tech industries) and resort to external knowledge sources to offset their internal resource constraints, with suppliers being the most important source of innovation and knowledge (in the case of low tech industries).

Focusing on a very different context, that on a leader of innovation, the UK, Archibugi et al. (2013a) analysed 2500 UK companies from different sectors.

The first significant conclusion of this study is that the 2008 economic crisis has substantially reduced the innovation expenditure of the companies. On average, companies reduced innovation expenditure in 2008 by 8 percent compared to 2006. The second conclusion is that innovation expenditure started to be more concentrated: fewer companies were responsible for an increased share of innovation expenditure. The authors also found evidence that during economic crisis the sources of perseverance in innovation are the existence of an R&D department which suggests that companies have made a medium or long-term commitment

to innovation and, the important contribution of following an explorative strategy, that is, of exploring new markets and new product developments.

Addressing also the case of the UK but combining it with the analysis of two strong innovator countries (France and Germany), Teplykh (2018) investigated how the recent crisis of 2008 changed significantly the behaviour of 420 listed manufacturing companies from the three countries. Teplykh (2018) found significant shifts in many aspects of innovative behaviour, especially in R&D and knowledge creation processes. Overall, the 2008 economic crisis led to strong changes in most aspects of the innovation process. The new economic reality, the decline in market demand, economic uncertainty and appearance of new entrants led to faster market dynamics and strengthened competition for existing companies. A harsher environment made companies more rational and exploiting their own resources (human capital, physical assets, innovations, processes) with higher efficiency. Companies with a good resource base and a better ability to generate knowledge retain incentives for R&D in the current, more competitive environment, whereas such investment became unattractive for less-capable companies and those with low resource potential. The author also observed that some companies were discriminated against following the crisis. Smaller companies are on average more innovative, but after the crisis and with increased uncertainty they became reluctant to initiate new risky projects.

Finally, focusing on a wider set of European countries, Archibugi et al. (2013b) and Cincera et al. (2012) scrutinized the impact of the crisis, respectively on 200 multisector companies and 1000 companies from 39 different sectors. Archibugi et al. (2013b) found that the crisis has substantially reduced the number of companies willing to increase their innovation investment, from 38% to 9%; in other words, during the crisis only 9% of companies are still expanding their investment in innovation. Before the economic downturn, companies expanding their investment in innovations were well-established, engaged in formal research activities both internal and external and involved in collaboration with suppliers and customers. During the economic downturn the few companies that were increasing their investment in innovations were smaller than before, collaborating with other businesses, exploring new market opportunities, using methods of technological appropriation and less likely to compete on costs. Due to greater uncertainty companies face they exhibit a more explorative attitude, vis-à-vis an exploitative attitude. R&D and technological opportunities stop to play a significant role in explaining companies' willingness to expand innovation because of the

decline of technological opportunities in established sectors. Archibugi et al. (2013b) also stated that the most important characteristics of innovative companies are no longer size or internal R&D but flexibility, collaborative partnerships, and exploration of new markets.

Overall, and in line with other studies, during economic crisis, Cincera et al. (2012) evidence that a large number of companies have reduced their R&D budgets. Hence, in terms of the relationship between the business cycle and R&D investment, a pro-cyclical response to the crisis seems to be predominant over a more counter-cyclical. The authors also found out that companies with high profitability in 2008 were those that increase their R&D activities the most which suggests that when not under financial constraints (i.e. high profitability provides cash to maintain or increase R&D expenditure) companies increase R&D expenditures.

Table 1: Summarizing the empirical studies on the impact of crisis in companies' innovation efforts and performance

Author(s)	Country	Period	Methodology	Dependent variable	Proxy for the dependent variable	Data Source	Independent variable	Proxy/ Measure for independent variables	
Zouaghi. Sánchez & García Martínez (2018)	Spain	2006 – 2013	Tobit model	Radical and incremental innovative performance	Percentage of the firm's total sales from innovations	Spanish Technological Innovation Panel (PITEC)	R&D intensity	Ratio of expenditure by a firm on R&D to the firm's total sales	+++ (1%)
							R&D human capital	Percentage of highly skilled R&D workers	+++ (1%)
							Collaboration breadth	Constructed as the combination of ten sources of knowledge for innovation:	+++ (1%)
							Collaboration depth	The intensity of collaboration with each partner type	+(10%)
D'Agostino & Moreno (2018)	Spain	2004 - 2013	Wooldridge's (1995) consistent estimator and Linear regression (OLS)	Innovation performance	Share of sales of new products (new to company)	Spanish Technological Innovation Panel (PITEC)	Cooperation	Dummy variable assuming value 1 when the company declares to have undertaken innovative activities with other entities and 0 otherwise.	+++ (1%)
					Share of sales of new products (new to the market)		In-house R&D intensity	Share of internal R&D expenditures over total sales	+++ (1%)
							Openness		0
Archibugi. Filippetti & Frenz (2013)	27 EU member states. plus Norway and Switzerland	2006 - 2010	Logistic regression model and a multinomial logistic regression model	Innovative Related Investment	Innovation related investment incorporates expenditures on in -house R&D and technology	Innobarometer Survey 2009	Type of knowledge sources	All independent variables are dummy variables coded 1 if a characteristic is met or 0 otherwise	+(10%)
							Type of innovations		+++ (1%)
							Characteristics of the innovating firms		+(10%)
							Market characteristics		0
Filippetti & Archibugi (2011)	European Union	2006-2009	Multiplicative interaction model	Innovative Behaviour	Reflects a change in the behavior of the firm related to its innovation investment as a response to the crisis vis-à-vis the period before the crisis.	Innobarometer 2009 and the European Innovation Scoreboard 2008	Stock of Knowledge;	Business R&D expenditures (% GDP)	0
							Quality of human capital;	S&E and SSH graduates	++ (5%)
							The depth of the financial and credit system	Private Capital	– – – (1%)
							The specialization of the country	Employment in medium-high and high-tech manufacturing	– – – (1%)
Teplykh (2018)	U.K.. Germany and France	2004-2012	Quantitative – Random effect probit	Innovative Activity		Amadeus. Thompson. Bloomberg. Orbis. Eurostat	*R&D Intensity*	Stock of expenditures	+++ (1%)
							R&D doing	Dummy variable for actual investment	++ (5%)
							Awards	Creation of revolutionary products	+ (10%)
							Patent Intensity	Protection of recently generated knowledge	+++ (1%)

Source: Own elaboration.

3. Methodology

3.1. Main hypotheses method of analysis and econometric specification

The present dissertation aims to improve our knowledge about how the economic slowdowns affect companies' innovative performance and, more specifically, their open innovation (OI) strategies by studying how the impact of the importance attributed to external sources of knowledge (e.g., universities, clients, suppliers) and the acquisition of external R&D on their innovation propensity changed over the business cycle, namely comparing those impacts in three distinct time periods: 1) 'before the crisis', covering the firms' innovation strategies between 2006 and 2010; 2) 'during the crisis', which comprise firms' innovation strategies between 2010 and 2014; and 3) 'after the crisis', covering the most recent available period, 2014-2016.

According to the literature review (Section 2), two main hypotheses are to be tested:

H1: Economic crisis fosters companies' innovation performance.

H2: During periods of economic crisis, companies that rely more extensively on open innovation related strategies tend to outperform the other companies in terms of non-radical and/or radical innovation.

H2a: Companies that attribute higher importance to science-based external knowledge sources, such as Universities and R&D Institutions, tend to outperform their counterparts in terms of radical innovation, particularly during periods of crisis.

H2b: Companies that attribute higher importance to market-based external knowledge sources, such as clients, suppliers and competitors, tend to outperform their counterparts in terms of (non-radical and radical) innovation, particularly during periods of crisis.

H2c: Companies that rely more on external R&D activities tend to outperform their counterparts in terms of (non-radical and radical) innovation, particularly during periods of crisis.

The extant empirical literature (surveyed in Section 2.4), which have analysed the impact of crisis on firms' innovation performance has resorted to quantitative methods (see Table 1), most notably Tobit models (Zouaghi et al., 2018), Wooldridge's consistent estimator and linear regression (OLS) (D'Agostino and Moreno, 2018; Archibugi et al., 2013a), and random effect probit (Teplykh 2018). The studies use different econometric methods mostly due to

the nature of their data and *proxy* for the dependent variable. The studies that have as dependent variable a binary measure - to innovate or to not innovate - resort to probit or logistic models (Zouaghi et al., 2018, Teplykh 2018).

Given that our dependent variable's proxy is also binary, and we have a panel of data, we opted for logistic panel econometric estimation techniques.

The econometric specification, estimated for 3 CIS waves, associated to our main hypotheses is:

$$Innov\_Perf_{it} = \beta_1 + \beta_2 Science_{it} + \beta_3 Market_{it} + \beta_4 RD\_Ext_{it} + \beta_5 Train_{it} + \beta_6 Mach_{it} + +\beta_7 CRD\_Int_{it} + \beta_8 HC_{it} + \beta_9 \mathbb{X}_{it} + \mu_{it}$$

where

i represents the company;

t represent the period: 1) 'before the crisis', covering the firms' innovation strategies between 2006 and 2010 (CIS08 and CIS10); 2) 'during the crisis', which comprise firms' innovation strategies between 2010 and 2014 (which and the CIS12 and CI14); and 3) 'after the crisis', covering the most recent available period, 2014-2016 (CIS16);

Innov_Perf represents the innovative technological performance (dummy: company innovates in terms of product and process (1) or company does not innovate (0);

Science represents a measure for the importance attributed to scientific sources (Universities and R&D institutes);

Market represents a measure for the importance attributed to market sources (Customers, Suppliers and Competitors);

RD_Ext represents a measure for external R&D acquisition;

Train represents a measure for training activities for innovation;

Mach represents a measure for acquisition of machinery, equipment and software;

RD_Int represents a measure for continuous intramural R&D;

HC represents a measure for human capital;

$\mathbb{X}$ represents the vector of control variable, which includes companies' size, sector and whether the company belongs to a multinational or not;

$\boldsymbol{\mu}$ is the error term.

3.2. Data source and variable proxies

To reach the objectives of the present study and test the corresponding hypotheses, we resort to secondary data, supplied by the Community Innovation Survey (CIS) for Portugal. In particular, we created a new database that including five CIS, CIS08, CIS10, CIS12, CIS14 and CIS16, which cover innovation activities of companies in the periods 2006-2008, 2008-2010, 2010-2012, 2012-2014, and 2014-2016, respectively. These were recoded into 3 main periods: 1) 'before the crisis', encompassing companies' innovation strategies from 2006 to 2010 (that is, CIS08 and CI10); 2) during the crisis', from 2010 to 2014 (CIS12 and CIS14); and 3) 'after the crisis', targeting the most recently available information, from 2014 to 2016 (CIS16).

Each CIS encompasses, on average, around 6600 companies with 10 or more employees which operate in a myriad of activities. The study of innovation strategies of the companies involved over the ten-year period (2006 to 2016) required that we retained for analysis the companies that were present in all the CIS. Thus, the five CIS databases were merged yielding to a balanced panel with 920 companies and 5 periods (corresponding to the five CIS waves).

Our dependent variable is innovative technological performance (to have innovated in the relevant period in terms of product and process), including non-radical (new to the company) and radical (new to the market) technological innovation.

Economic literature on innovation has struggled with the measurement of the innovative performance of companies. As measures of innovation performance, we considered whether the company had introduced new non-radical (new to the company) and radical (new to the market) product/services or processes over the period in analysis. These measures were also used by Zouaghi et al. (2018), whereas D'Agostino and Moreno (2018) used a similar one, the percentage of sales due to new or significantly improved products that constitute a novelty for the firm (new incrementally innovative products) or to the market (new radically innovative products). Archibugi et al. (2013a) and Teplykh (2018) used two very different measures, innovation related investment and per capita business R&D expenditure, respectively. We disregard these latter as proxies for the dependent variables because they do not refer to output, but they are rather input measures of the innovative effort. As such, in our estimations they are part of the 'absorptive capacity' proxy.

Our core independent variables are the importance attributed by companies to external sources of knowledge, namely Scientific Sources, Market Sources, the acquisition of external

R&D activities, and the absorptive capacity dimensions of the companies, namely their investment in training activities for innovation, acquisition of machinery, equipment and software, continuous intramural R&D, and human capital endowments.

Based on the relevant literature in the field of innovation studies, most notably, Zouaghi et al. (2018), D'Agostino and Moreno, (2018) and Ignatov (2018), we compute the proxies for such variables based on the responses to the questions put forward in the Community Innovation Survey (see Table 2).

Scientific (market) sources are measured as dummy variables in which the value 1 exemplifies the case when companies attribute high importance to scientific (market) sources for the undertaking of their innovation efforts.

External R&D acquisition is measured by a dummy variable which assumes the value 1 when, in the relevant period, the company acquired external R&D services.

Excluding human capital, all the absorptive capacity related variables are measured as dummy-variables. Continuous intramural R&D assumes value 1 (and 0 otherwise) when the company has developed indigenous R&D activities aimed at creating new knowledge or to solve any technical/scientific problem. Training activities for innovation is also a dummy variable which measures whether the company undertook activities targeting the improvement of staff skills specifically to develop new products and processes. Acquisition of machinery, equipment and software assumes value 1 (and 0 otherwise) when the company has acquired advanced machinery, equipment, software or buildings to be used in the development of product or processes. In what concerns human capital, the original metrics (see Table 2) consists in 7 categories of the percentage of employees with tertiary degree: 1) 0%; 2) 1% to less than 5%; 3) 5% to less than 10%; 4) 10% to less than 25%; 5) 25% to less than 50%; 6) 50% to less than 75%; and 7) 75% or more. Based on these categories we compute two alternative proxies: 1) the natural logarithm of the categories listed; 2) dummies to 3 main categories, low HC intensity (including categories 1 to 4); medium HC intensity (including categories 5-6); and high HC intensity (including category 7).

The control variables include size of the company (small, medium and large), sector of activity (Extractive, Manufacturing, Construction & Utilities, Knowledge Intensive Services (KIBS), and Other Services), and Multinationality (assuming value 1 when the company belongs to a group with foreign headquarters).

Table 2: Proxies of the relevant variables

		Variable	Questions*	Proxy
Dependent variable		**Innov_Perf** – Innovative Performance	2.1 (3.1) – During the period, did the company introduced any innovations of product or services or process … **new to the company**)?	*Dummy* variable - 1 when in the period in analysis the company introduced **new to the company (non-radical)** product/services or process innovation (0 otherwise).
			2.3 –… **new to the market**	*Dummy* variable assuming value 1 when in the period in analysis the the company introduced a **new to the market (radical)** product/services or process (0 otherwise).
Independent variables	OI startegies	**Science** - Scientific sources (Universities and R&D institutes)	7.1 – What is the importance **of scientific sources of knowledge** for the innovative activities of the company?	*Dummy* variable - 1 when the company attributed **high importance to scientific sources of knowledge** and 0 otherwise.
		Market - Market Sources (Customers, Suppliers and Competitors)	7.1 – What is the importance **of market sources of knowledg**e for the innovative activities of the company?	*Dummy* variable - 1 when the company attributed **high importance to market sources of knowledge** and 0 otherwise.
		RD_Ext - External R&D acquisition	5.1 – During the relevant period, did the company **hire or buy any R&D service to other companies or other public or private organizations?**	*Dummy* variable - 1 when the company **hire or buy any R&D service to other companies or other public or private organizations** (0 otherwise).
	Absorptive capacity	**Train** - Training activities for innovation	5.1 – During the period, did the company **improve their staff skills specifically to develop new products and processes**?	*Dummy* variable - 1 when the company **improve their staff skills specifically to develop new products and processes** (0 otherwise).
		Mach - Acquisition of machinery, equipment and software;	5.1 – During the period, did the company **acquire advanced machinery, equipment, software or buildings to be used in the development of product or processes?**	*Dummy* variable - 1 when the company **acquire advanced machinery, equipment, software or buildings to be used in the development of product or processes** (0 otherwise).
		RD_Int - Continuous intramural R&D	5.1 – During the period, did the company **develop any R&D to create new knowledge or to solve any technical/scientific problem?**	*Dummy* variable - 1 when the company **develop any R&D to create new knowledge or to solve any technical/scientific problem** (0 otherwise).
		HC - Human capital	17.4 – Percentage of employees with tertiary degree with 7 alternative categories: 1- 0%; 2 - 1% to less than 5%; 3 - 5% to less than 10%; 4 - 10% to less than 25%; 5 - 25% to less than 50%; 6 - 50% to less than 75%; 7 - 75% or more	We considered two alternative proxies: 1) the natural logarithm of the categories; 2) dummies to 3 main categories, low HC intensity (categories 1-4); medium HC intensity (categories 5-6); high HC intensity (category 7)
Control variables		Size	17.3 – Number of people working for the company	Dummies for three categories: 1) small company (10-49 employees); 2) medium company (50-249 employees); 3) large company (250 + employees).
		Sector	1 - Code of activity (CAE)?	Dummies for five categories: 1) Extractive; 2) Manufacturing; 3) Construction and utilities; 4) KIBS; 5) Other services.
		Multinational	1.1 – Does the company belong to any group of companies whose headquarters is not in Portugal?	*Dummy* variable - 1 when the company belongs to a group whose headquarters is located outside Portugal (0 otherwise).

Note: *All the questions are quoted from the Community Innovation Survey (CIS) for Portugal of 2016.
Source: Own elaboration

4. Empirical results

4.1. Descriptive analysis

The goal of this study is to assess to what extent the 2008/2009 economic and financial crisis affected the impact that open innovation strategies have on companies (non-radical and radical) technological innovation performance of Portuguese companies. Thus, we proceed with an exploratory analysis of the relevant variables considering their time evolution (before, during and after the crisis), detailing within each period how the variables evolved.

For the elaboration of the study it was used a balanced panel constituted by 920 companies. In order to have a rigorous view of how crisis impacted on the relation between OI strategies and innovation performance, we must exclude any bias effect caused by companies' survival propensity. Thus, we could only include in the analysis companies that were in all the five Community Innovation Surveys (CIS) waves.

In each wave, we had an average of 6600 companies (see Table 3), so the sample used in this study is very different in terms of size distribution from the samples corresponding to each wave of the CIS. Specifically, the panel of 920 companies is, as expected, biased towards medium and large companies. In each was, on average, 67.2% of total companies are small while in the panel used in the present study this percentage is only 33.6%. The average weight of medium and large companies in each wave is respectively, 27.2% and 5.6%, while in our panel the corresponding percentages are 45.6% and 20.8%.

Table 3: Number of companies in each CIS wave, by size

	CIS2008 (2006-2008)	CIS2010 (2008-2010)	CIS2012 (2010-2012)	CIS2014 (2012-2014)	CIS2016 (2014-2016)	Balanced panel
Small	69.9%	67.0%	67.4%	65.5%	66.0%	33.6 %
Medium	25.1%	28.4%	27.1%	28.3%	27.3%	45.6 %
Large	5.0%	4.6%	5.6%	6.2%	6.7%	20.8%
Nº of firms	6593	6160	6775	6775	6775	920

Source: Own elaboration

Restricting the exploratory analysis to the panel of 920 companies (see Table 4), we observe that, for the entire period, 2006-2016, 66.5% of companies are non-radical technological innovators, and that the percentage of companies that radical innovators is 30.8%. However, these two variables did not evolve in the same way during the crisis. The percentage of companies that are non-radical technological innovators grew over the ten-year period, whereas

radical innovators remained relatively constant (30%) before and during the crisis, observing an increase of 4 percentage points from the period 'during crisis' to the most recent period ('after crisis').

Thus, hypothesis H1 ("*Economic crisis fosters companies' innovation performance*") can only be partially validated in the sense that non-radical technological innovation increased during crisis (and kept increasing after crisis) but radical technological innovation was only spurt after crisis, observing a very slight decrease in the crisis period.

According to Blanchard and Portugal (2017), Portugal lived two distinct periods before the financial crisis of 2008: the boom of the 1990s, when there was high expectations that the participation in the euro would lead Portugal to a faster convergence with other European countries and higher growth which, together with very low and decreasing interest rates, led consumers to borrow increasing amounts of money. In this period, Portugal faced high demand which combined with strong imports and decrease in competitiveness, led to a deterioration of the current account balance. In 2001 the Portuguese economy was operating below potential. From 2002 to 2007, Portugal faced a period of total divergence from the European Union, with high unemployment rates, low growth rates and high levels of private and public debts. From the work of Blanchard and Portugal (2017), we can conclude that by 2006 Portugal was already facing an economic crisis and companies were facing restrictions and problems. This may explain why the number of companies doing innovative activities almost did not change in the periods we categorise as 'before' and 'after' the crisis. From 2014 onwards Portugal started recovering economically, although this recovery is still timid (Blanchard and Portugal, 2017). The unemployment has decreased, competitiveness and productivity have improved, but both private and public debt remain high, the economy is still far below potential and so the recovery remains fragile (Blanchard and Portugal, 2017). This short economic improvement may justify our results regarding the number of companies that innovate. In the period after the crisis (2014-2016), the percentage of companies that are non-radical and radical technological innovators is, respectively, 71.7 % and 33.8 %.

Thus, the theoretical approaches that emphasizes recourses might be more aligned with the Portuguese evidence than the Schumpeterian perspective, which emphasizes the issue of opportunity. Schumpeterian thesis might be adequate for a context of economic crisis, where economy as a whole is facing a downfall in aggregate demand but financial system is functional. The 2008 crisis is characterised by a financial turmoil, which restricted credit severely,

especially for small and medium companies located in countries like Portugal facing sovereign debt crisis.

Regarding the variables Open Innovation (OI) strategies, namely the importance attributed to external sources of information for innovation, science and market related, and external R&D acquisitions, and considering the whole period, only 19% (25%) of companies consider the scientific (market) sources of great importance in their innovative process, with about one third stating to have acquired external R&D services from other organisations, namely R&D institutions.

Table 4: Proportion of companies that are/consider/perform … by period

				Whole period (2006-2016)	Before Crisis (2006-2010)	During Crisis (2010-2014)	After Crisis (2014-2016)
Dependent variable	Innovation performance	Non radical technological innovators		0.665	0.646	0.657	0.717
		Radical technological innovators		0.308	0.303	0.299	0.338
Core independent variables	OI strategies	Scientific sources (Universities and R&D institutes) very important		0.190	0.180	0.197	0.195
		Market Sources (Customers. Suppliers and Competitors) very important		0.255	0.223	0.245	0.337
		External R&D acquisition		0.329	0.304	0.334	0.368
	Absorptive capacity	Continuous intramural R&D		0.421	0.392	0.426	0.467
		Training activities for innovation		0.412	0.367	0.415	0.496
		Acquisition of machinery, equipment and software		0.468	0.424	0.458	0.576
		Human Capital	Medium	0.437	0.433	0.430	0.460
			High	0.116	0.133	0.112	0.088
Control variables		Size	Medium	0.462	0.465	0.476	0.430
			Large	0.200	0.200	0.193	0.214
		Sector	Extractive	0.012	0.012	0.012	0.012
			Manufacturing	0.545	0.545	0.545	0.545
			Constrution & Utililties	0.147	0.147	0.147	0.147
			Retail & Transportat	0.141	0.141	0.141	0.141
			KIBS	0.155	0.155	0.155	0.155
		Multinational		0.500	0.502	0.502	0.491

Source: Own elaboration

Analysing the different periods (before, during and after the crisis), we observe that, albeit not in a very pronounced manner, the importance companies attributed to scientific and market sources increased during crisis, with the importance attributed to market sources increasing even further, and in a most accentuated manner, after the crisis.

In the case of absorptive capacity related variables - Training activities for innovation, acquisition of machinery, equipment and software, continuous intramural R&D - , we observe distinct patterns. Whereas in terms of human capital intensity, namely the percentage of companies with a very high proportion (75% or more) of tertiary educated employees decreased in the period 'during crisis', all the remaining 'knowledge basis' variables experienced an increase, which was intensified in the period 'after crisis'. Between the two extreme periods (before and after the crisis), the percentage of companies that performed training for innovation increased 13 percentage point (p.p.). The corresponding increase for the acquisition of machinery, equipment and software was 15 p.p., whereas for intramural R&D the increase was 7 p.p..

The structural variables – size, industry, and multinationality – as expected, present similar percentages all over the period with 20% of large companies, 55% operating in Manufacturing and 50% multinationals.

According to the analysis of correlations we can verify (see Table 6), that for both non-radical and radical technological innovation all variables except for the Construction and Utilities activity sector are positively related. In the case of non-radical technological innovation, correlation values are higher, especially those related with absorptive capacity related variables - training, the acquisition of machinery, equipment and software, and continuous intramural R & D.

4.2. Causality analysis

Based on a balanced panel of 920 companies operating in Portugal between 2006 and 2016, we estimated 8 econometric specifications (see Table 6).[1] Two, Models A0 and B0, were estimated for the whole period (2006-2016), resorting to binary logistics models. The remaining specifications were estimated by panel logistic models and respect to non-radical (Models A1-A3) and radical (Models B1-B3) technological innovation 'before crisis' (Models A1 and B1), 'during crisis' (Models A2 and B2), and 'after crisis' (Models A3 and B3).

[1] Table A1, in Annex, presents the same model specifications but considering each CIS wave in isolation that is, encompassing all the surveyed companies in each wave. These results are very similar to the ones obtained with the balanced panel of 920 companies.

Table 5: Descriptive statistics and correlation matrix

Variables			Descriptive Statistics				Correlation matrix														
			Mean	Stand Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dependent		1. Non-radical technological Innovation	0.665	0.472	0	1	1.000														
		2. Radical technological innovation	0.308	0.462	0	1	0.333	1.000													
Core independent	OI strategies	3. Scientific Sources	0.190	0.392	0	1	0.313	0.205	1.000												
		4. Market Sources	0.255	0.436	0	1	0.394	0.241	0.637	1.000											
		5. External R&D acquisition	0.329	0.470	0	1	0.465	0.240	0.421	0.446	1.000										
	Absortive capacity	6. Human Capital	1.183	0.492	0	1.95	0.278	0.124	0.258	0.243	0.274	1.000									
		7. Training activities for innovation	0.412	0.492	0	1	0.562	0.267	0.352	0.387	0.456	0.241	1.000								
		8. Continuous intramural R&D	0.421	0.494	0	1	0.561	0.302	0.466	0.492	0.509	0.307	0.472	1.000							
		9. Acquisition of machinery, equipment and software	0.468	0.499	0	1	0.624	0.241	0.294	0.385	0.444	0.191	0.506	0.439	1.000						
Control	Size	10. Medium	0.462	0.499	0	1	0.132	0.046	0.097	0.077	0.069	0.217	0.086	0.123	0.086	1.000					
		11. High	0.200	0.400	0	1	0.133	0.086	0.135	0.158	0.197	0.099	0.151	0.188	0.156	-0.464	1.000				
	Sector	12. Manufacturing	0.545	0.498	0	1	0.111	0.075	0.051	0.034	0.015	-0.259	0.042	0.132	0.113	0.111	-0.082	1.000			
		13. Constrution and utililities	0.147	0.354	0	1	-0.080	-0.061	0.001	-0.036	-0.042	0.055	-0.043	-0.082	-0.070	-0.085	-0.045	-0.454	1.000		
		14. KIBS	0.155	0.362	0	1	0.027	0.033	0.010	0.029	0.050	0.372	0.043	0.040	-0.032	0.020	0.023	-0.469	-0.178	1.000	
	Multinational	15. Multinational	0.500	0.500	0	1	0.176	0.119	0.189	0.210	0.263	0.391	0.162	0.244	0.148	0.128	0.265	-0.151	-0.008	0.186	1.000

Source: Own elaboration (extracted data from Stata v14 program).

4.2.1 Diagnostic tests and goodness of fit

Before the estimations of the models we performed several diagnosis tests, particularly testing for multicollinearity of the explanatory variables and the heteroscedasticity of the random errors. The Variance Inflation Factors (VIF) coefficients evidence that no signs of serious multicollinearity among the explanatory variables (Mean VIF < 10). Regarding heteroscedasticity, we carry out the Breusch-Pagan/Cook-Weisberg test to check whether the errors terms were homoscedastic. The null hypothesis (H0) underlying this test states that there are constant variances. After the Breusch-Pagan/ Cook-Weisberg test, we reject the null hypothesis for the commonly used levels of significance (i.e. 1%, 5% and 10%) for the 8 estimated models (see Table 6). Since our models show the presence of heteroscedasticity it was necessary to estimate the models with robust standard errors.

In general, the estimated models have a good quality of adjustment as reflected by the Wald test (see Table 6). Looking this test and their respective p-values, we can conclude that the models are globally significant.

4.2.2. Estimation results

Observing the significance and magnitude of the estimates associated to OI strategies related variables by period, we can infer whether H2 ("*For highly (non-radical and radical) innovation performers, economic crisis tends to foster higher reliance on open innovation related strategies"*) is validate by our data or not.

The importance companies attribute to *science* sources of external knowledge fail to distinguish between non-radical/ radical technological innovators from the remaining companies irrespective, in general, of the period. The exception is to the 'After the crisis' period which convey the idea that companies that attribute higher importance to these sources of knowledge tend, on average, to present low non-radical technological innovation (though no significance exists in radical technological innovation). Regarding the *market* sources of external knowledge, data seems to support the hypothesis that for radical technological innovation those companies that attribute more importance to such sources are more likely, all the remaining factors being constant, to innovate radically ('during the crisis', the odds of radical technological innovation is almost $1.8=e^{0.566}$ for companies that praise most highly these type of external knowledge sources – see Model B2 in Table 6).

The above results are reinforced in the case of external R&D acquisitions. Indeed, companies that during the crisis relied more on the acquisition of external R&D services (combining it with continuous internal R&D activities) are much more likely to be radical technological innovators than their remaining counterparts. During the crisis, the estimate of the odds of radical technological innovation for companies that acquire external R&D is 1.5 ($e^{0.400}$) times that of companies that do not acquired this type of services. The corresponding estimate for non-radical technological innovation is 11.3 ($e^{2.428}$), which is similar to the odds observed before the crisis ($14.2=e^{2.654}$), but much higher than the one observed after the crisis ($3.7=e^{1.301}$).

Summing up, panel logistics estimations seem to validate the hypothesis H2c, which convey the idea that *"Companies that rely more on external R&D activities tend to outperform their counterparts in terms of (non-radical and radical) innovation, particularly during periods of crisis."*. In contrasts, the hypothesis H2a, "*Companies that attribute higher importance to science-based external knowledge sources, such as Universities and R&D Institutions, tend to outperform their counter-parts in terms of and radical innovation, particularly during periods of crisis*" is not corroborated. If we considered instead market related sources, results evidence that during periods of crisis companies that attribute higher importance to market external knowledge sources tend to outperform their counterparts in terms of radical but not non-radical innovation. This means that H2b, "*Companies that attribute higher importance to market-based external knowledge sources, such as clients, suppliers and competitors, tend to outperform their counterparts in terms of radical and non-radical innovation, particularly during periods of crisis*", is partially validated as market related sources are critical for radical (though not for non-radical) technological innovation during crisis.

Taking these evidences into account, we contend that H2 – "*During periods of economic crisis, companies that rely more extensively on open innovation related strategies tend to outperform the other companies in terms of non-radical and/or radical innovation*" - is validated by our data.

As stated in the literature, the choice of each type of partner depends on the strategy and resources of the firms, and has been found that having multiple types of partners has a positive relation with innovation performance (Becker and Dietz, 2004; Nieto and Santamaría, 2007), and in this case, and for these sample of companies, the perception of the importance of the collaborations with customers, suppliers and competitors, emerges as critical in times of crisis for radical technological innovation performance.

Our results support the open innovation approach that states that companies use inflows of knowledge to accelerate internal innovation, and the use of outflows of knowledge to expand the markets for external use of innovation (Chesbrough, 2003). (Chesbrough, 2003; Chesbrough and Garman, 2009) also state that inter-organizational alliances are increasingly recognized in the innovation management literature as 'access relationships' that enable partners to acquire non-redundant knowledge and capabilities residing outside their organizational and technological boundaries. (Berg-Jensen et al., 2007). Horizontal alliances are more likely to be strategically motivated to improve long-term product technology development whereas vertical alliances tend to be more concerned with cost reduction (Kotabe, 1990). Collaboration with competitors and the acquisition of knowledge insensitive services, most notably external R&D supplied, in Portugal, mainly by interface institutes and universities, enables firms' rapid market penetration and access to technological abilities that can be difficult, time-consuming, and costly to develop alone within their boundaries (Van Beers and Zand, 2014).

Companies' absorptive capacity is, in general, fundamental for both non-radical and radical technological innovation regardless the period in analysis. However, it is interesting to note that, during crisis, human capital endowments, training, and the acquisition of machinery, equipment and software, are even more critical for radical technological innovation (see Model B2 in Table 6). The impact of continuous intramural R&D activities and the acquisition of machinery, equipment and software on non-radical innovation performance is enhanced during the crisis (Model A2 in Table 6).

Although company size does not seem to influence (both non-radical and radical) technological innovation performance, operating in Manufacturing and KIBS during the time of crisis enhances the odds of radical technological innovation performance.

Table 6: Determinants of non-radical and radical technological innovation - random effects panel logistic estimations

	Group of variables	Description	Non-radical technological (product & process) innovation				Radical technological innovation			
			Whole period	Before the crisis	During the crisis	After the crisis	Whole period	Before the crisis	During the crisis	After the crisis
			2006-2016	2006 - 2010	2010 - 2014	2014-2016	2006-2016	2006 - 2010	2010 - 2014	2014-2016
			Model A0	Model A1	Model A2	Model A3	Model B0	Model B1	Model B2	Model B3
Open innovation strategies	Scientific sources (Universities and R&D institutes)	Dummy variable - 1 when the company attributed high importance to scientific sources of knowledge and 0 otherwise.	**-1.320** (0.559)**	-0.927 (0.851)	-1.258 (1.158)	**-2.135** (0.907)**	0.050 (0.140)	0.072 (0.348)	0.439 (0.268)	-0.265 (0.232)
	Market Sources (Customers. Suppliers and Competitors)	Dummy variable - 1 when the company attributed high importance to market sources of knowledge and 0 otherwise.	**1.668*** (0.453)**	**1.458** (0.738)**	1.672 (1.077)	**2.088*** (0.704)**	**0.362*** (0.124)**	0.082 (0.301)	**0.566** (0.258)**	**0.565*** (0.214)**
	External R&D acquisition	Dummy variable - 1 when the company hire or buy any R&D service to other companies or other public or private organizations (0 otherwise).	**2.563*** (0.367)**	**2.654*** (0.828)**	**2.428*** (0.536)**	**1.301** (0.648)**	**0.264** (0.110)**	0.088 (0.249)	**0.400* (0.227)**	0.218 (0.204)
Absorptive capabilities	Continuous intramural R&D	Dummy variable - 1 when the company develop any R&D to create new knowledge or to solve any technical/scientific problem (0 otherwise).	**2.969*** (0.282)**	**2.787*** (0.778)**	**3.282*** (1.170)**	**1.770*** (0.477)**	**0.669*** (0.113)**	0.418 (0.257)	**1.175*** (0.226)**	**1.181*** (0.210)**
	Human Capital	Percentage of employees with tertiary education by groups (in ln)	**0.485*** (0.151)**	0.037 (0.335)	0.273 (0.252)	0.304 (0.251)	0.039 (0.117)	0.170 (0.247)	**0.441** (0.255)**	-0.296 (0.224)
	Training activities for innovation	Dummy variable - 1 when the company improve their staff skills specifically to develop new products and processes (0 otherwise).	**3.224*** (0.298)**	**3.411*** (1.193)**	**3.227*** (1.075)**	**2.347*** (0.460)**	**0.469*** (0.101)**	**0.464** (0.231)**	**0.901*** (0.208)**	**0.645*** (0.208)**
	Acquisition of machinery. equipment and software;	Dummy variable - 1 when the company acquire advanced machinery. equipment. software or buildings to be used in the development of product or processes (0 otherwise).	**3.775*** (0.258)**	**3.518*** (1.197)**	**3.543*** (1.300)**	**3.314*** (0.377)**	**0.394*** (0.095)**	0.235 (0.224)	**0.662*** (0.202)**	**0.496** (0.206)**
Control variables	Size	Medium	0.207 (0.153)	-0.034 (0.222)	0.195 (0.196)	0.399 (0.250)	-0.036 (0.115)	-0.108 (0.287)	-0.130 (0.224)	0.016 (0.199)
		Large	0.077 (0.225)	-0.205 (0.307)	0.092 (0.312)	0.066 (0.351)	0.010 (0.145)	-0.114 (0.359)	0.338 (0.291)	-0.220 (0.230)
	Sector	Manufacturing	**0.427** (0.189)**	0.230 (0.199)	**0.686** (0.339)**	0.383 (0.251)	**0.419*** (0.119)**	0.097 (0.279)	**1.306*** (0.245)**	**0.513*** (0.191)**
		Construction and Utilities	-0.162 (0.231)							
		KIBS	0.182 (0.241)	0.269 (0.259)	0.125 (0.289)	0.473 (0.362)	0.393** (0.149)	-0.186 (0.389)	**1.285*** (0.308)**	0.430 (0.273)
	Multinational		-0.071 (0.095)	0.104 (0.117)	-0.221 (0.162)	-0.043 (0.123)	**0.147** (0.061)**	0.300* (0.170)	0.100 (0.139)	0.138 (0.088)
		Number of observations	4600	1840	1840	920	4600	1840	1840	920
		Number of companies	920	920	920	920	920	920	920	920
	Diagnosis tests	Breusch-Pagan / Cook-Weisberg test for heteroskedasticity (P-value)	545.88 (0.000)	189.52 (0.000)	190.00 (0.000)	161.11 (0.000)	199.35 (0.000)	17.81 (0.000)	232.53 (0.000)	73.21 (0.000)
		Variance inflation factor mean [max]	1.71 [2.22]	1.60 [1.90]	1.64 [2.09]	1.57 [1.90]	1.60 [1.94]	1.60 [1.90]	1.64 [2.09]	1.57 [1.90]
	Quality of adjustment	Wald test (p-value)	267.72 (0.000)	30.34 (0.003)	27.63 (0.006)	98.37 (0.000)	326.30 (0.000)	33.02 (0.001)	196.41 (0.000)	192.65 (0.000)
		Pseudo R2				0.6122				0.1866
		Robust standard errors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Multicolinearidade	No	No	No	No	No	No	No	No

Notes: Standard errors in parentheses. *** (**) [*] statistically significant at 1% (5%) [10%].

5. Conclusions

The main goal of the present study was to improve scientific empirical knowledge about how the economic slowdowns might affect Portuguese companies' innovative performance. More specifically, how the economic slowdowns impact on companies' open innovation strategies.

Resorting to a quantitative econometric approach (random effect logistics panel model), based on a sample of 920 companies located in Portugal, over a ten-year period (2006-2016), we analyse how the impact of cooperation strategies of companies with external sources of knowledge (e.g., universities, clients, suppliers) and the acquisition of external R&D on their innovation propensity changed over the business cycle. For that, we compared those impacts in three distinct time periods: 1) 'before the crisis', covering the firms' innovation strategies between 2006 and 2010; 2) 'during the crisis', which comprise firms' innovation strategies between 2010 and 2014; and 3) 'after the crisis', covering the most recent available period, 2014-2016.

Three main results were obtained. First, although non-radical technological innovation increased during crisis (and kept increasing after crisis) radical technological innovation was only spurt after crisis, observing a very slight decrease during the crisis period. Second, it was demonstrated that during the period of economic crisis, companies that rely more extensively on OI strategies, most specially related to the importance attributed to market sources of knowledge and R&D collaboration, tended to outperform the other companies in terms of non-radical and/or radical innovation. Third, during the crisis period several dimensions of companies' absorptive capacity. In particular, human capital endowments, training, and the acquisition of machinery, equipment and software, explained companies' higher radical technological innovation, whereas continuous intramural R&D activities and the acquisition of machinery, equipment and software enhanced non-radical innovation performance.

The present dissertation entails two main scientific contributions. First, at the theoretical level, it proposes a comprehensive framework by combining several complementary theoretical approaches - innovation-based approaches (Schumpeterian and open innovation), and the resource and competencies-based approaches (Penrose's theory of the firm, the resource-based view, and Teece's dynamic capability approach) – in order to highlight through which channels economic slowdowns might impact on companies innovation performance. Although several studies (Teplykh, 2018; Filippetti and Archibugi, 2011; Archibugi et al., 2013a;

D'Agostino and Moreno, 2018; Zouaghi et al., 2018), addressed already this endeavour, to the best of our knowledge this is the first attempt to combine all these theoretical approaches to explain the changing of companies' innovation strategies and performance. Second, at the empirical level, albeit some few studies have addressed the impact of economic crisis on companies' collaboration propensity (Martinez et al., 2018; D'Agostino and Moreno, 2018), and reliance on external sources of knowledge (Archibugi et al., 2013), no study had yet addressed how economic crisis mediated impact distinct OI strategies potential have on companies non-radical and radical technological innovation performance.

Our study entails two noticeable policy implications. First, given the relevance of OI strategies in fostering radical technological innovation performance during crisis (and in all periods in the case of non-radical technological innovation performance), during economic slowdowns it is required that public policy support bring OI strategies to the forefront of the programmes. In particular, public policy targeting increases in technological innovation, namely of the radical type, should device holistic programmes that create a solid basis/ encourage companies to combine indigenous R&D efforts with the acquisition of external R&D services from both R&D institutes and universities and similar organisations. Second, regardless the periods, but with much more firmness during crisis periods, public policy programmes have to include financial support and /or fiscal incentives to push companies to invest in absorptive capacity related factors, most notably, human capital, training, internal R&D and acquisition of machinery, equipment and software.

Despite the above-mentioned contributions, the present study entails several limitations that need to be highlighted. First, the study was based on companies located in a moderate innovator country. Albeit our results can be useful to other countries that are also moderate innovators (e.g., Croatia, Cyprus, the Czech Republic, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Slovakia, or Spain), they cannot be extrapolated to other countries, particularly the so-called innovation leaders (e.g., Denmark, Finland, Luxembourg, the Netherlands, Sweden, and the United Kingdom) or strong innovators (e.g., Austria, Belgium, France, Germany, Ireland, and Slovenia). To replicate our study in these latter countries would constitute a challenging and scientific pertinent path of research. Second, the focus of our study was on technological (product and process) innovation. Thus, we neglect other types of innovation such as marketing or organisational innovation. This again would be an interesting and stimulating line for further research.

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Annex

Table A 1: Determinants of non-radical and radical technological innovation – binary logistic estimations

	Group of variables	Description	Technological (product & process) innovation					Radical technological innovation				
			Before the crisis		During the crisis		After the crisis	Before the crisis		During the crisis		After the crisis
			2006 - 2010		2010 - 2014		2014-2016	2006 - 2010		2010 - 2014		2014-2016
			CIS08	CIS10	CIS12	CIS14	CIS16	CIS08	CIS10	CIS12	CIS14	CIS16
OI strategies	Scientific sources (Universities and R&D institutes)	Dummy variable - 1 when the company attributed high importance to scientific sources of knowledge and 0 otherwise.	**-1.777**** **(0.696)**	-0.918 (0.766)	**-1.317*** **(0.678)**	**-1.385***** **(0.453)**	-0.974 (0.690)	-0.012 (0.131)	0.065 (0.141)	0.205 (0.342)	**0.302**** **(0.145)**	**0.247*** **(0.138)**
	Market Sources (Customers. Suppliers and Competitors)	Dummy variable - 1 when the company attributed high importance to market sources of knowledge and 0 otherwise.	**2.101***** **(0.419)**	**2.478***** **(0.633)**	**1.723**** **(0.701)**	**2.606***** **(0.590)**	**1.542***** **(0.494)**	**0.583***** **(0.106)**	**0.765***** **(0.124)**	-0.297 (0.333)	**0.356***** **(0.135)**	**0.394***** **(0.116)**
	External R&D acquisition	Dummy variable - 1 when the company hire or buy any R&D service to other companies or other public or private organizations (0 otherwise).	**1.828***** **(0.358)**	**2.486***** **(0.368)**	**3.549***** **(0.283)**	**3.026***** **(0.266)**	**3.102***** **(0.228)**	**0.261***** **(0.092)**	**0.464***** **(0.099)**	-0.230 (0.205)	**0.345***** **(0.105)**	**0.464***** **(0.086)**
Absorptive capabilities	Human Capital	Percentage of employees with tertiary education by groups (in ln)	**0.183**** **(0.080)**	0.122 (0.082)	**0.331***** **(0.089)**	**0.349***** **(0.079)**	**0.303***** **(0.081)**	**0.232***** **(0.072)**	**0.295***** **(0.088)**	0.183 (0.133)	**0.441***** **(0.086)**	**0.470***** **(0.075)**
	Training activities for innovation	Dummy variable - 1 when the company improve their staff skills specifically to develop new products and processes (0 otherwise).	**3.364***** **(0.207)**	**3.314***** **(0.205)**	**4.377***** **(0.215)**	**3.956***** **(0.206)**	**3.644***** **(0.191)**	**0.665***** **(0.090)**	**0.732***** **(0.098)**	-0.089 (0.175)	**0.842***** **(0.093)**	**0.776***** **(0.078)**
	Continuous intramural R&D	Dummy variable - 1 when the company develop any R&D to create new knowledge or to solve any technical/scientific problem (0 otherwise).	**2.585***** **(0.233)**	**2.772***** **(0.225)**	**3.875***** **(0.213)**	**3.817***** **(0.189)**	**3.357***** **(0.204)**	**1.017***** **(0.089)**	**1.206***** **(0.099)**	0.361* (0.188)	**1.463***** **(0.093)**	**1.127***** **(0.082)**
	Acquisition of machinery. equipment and softwar	Dummy variable - 1 when the company acquire advanced machinery. equipment. software or buildings to be used in the development of product or processes (0 otherwise).	**4.068***** **(0.157)**	**4.161***** **(0.187)**	**4.521***** **(0.177)**	**4.375***** **(0.165)**	**4.006***** **(0.166)**	**0.742***** **(0.090)**	**0.678***** **(0.098)**	-0.254 (0.176)	**0.780***** **(0.091)**	**0.639***** **(0.079)**
Control variables	Size	Medium	-0.016 (0.106)	**0.186*** **(0.112)**	**0.241**** **(0.117)**	0.097 (0.101)	-0.309*** (0.107)	0.063 (0.081)	0.091 (0.091)	**0.721***** **(0.143)**	-0.052 (0.088)	**-0.220***** **(0.082)**
		High	0.054 (0.244)	0.133 (0.259)	**0.433*** **(0.250)**	-0.163 (0.257)	-0.278 (0.261)	-0.064 (0.135)	0.197 (0.149)	**0.981***** **(0.247)**	0.028 (0.165)	-0.212 (0.157)
	Sector	Extractive	0.133 (0.307)	-0.137 (0.237)	-0.067 (0.353)	**-0.713*** **(0.432)**	**-0.640*** **(0.346)**	-0.487 (0.369)	**-0.884*** **(0.534)**	0.214 (0.525)	-0.394 (0.416)	-0.053 (0.356)
		Manufacture	0.099 (0.112)	0.158 (0.105)	0.075 (0.107)	0.105 (0.097)	-0.059 (0.093)	**0.233**** **(0.092)**	**0.451***** **(0.103)**	0.062 (0.150)	0.147 (0.099)	0.056 (0.082)
		Construction and Utilities	**-0.446*** **(0.229)**	**-0.588***** **(0.196)**	**-0.387*** **(0.203)**	**-0.602***** **(0.176)**	-0.236 (0.191)	**-0.555***** **(0.173)**	**-0.439***** **(0.169)**	**-0.861***** **(0.322)**	**-0.603***** **(0.167)**	**-0.522***** **(0.173)**
		KIBS	-0.092 (0.162)	**-0.372*** **(0.158)**	-0.236 (0.150)	**-0.348***** **(0.134)**	**-0.320**** **(0.131)**	0.107 (0.120)	0.147 (0.129)	**-1.598***** **(0.305)**	0.093 (0.124)	**-0.210**** **(0.107)**
	Multinational		**0.136**** **(0.057)**	0.066 (0.093)	0.067 (0.082)	0.083 (0.068)	0.108 (0.072)	**0.083**** **(0.042)**	**0.127**** **(0.062)**	0.104 (0.102)	0.014 (0.062)	0.062 (0.055)
		Number of observations	6593	6160	6775	6775	6775	6593	6160	6775	6775	6775
Diagnosis tests		Breusch-Pagan / Cook-Weisberg test for heteroskedasticity (P-value)	393.35 (0.000)	180.76 (0.000)	0.47 (0.494)	23.90 (0.000)	399.54 (0.000)	1408.79 (0.000)	1720.14 (0.000)	1102.29 (0.000)	2153.78 (0.000)	1023.02 (0.000)
		Variance inflation factor mean [max]	1.54 [2.01]	1.51 [1.87]	1.49 [2.05]	1.40 [1.67]	1.39 [1.69]	1.54 [2.01]	1.51 [1.87]	1.49 [2.05]	1.40 [1.67]	1.39 [1.69]
Quality of adjustment		Wald test (p-value)	739.09 (0.000)	549.78 (0.000)	787.26 (0.000)	929.38 (0.000)	682.93 (0.000)	1456.13 (0.000)	1494.13 (0.000)	88.63 (0.000)	1533.42 (0.000)	1327.97 (0.000)
		Pseudo R2	0.6574	0.6622	0.6942	0.6415	0.5991	0.2244	0.2868	0.0469	0.2724	0.2092
		Robust standard errors	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Multicolinearity	No	No	No	No	No	No	No	No	No	No