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Open innovation and its impact in innovation performance in Portuguese firms

Francisco Seabra Guimarães

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Supervisor: Prof. Miguel Simões Torres Preto

Examination Committee

Chairperson: Prof. Ana Isabel Cerqueira de Sousa Gouveia Carvalho

Supervisor: Prof. Miguel Simões Torres Preto

Member of the Committee: Prof. Tiago Fonseca

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Declaração/Declaration

Declaro que o presente documento é um trabalho original da minha autoria e que cumpre todos os requisitos do Código de Conduta e Boas Práticas da Universidade de Lisboa.

I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

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Abstract

As management practices evolved in the 20th century, businesses realized there was value outside the firm's scope that could be harnessed and used to generate competitive advantages. The freedom of movement of human resources in liberal markets and the ever-increasing number of resources with a higher education meant that knowledge was less confined to a few companies that held all innovation potential to being more obliquus. The practice of looking to the outside environment for resources and incorporate them in a company's own innovation processes is called open innovation.

This work analyzes to what extent are Portuguese firms using open innovation practices and to what extent do these practices improve the firm's innovation performance. The work draws on the data available on the Community Innovation Survey 2016 carried out between 2014 and 2016. A literature review was conducted and allowed to build an econometric model in which performance is measured in two dimensions: the introduction of novelty to the market and the share of sales of these innovations. The regression models are built using a probit and a fractional probit regression to test the hypotheses. Based on the survey, open innovation indicators are built to capture different activities from a breadth and depth perspective. The results show that open innovation practices in Portugal have a significant and positive impact on innovation performance measured as both introduction of novelty and the share of sales of these novelties, and that inbound open innovation activities are much more prevalent that outbound or coupled.

Keywords: Open Innovation; Innovation Breadth and Depth; Open innovation practices; Innovation determinants; CIS

Resumo

Com o evoluir das práticas de gestão no século XX, várias organizações identificaram a existência de valor fora do âmbito da empresa que poderia ser aproveitado para construir vantagens competitivas. A liberdade de circulação de recursos humanos e o maior número de recursos com ensino superior, libertaram o conhecimento de um número reduzido de empresas – que concentravam o potencial inovador - e dispersaram-no. A prática de procurar recursos na envolvente externa da empresa e incorporá-los aos processos de inovação é chamada de inovação aberta.

Este trabalho analisa em que medida estão as empresas portuguesas a recorrer a práticas de inovação aberta e se essas práticas melhoram o seu desempenho de inovação. O trabalho baseia-se nos dados do Inquérito Comunitário à Inovação de 2016, realizado entre 2014 e 2016. Uma revisão da literatura permitiu construir um modelo econométrico no qual o desempenho de inovação é medido em duas dimensões: introdução de inovações no mercado e percentagem de vendas dessas inovações. Os modelos de regressão foram construídos usando uma regressão probit e uma fractional probit para testar as hipóteses. Com base na revisão da literatura, foram criados indicadores de inovação aberta para capturar diferentes atividades de inovação aberta. Os resultados mostram que as práticas de inovação aberta têm um impacto significativo e positivo no desempenho da inovação, medido tanto na introdução de novidades, quanto na participação das vendas dessas inovações, e que as atividades de inovação de fora para dentro são muito mais praticadas do que de dentro para fora ou que a combinação das duas anteriores.

Palavras-chave: Inovação aberta; Amplitude e profundidade da inovação; Atividades de inovação aberta; Determinantes da inovação; CIS

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List of Acronyms

AME	Average Marginal Effects
CIS	Community Innovation Survey
DGEEC	Direcção-Geral de Estatísticas da Educação e Ciência
DUI	Doing, Using, Interacting
ESS	European Social Survey
EU	European Union
FS	Firm Size
GP	Part of A Group
IO	International Orientation
IP	Intellectual Property
LE	Large Enterprises
MLE	Maximum Likelihood Estimation
OECD	Organization for Economic Co-Operation and Development
OI	Open Innovation
OLS	Ordinary Least Squares
R&D	Research and Development
SME	Small and Medium Enterprises
STI	Science, Technology, Innovation

1. Introduction

In this chapter an overview of the context that led to this work will be introduced, focusing on innovation issues and especially on open innovation. This context leads to the exposure of the problem that this work pretends to address and how the document is outlined and structured.

The focus of this study is open innovation and the impact it has on the innovation performance of businesses in Portuguese firms. Open innovation is a set of processes and practices that companies can choose to pursue in their innovation strategy that involve the environment outside the firm's boundaries. It is an alternative (and opposite) strategy to closed innovation where a firm relies solely on its internal resources to generate innovation (Chesbrough & Appleyard, 2007; Enkel et al., 2009; Gassmann & Enkel, 2004; Huizingh, 2011). Companies that began to open up their innovation processes realized that there was relevant knowledge outside the firm's scope and that their capacity to absorb it, integrate it with their traditional R&D in certain cases and the ability to exploit it commercially, could represent big opportunities to generate competitive advantages in the market.

As we will see in the literature review, open innovation is not a new concept, but the study of this management phenomenon is quite recent and is still a subject of debate. The impacts of these practices on the firm's innovation performance can be measured in different ways although there are always some limitations as there are intangible value that is hardly measurable.

Several studies focusing on Portugal, such as Fernandes et al. (2017), Teixeira & Lopes (2012), Santos (2015) and Carvalho & Moreira (2015) reveal that open innovation practices are still scarce in Portuguese firms that show signs of opting for a more traditional closed innovation approach. As these findings contradict the trend found on other European countries it is of scientific relevance to deepen the research and try to understand if the latest data continues to show the same tendencies or if these types of practices have become more prevalent in Portuguese firms. The objective of this dissertation is thus to assess if open innovation is a practice being pursued by Portuguese firms and to what extend do these practices improve their innovation performance. For this purpose, the work will focus on the Portuguese market by analyzing data from the Community Innovation Survey (CIS) 2016.

1.1. Problem definition and relevance

Open innovation practices and its impact on innovation performance are not extensively studied in Portuguese firms and, since the open innovation practices and its impact of innovation performance are very much dependent on the context that the firm is inserted in (Huizingh, 2011), it makes it a relevant area of study. This context dependency increases the difficulty to study open innovation and to find systematic evidence of its benefits.

There is a strand of literature on innovation that whose work revolves around the study of open innovation, especially after Chesbrough (2003a) defined it as a concept and raised several challenges to the management science community. Since then, as will be shown in the literature review, many have studied the concept, the strategies companies follow, processes available, activities, drivers and determinants of open innovation. The difficulty in presenting empirical evidence of the effects of open innovation practices in innovation performances also makes this an interesting area of research.

1.2. Document structure

The document is structured as follows:

First a literature review is presented on the main relevant subjects. The literature review gives way to the problem definition and the hypothesis that this work pretends to answer. Before entering the methodology, the data for the analysis is introduced and statistically described along with the preparation work to then validate the hypothesis. Finally, the results are presented as well as the main conclusions of this work.

2. Literature Review

On this literature review the basic concepts of innovation and open innovation in firms/business will be introduced. Firstly, the concept of innovation will be explored: its origins as a management area of study; the different types of innovation and the different types of outcome that can derive from innovation. Then, open innovation in firms is introduced by looking at the phenomenon, its origins and the reasons that lead companies to recur to open innovation. Followed by the "how" firms are applying open innovation is analyzed in detail, by looking at the different processes, the activities of each process and the determinants of open innovation in firms. Afterwards, the impact of open innovation in terms of innovation performance will be reviewed in terms of what it means, and of the empirical evidence found in the literature, as well as some challenges or barriers to the successful implementation of open innovation. Finally, a review of the open innovation literature within the Portuguese scope is presented.

These different subjects build up to the next chapter where the research hypotheses are presented.

2.1. Innovation

Innovation was identified and studied as a management phenomenon from the beginnings of the twentieth century following the advances in technical and economic progress. One of the first authors to study the concept was Joseph Schumpeter that, in his work "Analysis of economic change", associated innovation with change (Schumpeter, 1935). The author stated that economic change is a result of outside factors but also from "the efforts of people trying to improve (...) their productive and commercial methods". Schumpeter then defined innovation by stating that "Innovations are changes in production functions which cannot be decomposed into infinitesimal steps" (Schumpeter, 1935, p.1).

With the advances in management sciences studies this definition has been the target of extensive analysis and several authors built upon this definition. One example is van der Kooij (2017, p.7) who gathered several ideas present in the literature to state that innovation is about "change and novelty, and about ideas based on knowledge" or inventions.

The underlying concept of novelty adds up to the Schumpeterian definition as there is a separation between "change innovation" where there is a discontinuity in the purpose of a "system" - whether it is product, process or organizational - (e.g. the change from analogue to digital watches) from simply changing certain properties from a product or service (e.g. presenting a car in a new color or new headlight design) and from an invention which is the creation of a new system, such as the invention of the car (van der Kooij, 2017). Innovation is then the result of both change and novelty.

Currently the Oslo Manual (OECD/Eurostat, 2019, p.20) defines innovation as "a new or improved product or process (or combination thereof) that differs significantly from the unit's (actor responsible for the innovation) previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)". Applied to the business context, the Oslo

Manual states that "*a business innovation is a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes and that has been introduced on the market or brought into use*" by the firm.

Another interesting dimension of innovation is innovation success as there are a multitude of factors that lead to it and affect it. There are several different critical factors for innovative success as represented in *Figure 1*.

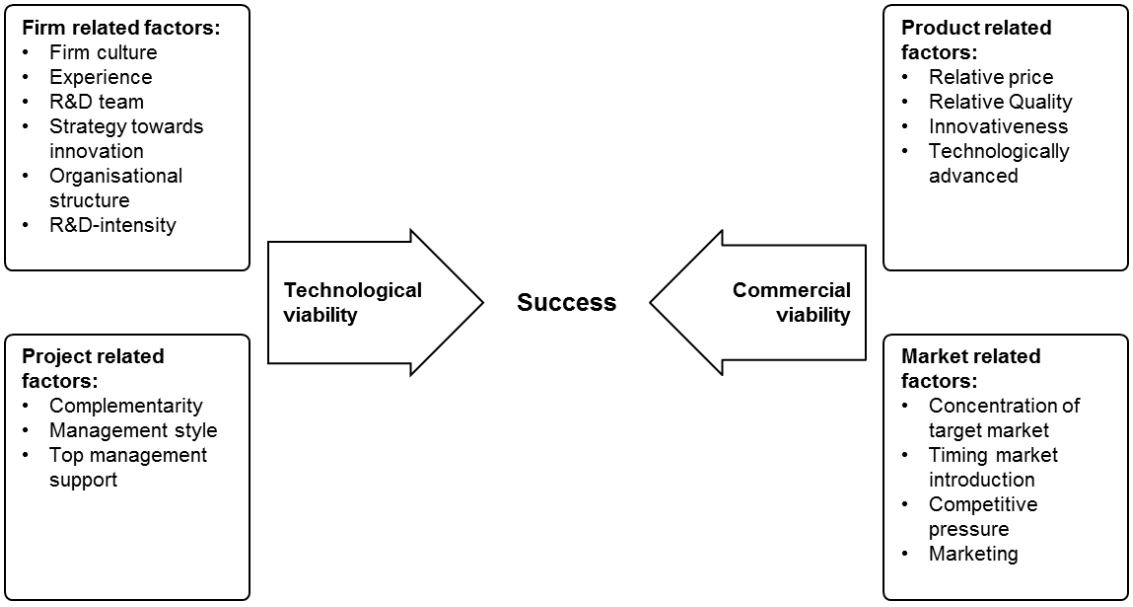

Figure 1 - Critical factors for innovative success. Adapted from van der Panne et al. (2003)

It is important to reflect on what success in innovation means. Success leads to the notion of outcome of innovation as Bessant et al. (2005) pointed out there are two types: radical innovations meaning a "discontinuity" happens and the company introduces something completely new to the market that represents breakthrough advancements and incremental strategy in which there is a minor improvement to the current situation.

As will be approached in section 2.2, Open Innovation is an approach to innovation that can be followed by companies and which success depends, not only on all these factors, but also on other specific factors related to the open innovation phenomenon itself.

2.2. Open innovation

2.2.1. Open Innovation Definition

OI is a broad concept encompassing several dimensions (van de Vrande et al., 2009) and several authors have tried to redefine open innovation and its components as the concept evolved over time.

Many researchers have used different definitions using many aspects making it difficult to find a single common definition (Dahlander & Gann, 2010). For some, it is still not a perfectly defined concept (Huizingh, 2011). Still, one of the best attempts in defining open innovation put it as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation and to expand the markets for external use of innovation” (Chesbrough & Vanhaverbeke, 2006, p.1) and later as “a distributed innovation process that involves purposively managed knowledge flows across the organizational boundary” (Chesbrough & Bogers, 2014).

The Oslo Manual (OECD/Eurostat, 2019, p.132) also points out to a broad concept by stating that open innovation is a “useful umbrella concept for generalizing existing and prospective forms of knowledge flows across the boundaries of innovation-active firms”.

These approaches to the definition demonstrates that open innovation is as much about inflows of knowledge as it is about outflows of knowledge and are used to improve the innovation process and improve its outcomes (Chesbrough & Crowther, 2006; Kline & Rosenberg, 2009).

The Oslo Manual (OECD/Eurostat, 2019, p.132) defines these flows of information as follows:

- Inbound (or inward) knowledge flows occur when a firm acquires and absorbs externally sourced knowledge in its innovation activities. This encompasses knowledge acquisition and sourcing activities.
- Outbound (or outward) knowledge exchanges occur when a firm intentionally enables other firms or organizations to use, combine, or further develop its knowledge or ideas for their own innovation activities. An example is when a firm licenses its technology, patents or prototypes to another firm.

The outflows of knowledge imply that the firm is willing to share their internal capabilities to the external environment, expecting to profit from that openness, and that new opportunities can arise. The inflows of knowledge imply that a company identifies partners outside the firm’s scope and creates the conditions for a collaboration that will eventually produce new opportunities (van de Vrande et al., 2009).

Adding another dimension to the definition, some authors pointed out that open innovation cannot be defined as a simply a dichotomy (open versus closed) but rather a “continuum with varying degrees of openness” (Dahlander & Gann, 2010 p.702-703; Huizingh, 2011). To simplify, Barge-Gil (2013) proposed the following classification and explanation:

- Closed: firms declaring no collaboration for innovation nor buying external R&D. These firms do not show any formal links related to inbound open innovation and, therefore, are considered closed.
- Semi-open: Firms indicating formal links for inbound open innovation but declaring that new products were obtained mainly by the enterprise on its own.

- Open: firms indicating formal links for inbound open innovation and declaring that new products were achieved mainly through co-operation with other organizations are regarded as open.
- Ultra-Open: firms whose new products are the result predominantly of the efforts of third parties are regarded as ultra-open.

2.2.2. Origins of Open Innovation

From Closed to Open:

Traditionally, innovation in companies was a closed practice in which the resources of the company sought internally to find competitive advantages for the firm and adopt defensive measures to protect them (Chesbrough & Appleyard, 2007). It was up to the R&D departments of firms to innovate and generate these competitive advantages and the outputs were tightly controlled by the companies (Chesbrough, 2003a). The protection of the tangibles and intangibles generated by these "indoors" practices were secured with protection means like intellectual property (IP) rights since they meant, in certain cases, the survival of the company or industry.

With an increase in the availability and access to information, freedom of movement of human resources in between companies, an increase in external suppliers and specially technology, the paradigm changed and knowledge broke boundaries. The borders between a company and its external environment is less defined and so allowed innovation to be transferred between them more easily (Chesbrough, 2003a). Knowledge sources ceased to be centralized in a few firms to being spread across several industry players as key individuals started to freely move from company to company taking with them their expertise and experience.

Although closed innovation (internal R&D departments) continues to be of great importance to firms, in the last decades it is possible to see that companies and even industries are making use of the "collective creativity" and the knowledge from outside resources to create new business models or improve existing ones (Chesbrough & Appleyard, 2007). One example is the software industry.

This meant that new strategies were needed:

To recognize the innovation potential outside the firm's walls means also to recognize the need to reassess and build new processes to capture, integrate and turn it into value (Chesbrough & Appleyard, 2007). This meant that companies needed a new approach as the more traditional views on strategy, as the ones presented by Michael Porter, which "are based upon ownership and control as the key levers in achieving strategic success" (Chesbrough & Appleyard, 2007, p.60). For firms to grasp the benefits of new innovation communities, ecosystems and networks, a new open strategy is needed, since it "also introduces new business models based on invention and coordination undertaken within a community of innovators" (Chesbrough & Appleyard, 2007, p.58).

The main difference between the two innovation paradigms (open vs. closed) is that in open innovation companies interact with other player incorporating them in different ways in their innovation

process (Gassmann & Enkel, 2004). The existence of opportunities outside the firm's scope led some companies to look for new ways to find and convert knowledge into innovative ideas that could be used to generate value. Closed innovation as a stand-alone even became, in some cases, obsolete and not sustainable for an ever-demanding market (Chesbrough, 2003a). This meant that it might be a good idea for companies to be looking to their environments and seeking opportunities to either find new ideas or to exploit their own, for it is possibly the only way to succeed.

In present times it has become a reality, firms are increasingly reshaping the fundamental ways in which they generate and bring ideas to the market and capturing them from the outside while still leveraging on their own internal R&D (Chesbrough, 2003a). The goal in innovation is - and always has been – about generating value and advancing technology to create competitive advantages. Firms now are simply more open to looking internally to exploit externally and looking externally to incorporate internally in their innovation pipeline.

New strategies meant new research opportunities:

Although some authors argue that the open innovation concept, as Chesbrough introduced, is not a new one (Christensen et al., 2005; Trott & Hartmann, 2009) the change from closed to open innovation and these new strategies needed did not pass by unnoticed by management science and several authors made it one of the most prominent areas of study in modern management science (Huizingh, 2011). Some authors believe open innovation to be an ever more common practice on firms that will eventually be considered business as usual and not a phenomenon, some authors argue that further empirical evidence it is still needed to validate existence of open innovation and its benefits for firms.

Fortunately, through the help of large scale, structured, formal questionnaires such as the CIS it is now possible to see the growth tendency of open innovation practices (Greco et al., 2016) and the number of studies dedicated to this area increased in large numbers.

2.2.3. Why do firms resort to Open Innovation?

As mentioned before, the main objective of innovation is to generate competitive advantages and value generation for the firm. In this sense open innovation practices are one available path for firms to achieve it. Although it also is widely agreed that open innovation is linked to a firm's innovation and technology strategy (Lazzarotti et al., 2017), the literature on what drives a firm to pursue open innovation practices is not consensual. Early adopters of open innovation realized that the way they had been conducting their traditional R&D processes and practices was not always the most efficient way to innovate. Given proper access to outside knowledge and the capability to absorb it, there could be significant benefits in terms of time-to market and output quality. Keupp & Gassmann (2009) found that firms were also looking for sources of innovation outside the firm's scope to overcome their internal weaknesses in innovation. Chesbrough, (2003b) believed it was the identification of additional opportunities to improve their innovation output. Ultimately, whether it is for one reason or the other, it is all about value, specifically making use of the context on which the organization is inserted to

generate ideas that can turn into value for the firm in a sustainable way (Chesbrough & Appleyard, 2007).

Researchers have found various reasons to what takes a company to choose to open their innovation process. Some have found it to be related to cost reduction, time to market and business risks; to extend skills and creativity, and access advanced technologies to develop breakthrough advancement (Calantone & Stanko, 2007; Hagedoorn, 1993). Other authors state the reasons to embark in such transformation may vary the company's business objectives. As Huizingh (2011) identified, some companies were practicing open innovation for offensive reasons (such as stimulating growth) and for defensive motives (such as decreasing costs and risks). Although some authors like Chesbrough & Crowther (2006) and van de Vrande et al. (2009) found that offensive reasons were more important than defensive reasons. Dahlander & Gann (2010, p.2) also made a relevant distinction between non-pecuniary, where no financial reward associated with knowledge flow, and pecuniary where "there is an immediate compensation related to a knowledge flow".

Not all companies and/or industries can expect to have the same efficiency or outcomes when applying open innovation nor will they always follow the same set of activities or practices. One of the key factors found in open innovation studies suggests that the ability to absorb external knowledge has become a major driver for open innovation success and consequently to value generation and competition (Spithoven et al., 2011).

Although the appeal of opening the innovation process varies with the firms context such as industry, sector or firm size, innovation through open strategies have been proven to be most favorable to reach innovation success (Barge-Gil, 2013). Some industries were even born out of the opportunities that open innovation brought, like in the open software industry. And there have been even bolder statements like "firms which do not cooperate and which do not exchange knowledge reduce their knowledge base on a long-term basis and lose the ability to enter into exchange relations with other firms and organizations" (Koschatzky et. al 2001, p. 6).

2.2.4. How are firms adopting OI?

Since "traditional concepts of business strategy either underestimate the value of open invention and open coordination, or they ignore them outright" (Chesbrough & Appleyard, 2007, p.73) companies had to find new paths in their innovation quests. The new paradigm of being able to harness potential value from the outside environment forced firms to rethink their innovation strategy. Early adopters realized that the way that they had been conducting their traditional R&D processes and practices was not always the best fit to incorporate these new activities. Soon they also realized that the strategy pursued by one company can have very different results in another and, "not all open innovation activities (...) have a positive effect on their innovation output" (Kim & Park, 2010, p.1).

Nonetheless the concept started to get more popular and these days open innovation is a practice present in many industries and companies often combine practices of both open and closed

innovation and apply one or more activities to different degrees of extent (Chesbrough & Appleyard, 2007; Enkel et al., 2009).

There are several key elements in a successful strategical approach to OI such as building an innovation strategy that ensure the right balance right balance between open and closed innovation (Enkel et al. 2009), finding the right partner or resource outside the firm's scope and ensuring the company has the capacity to incorporate the outside resources in their innovation process and the correct activities for each step of the innovation process.

The right partner is one of the main factors in the adoption of open innovation as firms rely for different kinds of innovations on specific knowledge sources and links (Tödtling et al., 2009). When analyzing the relation with partners it is important to be precise about the how the literature characterizes as there are different implications in the type of relationship that can lead to misleading conclusions. As the Oslo Manual (OECD/Eurostat, 2019) puts it there are four types of relationship that can be formed:

- Co-operation means that two or more parties decide to conduct a series of tasks and that information flows between them to enable reaching a common understanding to work together;
- Collaboration means each of the parties contributes in a coordinated way to address a common problem;
- Co-innovation, or coupled open innovation, occurs when collaboration between two or more partners results in an innovation (Chesbrough and Bogers, 2014);
- Alliances, consortia, joint ventures, and other forms of partnerships "are all mechanisms for knowledge flows that can be used in innovation activities, although each of these can be used for other purposes".

Another important strategical imperative is that companies needed to build an "absorptive capacity" that ensures that it will be easy to internalize external knowledge (H. Chesbrough, W. Vanhaverbeke, 2006) and consequently improve their open innovation effectiveness. This absorptive capacity has proven to be a precondition to successfully conduct open innovation (Spithoven et al., 2011) and, on the other side, to identify external paths for commercialize internally sourced innovation (Lazzarotti et al., 2017).

It is also key for a company to embark on the right set of activities that can benefit the innovation process the most as there are different practices that a company can decide to do open its innovation process. These activities will be outline in the following chapters.

2.2.5. Open Innovation Process

In this work we look at open innovation as being a set of practices with one (or more) objectives and, therefore, a process with a multitude of activities (Chesbrough & Appleyard, 2007; Enkel et al., 2009; Gassmann & Enkel, 2004; Huizingh, 2011).

The following framework (Gassmann & Enkel, 2004) has open innovation divided in three different core processes:

1. The inbound or outside-in process.
2. The outbound or inside-out process.
3. Coupled process.

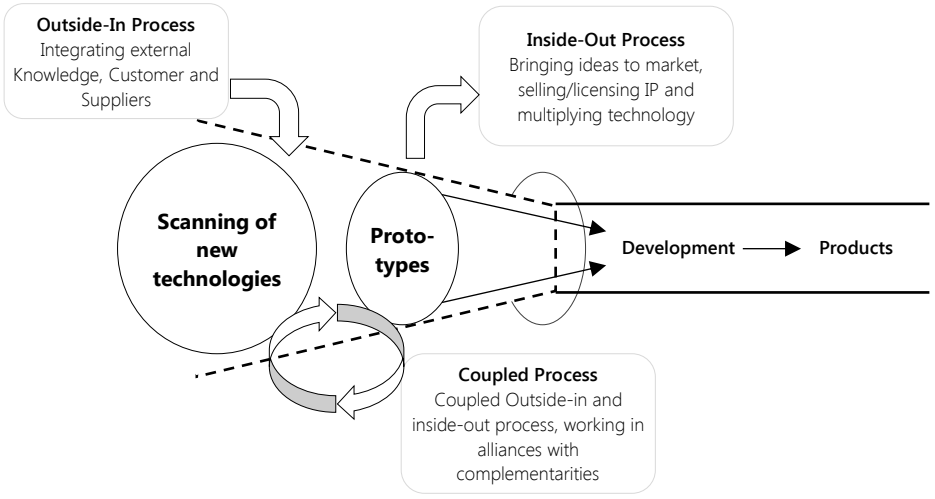

Figure 2 - Three archetypes of open innovation processes B. Adapted from Gassmann & Enkel, (2004)

Inbound process a company chooses to follow an innovation strategy that is based on searching and working together with suppliers, customers, or other partners in the integration of their knowledge (in several different possible ways) or resources. For firms to pursue this strategy is to assume that the "locus of knowledge creation does not necessarily equal the locus of innovation" (Gassmann & Enkel, 2004, p.9). The inbound process was found to be more prevalent in companies that belong to a low tech industry, that are on the lookout for similar technology acquisition, that act as knowledge brokers and/or knowledge creators, that have highly modular products or that belong to a high knowledge intensity sector (Gassmann & Enkel, 2004). This process relates to a number of activities detailed in the next chapter that include the search for knowledge outside the company as well as the purchasing of innovation concepts (Ebersberger et al., 2011). The most common way to measure inbound openness is to do so with the concepts of breadth (number of sources) and depth (level of intensity of the relationship) introduced by (Laursen & Salter, 2006).

The inside-out or outbound process refers to external exploitation of internal knowledge (Huizingh, 2011). In other words, earning profits by bringing ideas generated internally to the market. This can be done through different mechanisms such as selling IP or by making ideas (or internal knowledge) available to the outside environment (Huizingh, 2011; OECD/Eurostat, 2019). The exploitation of knowledge outside the company is related to the company's capability to multiply and transfer its knowledge to the outside environment (Enkel et al., 2009) and then of generating value from it. This process was found to be more prevalent in companies in perform (basic) research-driven sectors, or

that have objectives like decreasing the fixed costs of R&D, branding, setting standards via spillovers (Gassmann & Enkel, 2004). This is done through activities that commercialize knowledge generated in the company (Lichtenthaler, 2005), in a controlled way, through the protection of the intellectual property to ensure value creation for the company. In other words, out-licensing and/or selling IP (Huizingh, 2011). The outside-in process relates to several activities that include knowledge transfer capability and the selection of appropriate partners as will be detailed in the following chapter.

The coupled process is the process where a company gets involved in partnerships or other forms of collaboration to knowledge that will benefit to both collaborating parties (Gassmann & Enkel, 2004; Greco et al., 2016; Piller & West, 2017). Coupled open innovation was initially thought to be a combination of outbound and inbound processes (Chesbrough, 2003b) but has evolved to a stand-alone cooperation concept. This process is more prevalent in companies that want to have dominant design of their product and so are able to achieve higher returns than they would be able to achieve on their own (Gassmann & Enkel, 2004). The process relates to a number of activities such as the search and integration of the right partner, the capacity to integrate its knowledge and the ability to externalize their own knowledge (Gassmann & Enkel, 2004).

Although Greco et al. (2016) confirmed that the share of companies adopting the open innovation paradigm has increased, both in terms of inbound and coupled actions, Schroll & Mild (2011) found that inbound cooperation activities are used significantly more than acquisition or outbound activities and although these activities are context specific it is possible to generalize them. In line with these findings Enkel et al. (2009) pointed out that most research on the open innovation approach has discussed inbound open innovation processes, whereas outbound open innovation processes have not been explored much. Lichtenthaler & Lichtenthaler (2009) presented an alternative to the process described before and distinguished three knowledge processes (knowledge exploration, retention, and exploitation) that happen inside the company's scope or outside.

In many cases the strategy and activities that companies decide to pursue open innovation is not a formal one, but still based on trial and error (Gassmann et al., 2010).

2.2.6. Open Innovation Practices/Activities

As mentioned in the previous chapter open innovation can be seen as set of processes (inbound, outbound and coupled). Each of these processes can be characterized by a set of activities. As Parida et al. (2012) pointed out, different open innovation activities generate different outcomes (although the study was restricted to SME). These activities are associated with each of the processes seen before as was done in the studies conducted by Ebersberger et al. (2012) and Spithoven et al. (2013):

- Activities such as the search for knowledge and sourcing/innovation expenditure (e.g., in-licensing, minority equity investments, acquisitions, R&D contracts) are related to the inbound process (Bianchi et al., 2010);

- Activities of protecting intellectual property (e.g. protection out-licensing, new venture spin-out, sale of innovation projects, joint venture) are related to the Outbound process;
- Collaboration activities are related to the coupled process.

Each of the activities identified can also be viewed from a perspective of Breadth and Depth (Laursen & Salter, 2006). Breadth is related to the number of different resources used and depth is related to the intensity to which each resource is used. For example, a company might use a wide variety of innovation partners (high breadth) but with limited collaboration with each one while another company might make use of only one type of partner but develop a truly intensive collaboration with them (high depth). This way, each of the activity indicators can be seen from a breadth and depth perspective. Some studies recently show that companies adopting open innovation models "tend to be more open in terms of breadth than in terms of depth" (Bernal et al., 2019, p.11).

Each of the set of activities will be exposed in further detailed as there is extensive literature on each of them.

Search

The search for the right partner or source of knowledge (publication or database) in the environment outside the firm is one of the main activities in open innovation and it can have a substitution effect to internal R&D (Laursen & Salter, 2006). Although "outside environment" is a broad concept, it is linked to the existing knowledge outside the traditional in-house sources of "local search" (Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). Search can be done on the demand side, to find customer needs or future trends, or on the supply side, to find new capabilities or technologies that can be used in product or service developments (Ebersberger et al., 2012). Different sources of information can also have different objectives throughout the innovation process.

As identified by (Laursen & Salter, 2006), firms make strategical decisions so that their search is as prolific as possible. As stated before, search is related to the inbound process and it is possible to build an indicator to measure the openness degree of this process. Following the breadth and depth concept introduced in subsection 2.2.6 the measurement can be separated in two dimensions: search breadth, which refers to the "number of external sources or search channels that firms rely upon in their innovative activities" and the concept of search depth which refers to the "extent to which firms draw deeply from the different external sources" or, in other words, how intensive is the cooperation with the sources chosen (Laursen & Salter, 2006 p.134).

As pointed out by Ebersberger et al. (2012) the direction of search should also be taken into account as different types of partners (namely industrial sources vs science sources) may be useful in different steps of the innovation process.

Collaboration

Collaboration is about working together with a partner with dedicated teams to achieve a well-defined objective which is expected to be beneficial the several parties involved. A collaboration can vary in

terms of partner type (suppliers, customers, and competitors, to research institutions and organizations in very different industries), duration, and business reason (Huizingh, 2011). The main difference to innovation search is that collaboration involves the sharing of one's own knowledge and access to a much greater extent to the partners knowledge with the hopes of obtaining better innovation results (Ebersberger et al., 2012).

As stated before, different sources of information can have different objectives throughout the innovation process and so also collaboration can vary with the stage of the innovation process, the different types of partners (industrial sources such as customer or suppliers or science sources such as universities or research institutes) or the level of engagement. This latter is key to successfully conduct collaboration activities: too much engagement on a single channel and the company might miss out on important opportunities, too less, and it might not be enough to generate relevant results. With this in mind, collaboration breadth can be seen as the number of partners used and depth as the intensity on the collaboration with these partners (Ebersberger et al., 2012).

One of the main factors in collaboration is the portfolio of partners a company can choose to partner-up with (Faems et al., 2003) as well as the types of partners (Du et al., 2014):

- science-based partnerships (universities and knowledge institutions, etc.)
- and market-based partnerships (customers and suppliers)

Companies that look for universities and research organizations usually expect the scientific knowledge to give them more radical innovations and industrial innovation while companies that look for incremental innovations look for business sector partners such as suppliers and customers (Tödtling et al., 2009). Suppliers can help company's product reliability and performance by bringing expertise while customers align product expectation with market needs.

Sourcing or Innovation expenditure

One of the practices that has become widely spread in business is for companies to scan the outside environment and invest monetary funds to be able to either overcome a difficulty or generate a competitive advantage. In that sense, contracting R&D is nowadays a very common practice as a substitution for internal innovation since it requires less capital expenditure than to have the internal resources and allows to quickly have access to knowledge that can even be from a non-core area of expertise. This acquisition of knowledge can be done via the acquisition of participations in other smaller companies, via the purchase of external R&D machinery for innovation or by resorting to other outside firms (such as consulting agencies) to co-develop product or process innovations (Ebersberger et al., 2012). In the contracting of services like consulting, usually there are concrete objectives, a limited scope and a contract signing prior to the beginning of the work to ensure the return on the investment by the contracting firm. For the consulting company the knowledge gathered by conducting the project can mean new credentials that can be used to then replicate the project in other clients. At the same time, it can mean transferring knowledge to more people across the

organization that will, in turn, hopefully generate new opportunities with this acquired experience. It is possible to see these practices across different sector and areas of expertise where firms are willing pay for the services of other firms to conduct projects that involve knowledge transfer to them. To be successful, the project must have a clear scope, work must be delimited in time and stages and the result should be internalized by the company (Ebersberger et al., 2011). Although this practice can be seen as innovation for the company it rarely is radical innovation for the sector. It is used to gain access to cutting edge technologies and capabilities or a learning opportunity.

Sourcing breadth can be seen as the number of different sources contracted and depth the extent to which they were used (Ebersberger et al., 2011; Spithoven et al., 2011).

Protection

Intellectual property rights in the form of patents, licensing, trademark or copyrights can be used to ensure proprietary rights to those who innovate (Dahlander & Gann, 2010). These protection measures can be seen as an enabler for innovation R&D as it can ensure a higher return for the company that embarked on innovation investments via the commercialization of its rights. In some sectors protective measures have greater benefits than other industries due to the characteristics of the product and the regulatory environment of the sector. One common example is the pharmaceutical sector where the protective measures (up to a certain degree) foments firms to keep innovating by funding new R&D initiatives. IP protection can also enable companies to disclose their knowledge in a controlled way and market on their innovation. This promise of economic benefits in turn foments innovation. Tödtling et al. (2009, p.2) found that “Firms introducing more advanced innovations are relying to a higher extent on R&D and patents, and they are cooperating more often with universities and research organizations.”

IP has a relation with collaboration since it can foment collaboration as firms have more guarantees that there will not be a misappropriation of their internal knowledge and so are more willing to collaborate, although the effects are not the same in all stages of innovation (Stefan & Bengtsson, 2017).

Protection breadth can be seen as the number of different resources the company used to protect intellectual property (e.g. patents, trademarks, copyrights, etc.) (Ebersberger et al., 2012) and protection depth can be seen as the extent to which each of these practices is used.

2.2.7. Open Innovation and Innovation Performance – Empirical evidence

A firm’s success in the current competitive environment depends, in many cases, on its efficiency in generating innovation (reduce risks, costs, and time to market) and, on its ability to introduce novelty into the markets - new or significantly improved products/services - (Lazzarotti et al., 2011).

Unfortunately for firms, it is not always easy to achieve this, and what works for some companies might not work for others, since open innovation is dependent on its determinants and context, as it was discussed in the previous chapter.

It is important to differentiate the type of performance being measured with the adoption of open innovation, as performance can refer to different things. Some authors' studies are dedicated to measure the firm's performance, other focus on the firms' innovation performance and others focus on different measures such as the economic, financial and human capital performance (Moretti & Biancardi, 2020). The literature is not consensual on how to measure the output neither of innovation performance nor of the scale to do so. There are researchers who use scale measures, continuous measures - such as the number of new or significantly improved products - or percentage measures, such as the share of sales from innovative products/services (Moretti & Biancardi, 2020). An additional relevant factor related to open innovation and innovation performance is the two innovation and learning modes between the production and use of knowledge: One mode derives from science, technology and innovation (STI) which enables innovation leaps, while the other derives from the knowledge produced by experience by doing, using and interacting (DUI), which can be translated into incremental innovation (Jensen et al., 2007). As the authors who coined these concepts defend, a mixture of these two modes will improve a firm's innovative performance.

In this work innovation performance is considered as the ability to create and introduce new products and services to the market and the success these have in terms of the value generated for the firm, following the works of Ebersberger et al. (2011) & Spithoven et al. (2013).

So, what is the impact of open innovation in innovation performance? The literature is not consensual.

Positive effect on a firm's innovation performance:

Several studies demonstrate the existence of a positive relation between different aspects of open innovation and innovation performance: There are authors who analyzed different dimensions of open innovation and found a positive relation with innovation performance, such as Ebersberger et al., (2012); Spithoven et al., (2013) or Santamaría et al. (2010) who, followed a broad approach in terms of company types and open innovation strategies for the Spanish market and found these to have a positive effect on the internal R&D activities in both high and low-tech industries. There are authors that concentrated on a specific dimension of open innovation, such as Chen et al. (2011), who focused on the search for external knowledge and found that a greater breadth and depth of openness in a firm's search strategy improves its innovative performance, and Faems et al. (2003) who centered their research on collaboration and found a positive relationship between inter-organizational collaboration and innovative performance. Although by performance only the firm's innovation performance is taken into account in this work, there is also extensive work that found positive effects of OI in other aspects of a firm. For example, Du et al. (2014) focused on R&D projects and found them to have a positive relationship with open innovation partnerships and financial performance, Rass et al. (2013) found a positive relation between the implementation of open innovation instruments and the firm's performance through the organization's social capital, and Moretti &

Biancardi (2020) showed that the effects of external acquisition are positive and significant in several dimensions of a firm's performance.

Negative (or non-linear) relation between open innovation and innovation performance:

Although the majority of the literature shows a positive effect of open innovation in a firm's performance, there are several studies that demonstrate the existence of a negative or a non-linear relation between some aspect of open innovation and performance:

Laursen & Salter (2006) found that search breadth and depth have an inverted U-shaped relationship with innovation performance. This means that firms who have open search strategies tend to be more innovative but also that excessive search can cease to be useful at a certain level. Also, Greco et al. (2016) found that search breadth has a curvilinear relationship with innovation performance, while search depth does not show a reduction in marginal returns. Looking at the collaboration dimension of open innovation, Chen et al. (2011, p.2) found that the relation with external partners both in terms of diversity and intensity does not explain innovation performance. In terms of product development, Suh & Kim (2012) found that collaboration through networking does not have an impact on R&D performance. In terms of intellectual property, Stefan & Bengtsson (2017) found negative effects of formal intellectual property protection mechanisms for firms in certain stages of the innovation process. Lastly, Knudsen & Mortensen, (2011, p.1) found that projects with higher degrees of open innovation are more costly and take longer time to finish than closed innovation ones and also take longer than the industry standard.

2.2.8. Open Innovation Determinants (Context Dependency)

Different firms apply open innovation practices to different extents and obtain different results in their innovation process (Gassmann, 2006), which makes it difficult to find consensus in defining the determinants of openness. Although it is widely accepted now that the effectiveness of open innovation is context dependent (Huizingh, 2011) and companies should adapt their strategies according to its context (Gassmann, 2006), there is still much debate about what are its determinants (Moretti & Biancardi, 2020). To study the phenomenon effectively, there is a need for an approach that considers the context of the company in several dimensions. There are extensive studies dedicated to empirically finding which determinants better explain open innovation and determine the success of open innovation processes and activities.

The effect of these determinants on open innovation can be measured in several ways: adoption level of open innovation, adoption of particular activities or the relationship between open innovation and innovation performance (Huizingh, 2011).

The following review of the determinants that can affect open innovation follows the work of Lazzarotti et al. (2017) that made a distinction between firm specific and contextual factors. There are numerous

external factors that affect open innovation, and some can be more controllable and predictable than others. There are also several internal factors and it is up to the firm's management strategy to control them and find the best solution to maximize innovation results.

Internal context characteristics or firm specific factors that can have an effect the open innovation performance in a company:

- Company size (measured as the number of employees): the larger the firm, the more involved in open innovation activities, thus, more open is their innovation process (Stanisławski & Lisowsk, 2015; van de Vrande et al., 2009);
- Multi-nationality of the company: Ebersberger et al. (2012, p.137) found that companies that are affiliated with a domestically based multinational corporate group have a significant impact on open innovation practices and that "foreign ownership on external innovation expenditure is significantly positive";
- Ownership type: Keupp & Gassmann (2009) found foreign ownership to be significant to open innovation breadth and depth;
- Company's age: the older the firm, the more open it is to the environment (Stanisławski & Lisowsk, 2015);
- Location: Teixeira & Lopes (2012, p.435) found that firm locates at countries at an intermediate stage of technological development "tend, on average, to share a relatively closed innovation model when compared with firms located in countries where technological development is advanced";
- Company's innovation strategic orientation: "Firms that are more open to external sources of knowledge are more likely to achieve a higher level of innovative performance" (Laursen & Salter, 2006, p.146); (Ebersberger et al., 2011) Ebersberger et al. (2012, p.ix) found that "strong internal corporate knowledge bases, as measured directly R&D intensity" have a positive effect in external search and collaboration;
- Organizational: Foss (2011) found that the link from customer knowledge to innovation is completely mediated by organizational practices;
- Learning and innovation modes: Jensen et al. (2007) introduced two modes that companies can learn and innovate: STI (science, technology and innovation) which related to the "know-why" of things and DUI (doing, using and interacting) which is related to the "know-how" things. Chen et al. (2011, p.3) found that "openness in a firm's innovation activities improves innovative performance, although the influence differs for both innovation modes" positive all modes except for the scope of openness for firms using the STI-mode.

There are also, external context characteristics that can have an effect the open innovation performance in a company:

- Industry: there is extensive literature that focus on different industries and that show empirical differences in open innovation adoption and performance (Huizingh, 2011). One example is the

findings of the open software industries where IP plays a crucial role (West & Gallagher, 2006) compared to the nuclear and military industries in which a closed innovation process based on protection and non-disclosure is a key element of survival (Gassmann, 2006);

- Industry speed: industries with high industry speed benefit more from open innovation (Gassmann & Enkel, 2004);
- Public funding: Ebersberger et al. (2012) found that national public funding have a positive effect on the use and on the intensity of innovation practices;
- Type of industry (service vs. manufacturing): although the majority of the literature found is based on manufacturing industries, Schueffel & Vadana (2015), for example, found open innovation to be beneficial to the financial services industries.

2.2.9. Challenges on implementing OI

As mentioned earlier, by being context dependent, the implementation open innovation strategies are not an easy decision for companies and there are risks and difficulties that need to be accounted for. There are two main challenges extensively addressed in the literature: the first is that the opening of the company to the outside environment might lead to knowledge spill overs and for the company to lose any competitive advantage. The other barriers in the open innovation process are related to the capacity that a company needs to have enough to, on one side build the absorptive capacity to make the most of the inflow of knowledge, and, on the other side, to have the processes in place to exploit and retain it.

Studying open source software firms and their innovation strategies West & Gallagher (2006) found there are three challenges when firms in integration open and closed innovation:

1. Firms need to find new ways to maximize the returns of internal innovation.
2. Identifying and “incorporating external innovation into internal development” which requires new processes and absorptive capacity
3. Build with partners an “ongoing stream of external innovations”

The study that Rahman & Ramos (2013) presented on the challenges for open innovation adoption in SMEs in Portugal separates the barriers into four categories:

1. Human aspect (e.g. scarcity of skilled and non-skilled manpower, wages, poor image, etc.)
2. General constraint (e.g. lack of market demand, infrastructure, knowledge gaps, etc.)
3. Policy constrains (e.g. Financing, Government regulation, cost, etc.)
4. Competition (increased product differentiation, cost efficiency, formalization of strategic partnerships, etc.)

2.2.10. Limitations of studying Open Innovation

There are a multitude of authors that point out that there are several limitations in the study of OI. As the Oslo Manual (OECD/Eurostat, 2019) explains, the complexity of the knowledge flows between different actors materialized in a wide range of agreements makes open innovation a difficult phenomenon to measure.

Although the appearance of standardized innovation surveys with a cross country scope like the CIS has helped to study the phenomenon there are several aspects that are left out due to the complexity and extend of the questionnaire. Du et al. (2014) pointed out that open innovation studies based on CIS focused only on formal forms of collaboration (contract agreements) and not informal (participation in technology groups, conference participation).

Moretti & Biancardi (2020) point out several limitations: The majority of the studies are based on self-reported data and are country specific and so there might be several dimensions not being studied; The subjectivity around the measurement of performance in open innovation can possibly fail to encompass investments in external assets; The use of ratios of innovation over firm revenues does not guarantee that the firm will experience an increase in the latter, since the increasing incidence of innovation may come at expenditure of overall sales results.

2.2.11. Open innovation in Portuguese firms

The literature related to open innovation in Portugal is not extensive and it was not possible to find many studies with empirical evidence and none that relate open innovation practices with innovation performance.

In “Open Innovation in Portugal” by Teixeira & Lopes (2012), which was found to be the most detailed study analyzed, the authors surveyed a number of innovative dynamic Portuguese firms. They found that, contrary to other empirical studies in countries more technologically developed, there is a more relatively closed innovation model in Portugal. The authors also found that the inbound innovation activities are much more prevalent than outbound innovation activities and that this might indicate the lack of knowledge on how to capitalize internal knowledge to the outside environment of the firm. In their work two types of activities are identified Search & Sourcing and Transfer of technology to other organizations. Fernandes et al. (2017) found similar results that innovation in Portuguese firms is still mainly done internally rather than by collaborating with external partners especially in new products.

Santos (2015) has also dedicated his work on the determinants of open innovation in Portuguese clusters[1] having released a survey that 46 unique cluster members answered. In terms of open innovation activities, the author found the prevalence of collaboration through informal channels (e.g. internet usage) and formal collaborations channels (collaborative R&D projects), the search and

[1] Companies that “are in geographical proximity, which compete and cooperate (Porter, 2009) with each other in an interdependent relationship, with both formal and informal links”

integration for the right external knowledge (inbound) and the transfer of knowledge to other entities (outbound) although the latter was much less prevalent. Also, the author found there is an open innovation approach when developing ideas, but not when it comes to the generation of new business or the protection activities in the development of projects. Concluding, the author found that being part of a cluster helped out more on the collaboration activity, on knowledge absorption capability and on several barriers to open innovation adoption namely budget constraints, lack of information on how to develop new ideas, deficit of internal skills, and fear of knowledge spillovers amongst others. Aligned with these findings, Carvalho & Moreira (2015) focused on Portuguese SME and their relations with technological centers and business associations and also found evidence of inbound activities (but not of outbound) and that the type of partnerships differs between industries.

Leitão (2006) focused on cooperation in innovation and, through the analysis of the CISII data in Portugal, found that relationships with external partners has a positive influence in entrepreneurial innovation in terms of innovation advances and incremental innovations. The author found that firms who cooperate with business partners are more capable of developing more advanced innovation than firms that have a closed innovation approach. Also, they found that firms that chose a science partner find better innovation results when cooperating with universities instead of other research institutions or consultancy firms.

In terms of relationships between service firms and universities Janeiro et al. (2013, p.1) analyzed the data from the CIS 2006 on Portuguese firms to study factors which influence “the collaboration of service firms with universities for innovation activities” and found that “innovation success, radical innovations, and innovation intensity are crucial to the development of links between innovative service firms and universities”.

3. Hypotheses

The main question this dissertation tries to discuss is the effect of open innovation practices on innovation performance in Portuguese firms. As discussed in the literature review, open innovation practices and its impact on innovation performance may vary from one country to another. As was also exposed, this is because innovation performance through open innovation is dependent on a multitude of external and internal factors. As it was also possible to assess in the literature review, the practices of open innovation in Portuguese firms and its effect in innovation performance are not extensively studied, which provides an extra scientific relevance to this study.

As was already mentioned in 2.2.7, Ebersberger et al. (2012) showed that for several EU countries there is a positive effect between open innovation and innovation performance. There are also a multitude of authors who found a positive relationship between some of the several dimensions of open innovation and the firm's innovative performance (Faems et al., 2003, Du et al., 2014; Santamaría et al., 2010; Moretti & Biancardi, 2020; Rass et al., 2013). Since these studies show a positive effect of open innovation practices and innovation performance in other countries, it can be expected that companies in Portugal to have the same results. Nonetheless, since open innovation effects are so context dependent, and there are even some studies that show a negative effect (2.2.7), the results can be expected, although not predicted. This leads to the following hypothesis.

Hypothesis 1: The use of open innovation practices in Portuguese companies improves innovation performance.

As mentioned in the literature review, Laursen & Salter, (2006) made a distinction between the number of resources used by a firm in their open innovation activities and the intensity to which each one is used, coining the terms breadth and depth. Later, several authors such as Ebersberger et al., (2012); Moretti & Biancardi, (2020); Spithoven et al., (2013) followed the same approach and found different relationships between open innovation practices and innovation performance. The relevance of this distinction and the availability of data in the CIS dataset to analyze both dimensions, leads to the following hypothesis:

Hypothesis 2: The breadth of open innovation practices in Portuguese companies improves innovation performance.

Hypothesis 3: The depth of open innovation practices in Portuguese companies improves innovation performance.

To further understand the effect of open innovation in innovation performance it is relevant to drill down on each of its practices (search, sourcing, collaboration, protection) that are related to the open innovation three open innovation processes ("inside-out", "outside-in" and "coupled"), as it was done by Ebersberger et al., (2012); Spithoven et al., (2013) and partially by Teixeira & Lopes, (2012), the

latter in an analysis of the Portuguese market. Laursen & Salter, (2006) studied the relation between search breadth & depth and innovation performance and who found a curvilinear relationship between them which leads to the following hypothesis:

Hypothesis 4: The use of open innovation search (both in terms of breadth and depth) in Portuguese companies improves innovation performance.

Moretti & Biancardi (2020) found a positive relationship between innovation sourcing and innovation performance which leads to the following hypothesis:

Hypothesis 5: The use of open innovation sourcing (both in terms of breadth and depth) in Portuguese companies improves innovation performance.

Faems et al. (2003) found a positive relationship between collaboration and innovation performance for Belgian firms which leads to the following hypothesis:

Hypothesis 6: The use of open innovation collaboration (both in terms of breadth and depth) in Portuguese companies improves innovation performance.

Stefan & Bengtsson, (2017) found positive relationships between some protection activities and innovation performance for semi-formal appropriability mechanisms in early stages of the innovation process which leads to the following hypothesis:

Hypothesis 7: The use of open innovation protection in Portuguese companies improves innovation performance.

4. Data and Methodology

In this chapter the data used for the analysis as well as the methodology followed will be introduced.

4.1. Data

The data used in this work is from the CIS - Community Innovation Survey – which is an innovation survey conducted by the EU science and technology statistics (part of the Eurostat) and voluntarily answered by enterprises of all EU countries. The survey is a standardized questionnaire, first launched in 1992 and that, since then, has had some changes to better capture specific trends or dimensions of innovation. The survey is conducted "with two years' frequency by EU member states and number of ESS member countries"[2]. The objective of the survey is to "provide information on the innovativeness of sectors by type of enterprises, on the different types of innovation and on various aspects of the development of an innovation, such as the objectives, the sources of information, the public funding, the innovation expenditures, etc."[2] . This research draws its analysis on a subset of companies that follow certain criteria and whose answers provide information of their open innovation practices and of its impact on innovation performance.

The data used in this research is from the CIS 2016 and was obtained via the *DGEEC* which oversees the providing of data for Portuguese companies (DGEEC, 2014).

There are several questions on the survey that relate to open innovation practices and that have been used by the scientific community following the OSLO manual guidelines (OECD/Eurostat, 2019). The Oslo manual intends to provide these standardized guidelines on how innovation data should be collected and interpreted to "facilitate international comparability and provides a platform for research and experimentation on innovation measurement". Specifically, chapter 6 is dedicated to the knowledge flows of open innovation and provides the guidelines to study it. As is stated in the manual, "The measurement of knowledge flows between firms and other actors of the innovation system can contribute to a better understanding of (…) the effect of knowledge flows on innovation outcomes, and the methods that firms use to manage their knowledge capabilities." The manual also provides guidelines for the construction of the open innovation indicators used the research.

One of the main limitations in terms of data that the framework that will be used has, is that it is limited to product or service innovation (leaving out process and organizational innovation) since innovation performance measures in the CIS survey are only available for product innovators. This fact restricts the numbers of firms considered in the sample to those who reported product or service innovation.

[2] https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey

4.1.1. Dataset

There is a total of 6775 respondents (companies) in the CIS2016 survey on innovation. Of these companies only the ones having answered positively to question 2.1 which is related to product innovation by asking if the respondent's companies have introduced either goods or services innovation were considered innovative and were, therefore, used in this study. Although the survey also enquires the companies about process innovation, this dimension was left out of scope since, contrary to product innovation; there are no performance measures of innovation (novelty and share of sales). Of the 6775 companies, there are 3006 (44%) that answered positively to the introduction of either a good or a service innovation (*Figure 3*).

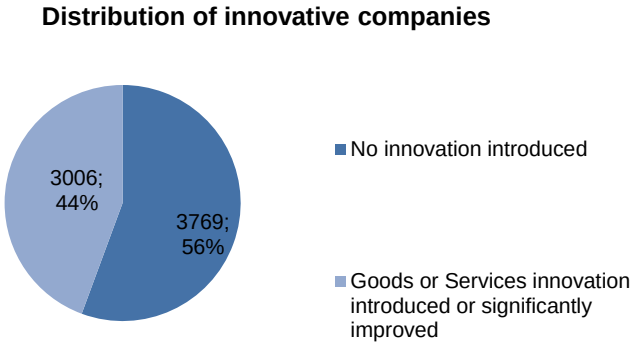

Figure 3 - Distribution of innovative companies in the CIS2016 survey

From the 3006 innovative firms, 76% has an open innovation score lower than 3 (*Figure 4*).

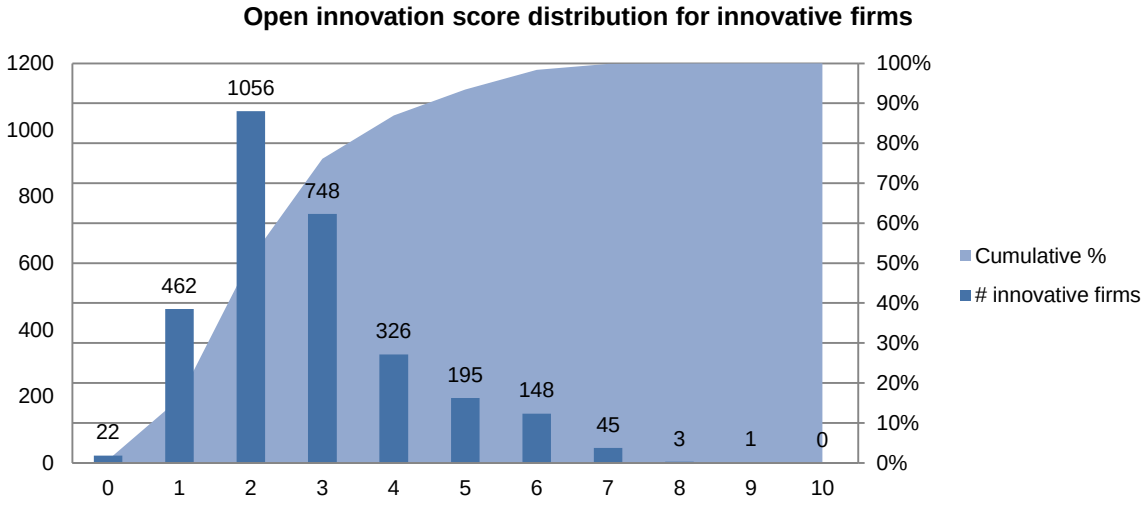

Figure 4 – Open innovation score distribution for innovative firms in the sample

Figure 5 shows the sample's distribution by company size where we see that 7% are labeled as "LE" - large companies - which are considered to have more than 250 employees and 93% are small or medium enterprises that have between 10 and 249 employees.

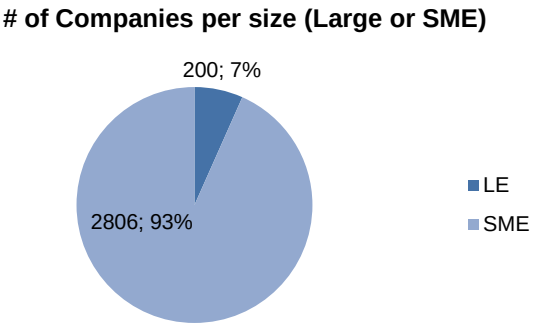

Figure 5 - Distribution of companies per size in the sample

Figure 6 shows the distribution of the sample by companies who belong to a group where we see that 68% of companies do not belong to a group whilst 32% do.

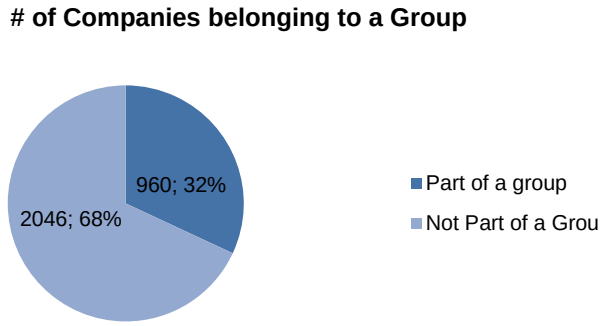

Figure 6 - Distribution of companies belonging to a group in the sample

Figure 7 shows the distribution of the sample by companies that show international orientation, meaning that their revenues have origin from both national and international sales.

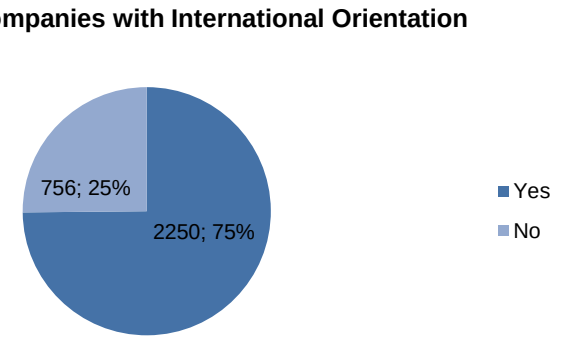

Figure 7 - Distribution of companies with international orientation in the sample

Figure 8 shows the number of companies per sector aggregation in the sample from both from knowledge-based services as well as manufacturing and others.

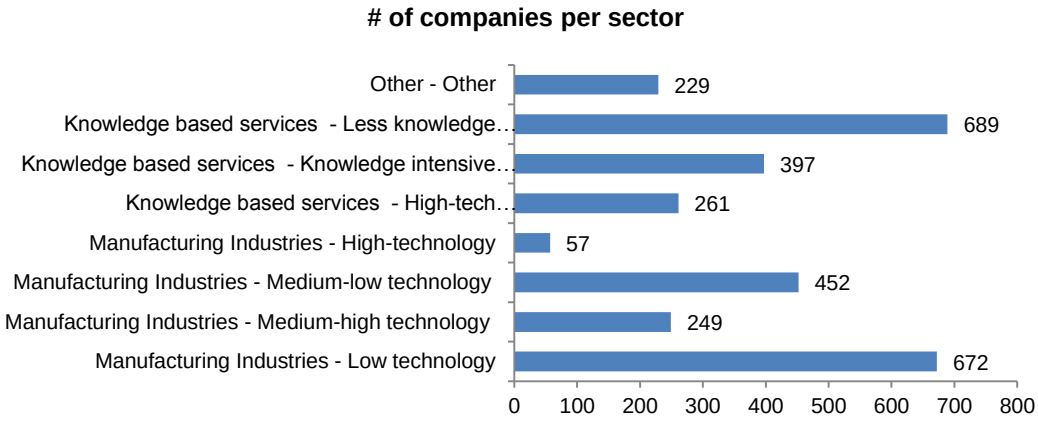

Figure 8 - Number of companies per sector in the sample

4.1.2. Sample Characterization

This section will focus on the description of the open innovation activities that can be derived from the survey.

Construction of the indicators

To study open innovation the framework presented by Ebersberger et al. (2011) is followed. The framework has been used by the other authors to examine open innovation practices and their impact on performance across several countries. It was also later used by Spithoven et al. (2013) to examine these practices in SMEs. The framework consists in the construction of four indicators that represent different open innovation practices (search, sourcing, collaboration and protection) that can be calculated from the CIS 2016 questionnaire and that, according to its authors, is much more complete

than earlier work. These indicators also allow studying these practices in terms of breadth (scope) and depth (intensity). The indicators are then combined to give overall indicators ultimately obtaining an overall open innovation indicator. No distinction is made in terms of importance of each of the practice indicators in the construction of OI. This methodology and the data it draws from, makes it possible to apply to different countries.

The following set of seven indicators that encompass different dimensions of open innovation practices based on the existing information on the CIS survey:

- Search (breadth & depth)
- Collaboration (breadth & depth)
- External sourcing (breadth & depth)
- Protection (breadth).

Search Breadth

The Search breadth indicator follows the approach introduced by Laursen & Salter (2006). The indicator is built is based on the answers each company provides to the question "*7.1 During the three years 2014 to 2016, how important to your enterprise's innovation activities were each of the following information sources*?". Each of the external sources is a binary code where zero is the value if the source of information was not used and one if it was used by the company. The answers are then added up to a total of 11 (the internal information source choice was excluded) so that a company with a score of 11 has used all the information sources in the survey and will have the highest score. Firms with a highest score are more "open" in terms of search breadth than firms that did not.

Information Sources:

a) Within your enterprise or enterprise group (excluded from calculation)
b) Suppliers of equipment, materials, components, or software
c) Clients or customers from the private sector
d) Clients or customers from the public sector
e) Competitors or other enterprises in your sector
f) Consultants or commercial labs
g) Universities or other higher education institutes
h) Government or public research institutes
i) Private research institutes
j) Conferences, trade fairs, exhibitions
k) Scientific/technical journals or trade publications
l) Professional or industry associations

Search Depth

The Search Depth indicator follows the work of Ebersberger et al. (2011) and refers to the intensity to which each of the information sources were used by the respondents. It also follows the same approach as introduced by Laursen & Salter (2006). This indicator is also a sum of several binary

answers drawn from the same question (7.1) but related to the intensity that each of the information sources was used. In this case, if the respondents answered that they used a source and with a high degree of importance, that variable takes the value of one and it takes the value of zero if otherwise. As in search breadth, each of the eleven information sources is then added up in a way that a company that used all of the 11 sources, with a high degree of importance, gets a score of 11 and on the opposite, a firm that although possible having used one or more sources but none to a high extent, gets a score of zero.

Collaboration Breadth

The collaboration breadth indicator follows the work of Ebersberger et al. (2011) and shows how many collaboration partners were used by each firm. The answers were extracted from the question "*7.3 Please indicate the type of innovation co-operation partner by location*". Similarly, to search breadth each of the possible answers (partners) is transformed into a binary variable taking the value one if the firm partnered up with them and zero if not, to a possible total of seven. A high score means that the firm was more "open" in terms of collaboration breadth than another one with a lower score.

Collaboration Partners in the survey:

a) Other enterprises within your enterprise group
b) Suppliers of equipment, materials, components, or software
c) Clients or customers from the private sector
d) Clients or customers from the public sector*
e) Competitors or other enterprises in your sector
f) Consultants or commercial labs
g) Universities or other higher education institutes
h) Government or public research institutes
i) Private research institutes

Collaboration Depth

The Collaboration Depth indicator follows the work of Ebersberger et al. (2011) and demonstrates (to a certain extent) the level of intensity of collaboration with each partner type. It derives from the question "7.3 Please indicate the type of innovation co-operation partner by location" present in the CIS2006. Each partner type is used as a binary variable taking the value of one if, in the answer, the firm states to have collaborated with both a local partner and an international partner and gets the value of zero if otherwise to a total of seven. A high score in collaboration depth means that a company is more "open" in terms of the intensity pf collaboration with partners than another.

Sourcing Breadth

The Sourcing Breadth indicator follows the work of Ebersberger et al. (2011) and intents to show the array of resources that companies decided to acquire or subcontracted in their innovation process. The indicator is built based on the question "*5.1 During the three years 2014 to 2016, did your enterprise engage in the following innovation activities?*" present in the CIS2016. Each of the sources

is converted into a binary variable that takes the value one if the firm engaged with in innovation activities and 0 if not and is then added up to a value of three. The other two variables take the value one if, for product or process innovation development, the company reported to have them exclusively developed by others which can bring overall indicator value up to five. A high value in sourcing breadth means a company used acquired or subcontracted innovation activities and so is more "open" than others with a lesser score.

Sourcing sources in the survey that were used:

a) Your enterprise contracted-out R&D to other enterprises (include enterprises in your own group) or to public or private research organizations
b) Acquisition of advanced machinery, equipment, software and buildings to be used for new or significantly improved products or processes
c) Acquisition of existing know-how, copyrighted works, patented and non-patented inventions, etc. from other enterprises or organizations for the development of new or significantly improved products and processes

Sourcing Depth

The Sourcing depth indicator follows the work of Ebersberger et al. (2011) and demonstrates the intensity of involvement that outside activities have in the innovation process. The objective is to assess both the dependence of third parties on both the acquisition or purchase (through question "*5.2 How much did your enterprise spend on each of the following innovation activities in 2016 only?*") as well as the extent to which product of process innovation were developed by third parties or together with other organizations (through questions *"2.2 Who developed these product innovations?" and "3.2 Who developed these process innovations?*"). The indicator is based on the sum of five binary variables. The first three binary variables take the value of one if the company spent more on each external source than the median of ratio of external expense over the total expense (External R&D; Acquisition of machinery equipment, software& building; Acquisition of existing knowledge from other enterprises or organizations) and zero otherwise. The other two variables take the value one if, for product or process innovation development, the company reported to have done it together with other organizations or they were exclusively developed by others. This way, the indicator can take a maximum value of five meaning that the company was more open in terms of development and acquisition of innovation activities from third parties.

Protection Breadth

The Protection Breadth indicator Ebersberger et al. (2011) shows how many different types of protection measures were used by a company. The idea is that a company can show more openness if it uses these types of measure to share its knowledge to the outside environment, hoping for some strategic advantage. The answers were extracted from the question "*13.1 During the three years 2014 to 2016, did your enterprise:*". Each of the answers is transformed into a binary variable taking the value one if the firm used the protection measure and zero if not up to a total of six.

These seven practices were calculated for each company in the sample and normalized in a 0-10 scale. The following step was to build the three remaining indicators: an overall open innovation breadth indicator, an overall open innovation depth indicator and an overall open innovation indicator that encompasses both breadth and depth according to the following table.

Table 1 - Aggregation open innovation indicators

Indicator	Calculation	Normalization
OI Breadth	For each company: OI Breadth = Average of (Normalized Sourcing Breadth; Normalized Search Breadth; Normalized Collaboration Breadth; Normalized Protection Breadth)	Normalization on a 1-10 scale
OI Depth	For each company: OI Depth = average of (Sourcing depth; Normalized Search Depth)	N/A
OI Total	For each company: OI Total = Average open innovation Breadth; open innovation Depth	N/A

A Chronbach's alpha analysis of the indicators was conducted (Table 2) to assess the reliability and all present a value over 0,6 which is a reasonable good reliability (Ebersberger et al., 2011).

Table 2 - Chronbach's alpha

Item	Alpha
oitotal	0,8221
oibreadth	0,8311
oidepth	0,8363
norm_cd	0,8548
norm_sed	0,8659
norm_sod	0,8878
norm_cb	0,8512
norm_seb	0,8652
pb	0,8769
norm_sob	0,8594

Indicators in the Dataset

Sourcing

From the 3006 innovative firms in the sample there are 2253 (75%) that developed Sourcing activities during the period from 2014 to 2016 with the following distribution (*Figure 9*) in terms of average score between breadth and depth.

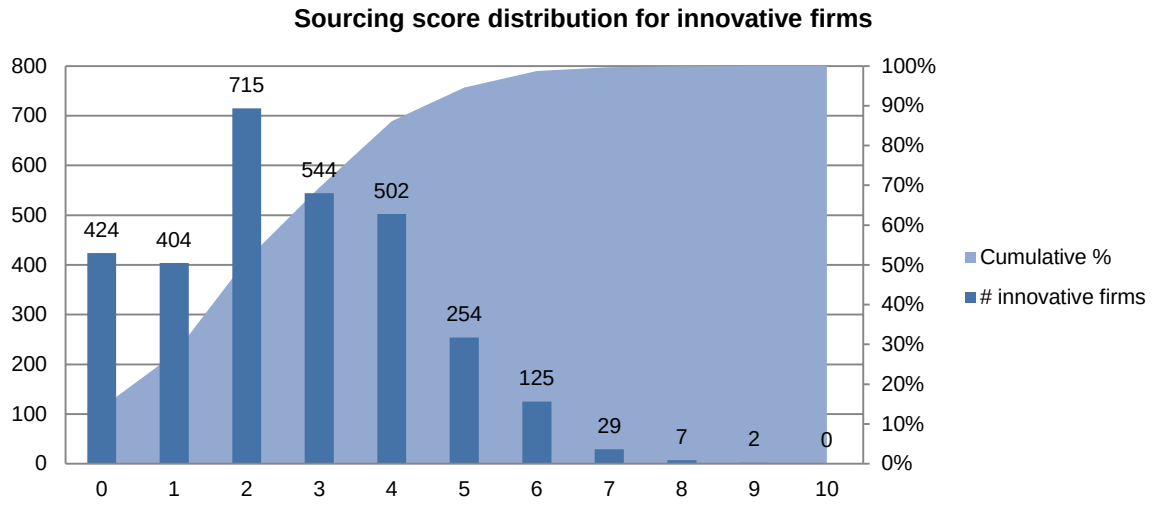

Figure 9 - Sourcing score distribution for innovative firms in the sample

The data in Table 3 illustrate the Sourcing Breadth by the activities that Portuguese firms recur to the most. It is possible to see that the acquisition of machinery, equipment, software & buildings to be used in new or significantly improved products or processes (65%) is the most common activity while the other two shows lower levels of adoption.

Table 3 - Sourcing Activities in the sample

Sourcing Activities	% of innovative companies practicing	Weight of activity in sourcing practicing firms
External R&D (contracting R&D)	29%	38%
Acquisition of machinery, equipment, software & buildings	65%	86%
Acquisition of existing knowledge from other enterprises or organizations	19%	26%

In terms of Sourcing Depth there are 1499 (49,9%) of the 3006 companies in the sample that have spent more than the median value of the Share of external over total expense (18,7%) and that so can be considered to have a high depth in Sourcing activities.

Collaboration

From the 3006 innovative firms in the sample, there were 838 (28%) that reported having conducted collaboration activities with the following distribution (*Figure 10*) in terms of average score between breadth and depth.

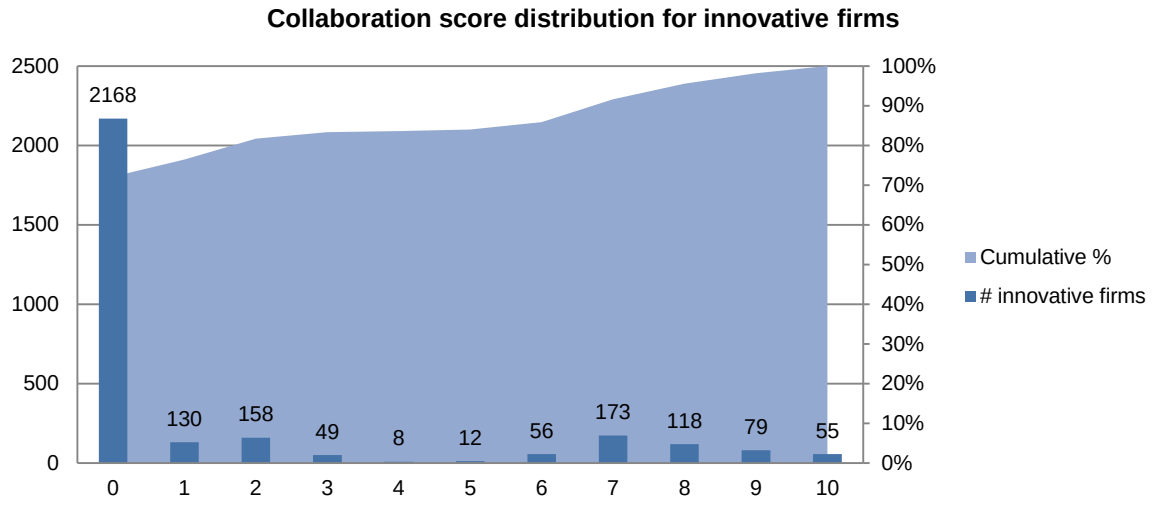

Figure 10 - Collaboration score distribution for innovative firms in the sample

The data illustrate (Table 4) that in terms of collaboration breadth there are a variety of different partners being used by companies and the highest levels of collaboration are practiced with business partners (suppliers and customers from the private sector, 65 and 55% respectively) as well as Universities or other higher education institutes (53%).

Table 4 - Collaboration activities in the sample

Collaboration Partners	% of companies practicing	Weight of activity in collaboration practicing firms
A. Other enterprises within your enterprise group	36%	10%
B. Suppliers of equipment, materials, components, or software	66%	19%
C. Clients or customers from the private sector	55%	15%
D. Clients or customers from the public sector*	21%	6%
E. Competitors or other enterprises in your sector	29%	8%
F. Consultants or commercial labs	30%	8%
G. Universities or other higher education institutes	53%	15%
H. Government, public or private research institutes	26%	7%
I. Private research institutes	24%	7%

In terms of Collaboration depth we can extract that 481 (16%) of the total sample were considered to have a high degree of collaboration since they collaborated in the period with both a local and an international partner, or 57% of the companies that have reported collaboration (*Figure 11*).

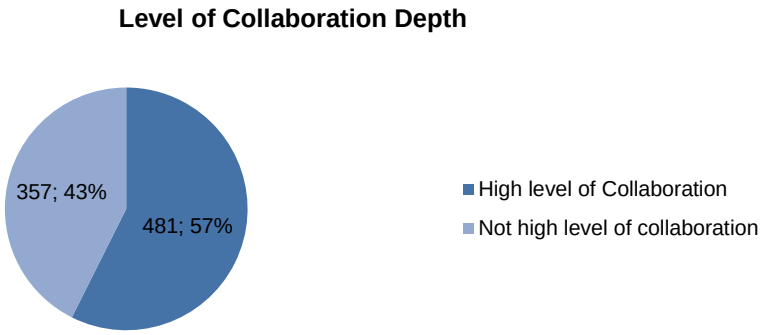

Figure 11 - Level of Collaboration Depth in the sample

Search

From the 3006 innovative firms, there were 2936 (98%) that reported having conducted Search activities with the following distribution (*Figure 12*) in terms of average score between breadth and depth.

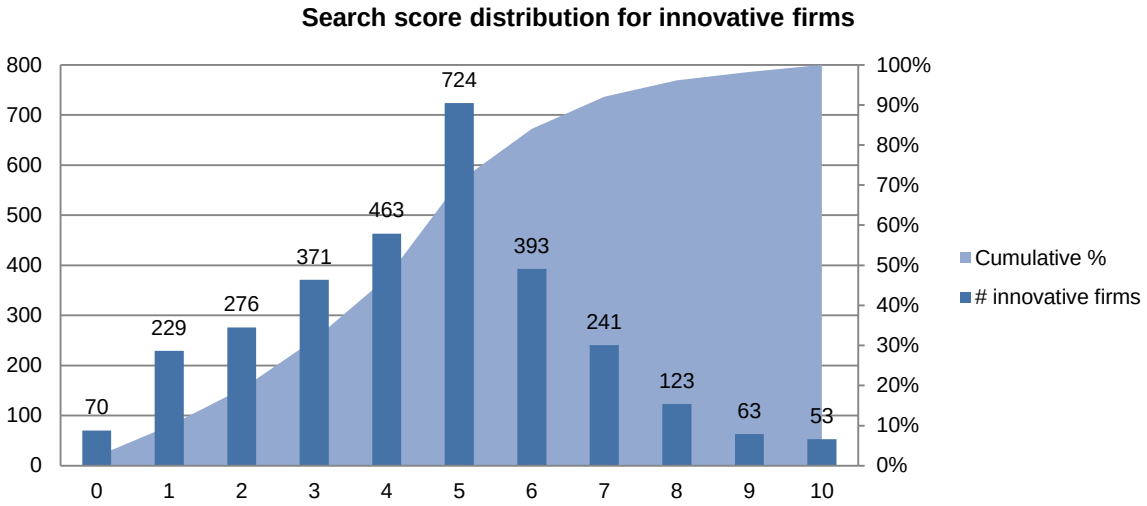

Figure 12 - Search score distribution for innovative firms in the sample

It is possible to see in Table 5 that the majority (94%) of the companies look for solutions internally. It is also interesting to see that in line with the findings in collaboration, one of the main search channels to find innovation is business partners - suppliers or clients - in the private sector (89% and 85% respectively) while on the contrary the search in Universities in relatively low (50%).

Table 5 - Search Breadth in the sample

Search Sources	% of companies practicing	Weight of activity in search practicing firms	Average Search Intensity
Within your enterprise or enterprise group	94%	96%	high
Suppliers of equipment, materials, components, or software	89%	91%	medium
Clients or customers from the private sector	85%	87%	medium
Clients or customers from the public sector	56%	57%	medium
Competitors or other enterprises in your sector	77%	79%	medium
Consultants or commercial labs	62%	64%	medium
Universities or other higher education institutes	50%	52%	low
Government or public research institutes	40%	41%	low
Private research institutes	39%	40%	low
Conferences, trade fairs, exhibitions	79%	81%	medium
Scientific/technical journals or trade publications	71%	73%	medium
Professional or industry associations	69%	70%	medium

In terms of intensity the level of depth (high being a score of 3, medium of 2, low of 1 and none of 0) the use of the different channel is in line with the breadth findings. The ones that are used with the highest level of intensity are the ones most sought by companies.

Protection

From the 3006 innovative firms, there were 908 (30%) that reported having conducted any form of IP activities (solely Protection Breadth) with the following distribution (*Figure 13*):

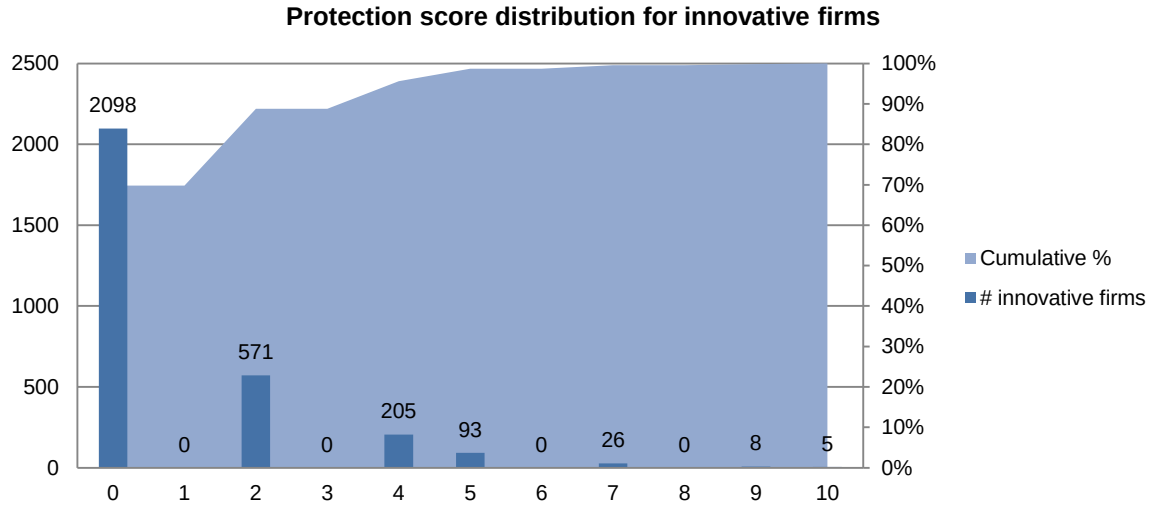

Figure 13 - Protection score distribution for innovative firms in the sample

In Table 6 terms of protection breadth, it is possible to see that trademarks are by far the preferred protection activity chosen by 70% of the firms that applied some form of protection measure. It is not possible to extract a depth measurement of protection based on the survey questions.

Table 6 - Protection activities in the sample

Protection Activities	% of companies practicing	Weight of activity in Protection practicing firms
Apply for a patent	8,3%	28%
Apply for an utility mode	2,5%	8%
Register an industrial design right	4,0%	13%
Register a trademark	21,0%	70%
Use trade secrets	6,2%	20%
Claim copyright	5,7%	19%

4.2. Variables and Model

4.2.1. Dependent Variables

This study focuses on innovation performance and so, on the outcome dimension of innovation and not on the innovation process and its prevalence as a measure of innovation success. This is important as the dependent variables are both related to the outcome of the innovation process. As mentioned before, there are two measures that provide us with a quantitative view on innovation performance: the introduction of innovation novelty (in this case product or service novelty and the share of sales accounted for by product innovations following the works of Ebersberger et al. (2011) & Spithoven et al. (2013).

The share of sales accounted for by product innovations "can be defined as the share of a firm's total sales in the reference year that respondents estimate is due to product innovations" and is an indicator of the economic significance of product innovations at the level of the innovative firm (OECD/Eurostat, 2019). It is a percentage variable that represents the percentage of turnover that was reported by the company as belonging to new or significantly improved products introduced to their market during the specific period. Note: The rest of the turnover percentage belongs to products only new to the company (not novelties to the market) and the turnover from unchanged or only marginally modified ones.

The introduction of product novelty serves to see if a company has introduced product that were new to their market. This variable is binary taking the value of "0" if the company did not introduce a new or significantly improved product onto their market before their competitors and the value "1" if they did.

Table 7 - Dependent Variables summary

Designation	Description	Values
NEWMKT	Implemented product novelty	0-No 1-YES
TURNMAR	% of turnover from product novelty	%

4.2.2. Independent Variables

The independent variables are characteristics of the firms that, as was shown in the context dependency of open innovation, have impacts on the outcomes of open innovation to some degree. The larger the number of variables introduced; the less error will be present at the model. The following independent variables were chosen:

Table 8 - Independent Variables summary

Designation	Description	Calculation Method
OI Total indicator	Implementation of OI practices	Average of: OI breadth indicator, OI depth indicator
OI Breadth indicator	Implementation of OI breadth practices	Average of sourcing breadth indicator, external search breadth, collaboration breadth, and protection breadth
OI Depth indicator	Implementation of OI depth practices	Average of sourcing depth indicator, external search depth, and collaboration depth
Sourcing Breadth indicator	Number of different activities that the firm invested in	Range from 0 to 7. 0 if only In-house R&D; +1 per each other option (external R&D; acquisition of machinery, acquisition of existing knowledge, …)
Sourcing Depth indicator	The extent to which firms draw from the different activities that the firm invested in	1 if turnover higher than median - and if innovation is exclusively developed exclusively by outside actors);
External Search Breadth	Number of external sources or search channels that firms rely upon in their innovative activities	Range from 0 to 12. For each source: 0 if "within your enterprise or enterprise group"; +1 per each other source (e.g. suppliers of equipment, materials, clients, or customers from the private sector, etc)
External Search Depth	The extent to which firms draw deeply from the different external sources or search channels (Laursen & Salter, 2006)	Range from 0 to 12. +1 per source with high degree of importance, 0 if any other option.
Collaboration Breadth	Number of external sources that were used in a “co-ordinated activity across different parties to address jointly defined problem, with all partners contributing.” Oslo Manual	Range from 0 to 9. For each source: 0 if no options chosen; +1 per each other source (e.g. Other enterprises within your enterprise group; Suppliers of equipment, materials, components, or software; etc.)
Protection Breadth		Range from 0 to 6. For each option: +0 if "No", +1 if "yes"

The first three variables refer to open innovation and are the focus of this study and are used to test the hypotheses.

4.2.1. Control Variables

Several control variables were added to the model that are extensively used in the literature and that were available in solely in the CIS2016 survey (single source of data).

R&D intensity (RD_I) – A measure of R&D intensity is added to the model calculated as the R&D expenditure of each firm divided by its sales to control the effect of internal R&D on innovation

performance as used by Laursen & Salter (2006). “Several authors have pointed out that companies with a strong basis in R&D are more open to knowledge created outside their boundaries and are also more capable of integrating this external knowledge in their internal, state-of-the-art body of knowledge (H. Chesbrough, W. Vanhaverbeke, 2006). Hence, these companies are generally considered to be very open and highly innovative (Cassiman & Veugelers, 2006; Spithoven et al., 2013).

Part of a corporate group (GP) – This variable has the value 1 if the company in the sample is part of a group, and the value of 0 if the firm operates as a standalone company.

International orientation (IO) – This variable indicates the firm’s willingness to do business in other geographic markets (besides its home market) and is captured by its degree of internationalization. The variable is a dummy variable that has the value of 1 if the firm reports having sold to foreign markets within Europe and/or other parts of the world in the period.

Firm size (FS) – is a variable that takes the value of 0 if the firm is a small or medium sized enterprise (employing fewer than 250 employees) and 1 if the firm is a large company (employing more than or equal to 250 employees)

Sector – The sector, which the firm is a part of, is taken into account in the model according to the OECD classification and as used by Ebersberger et al. (2012). These seven sector control variables were left out of the regression model Table 11 for presentation reasons although they were introduced in the model. They are excluded from the presentation as was the case in (Ebersberger et al., 2012)

- Manufacturing Industries - Low technology (MLT)
- Manufacturing Industries - High-technology (MHT)
- Manufacturing Industries - Medium-low technology (MMLT)
- Manufacturing Industries - Medium-high technology (MOTH)
- Knowledge based services - Less knowledge intensive services (LKIS)
- Knowledge based services - Knowledge intensive services (KIS)
- Knowledge based services- High-tech knowledge intensive services (HTKIS)
- Other – Other (OTH)

4.2.2. Model

Since the dependent variable Product Novelty (newmkt) is a binary one, taking the value 0 if no product novelty was introduced or 1 if there were, a logistic regression model can be applied. As for the share of sales from innovation (Turnmar), since it is a fraction between 0 and 1 (including the limit values), we can apply a fractional logit model as developed by Papke (1996).

For the binary dependent variable (product novelty) a probit model can be used. In this model,

Prob $(Y = 1 \mid X) = F(X'\beta)$ (1)

Prob $(Y = 0 \mid X) = 1 - F(X'\beta)$ (2)

Where Prob $(Y_i = 1)$ is the probability of a positive outcome (introduction of product novelty) and Prob $(Y_i = 0)$ or $[\mathbf{1} - (\boldsymbol{P}_i = \mathbf{1})]$ represents the probability of a negative outcome (no introduction of product novelty). This function is given by:

Prob $(Y = 1 \mid X) = \int_{-\infty}^{x'\beta} \phi(t)dt = \Phi(x'\beta)$ (3)

And since several explanatory variables will be used in the probit model, the generalized form will be:

$E(Y \mid X) = P(Y = 1 \mid X) = \Phi(\beta_0 + \beta_1 X)$ (4)

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + u$ (5)

Prob $(Y = 1 | X_1, X_2, \ldots, X_k) = \Phi(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k)$ (6)

where β representing the control variables' coefficients, x the control variables and u being the associated error. The estimation of the parameters β is done via a method of maximum likelihood estimation. "Each observation is treated as a single draw from a Bernoulli distribution (binomial with one draw). The model with success probability F(x'β) and independent observations leads to the joint probability, or likelihood function.

Prob $(Y_1 = y_1, Y_2 = y_2, \ldots, Y_n = y_n | X) = \prod_{y_i=0}[1 - F(x'_i\beta)] \prod_{y_i=1} F(x'_i\beta)$ (7)

Where X| denotes $[x_i]_{i=1,\ldots,n.}$ the likelihood function for a sample of n observations can be conveniently written as

$L(\beta | data) = \prod_{i=1}^{n}[F(x'_i\beta)]^{y_i}[1 - F(x'_i\beta)]^{1-y_i}$ (8)

Taking logs, we obtain

$\ln L = \sum_{i=1}^{n}\{y_i \ln(F(x'_i\beta) + (1 - y_i)\ln[1 - F(x'_i\beta)])\}$ (9)

The other dependent variable is the share of sales is a ratio and so the fractional logit model developed by Papke (1996). Fractional models also admit values between 0 and 1 but allow for all possible values in that interval. The model states the conditional expectation of the fractional response variable:

$E(y_i | x_i) = G(x_i\beta), i = 1, \ldots, N,$ (10)

where 0 ≤ yi ≤ 1 denotes the dependent variable and (the 1 × k vector) xi refers to the explanatory variables of observation i. This model follows a link function very similar to the logit regression taking the following form:

$E[y \vee x] = \frac{\exp(x\beta)}{1+\exp(x\beta)}$ (11)

With the difference that the y variable can take on values in the unit interval. Since $G(x_i\beta)$ is chosen to be a cumulative distribution function (cdf) the β can be estimated by a quasi-likelihood method using the log-odds ratio.

$$l_i(b) \equiv y_i \log[\, G(x_i\beta)] + (1 - y_i) log[1 - \, G(x_i\beta)] \quad (12)$$

5. Results

A brief description of the statistical information is introduced in the chapter leading to the presentation of the regression results and marginal effects for each of the models run. Finnaly a summary of the results is presented.

5.1. Descriptive Statistics

The following table provides information that characterizes sample used in the analysis and that is worth to view in further detail. From the 6775 firms that answered the survey the ones that did not report having introduced any good or service innovation (inpdgd, inpdsv) were excluded leaving a total of 3006 observations. In this sample, 54% of companies reported to have introduced a new or significantly improved product in their market before their competitors (newmkt). The average percentage of turnover from new or significantly improved new to the market products introduced during the period is of 9% of the total turnover (turnmar).

In terms of the innovation activities:

Collaboration - It is possible to see that the Portuguese companies in the sample use a low average number of collaboration sources (mainly one) and a low average intensity of collaboration.

Search - Portuguese companies in the sample use a high number of different sources (more than seven) but with limited intensity on each source.

Protection – We see a low score in terms of different means of protection measures which was expected as these are not widely extended practices in Portugal.

Sourcing - It is possible to see an average of almost two sources of sources of external innovation and a low level of intensity of outside contribution.

Table 9 - Descriptive statistics for each variable

	mean	sd	min	max
Market Novelty (Newmkt)	0,5376	0,4987	0	1
Share sales of novelty (Turnmar)	0,0855	0,1397	0	1
Open innovation global indicator (Oitotal)	2,2812	1,4106	0	8,19
Open innovation breadth indicator (Oibreadth)	3,0737	1,5621	0	9,72
Open innovation breadth indicator (Oidepth)	1,4896	1,5687	0	8
Collaboration breadth indicator	0,9441	1,9149	0	9
Collaboration depth indicator	0,1600	0,3667	0	1
Search breadth indicator	7,1643	3,3383	0	11
Search depth indicator	1,7974	2,1931	0	11
Protection breadth indicator	0,4770	0,8824	0	6
Sourcing breadth indicator	1,9687	1,3515	0	5
Sourcing depth indicator	0,6164	0,6584	0	4
Part of a group (1 if part of a group)	0,3194	0,4663	0	1
R&D intensity	0,0194	0,0711	0	0,83
International orientation	0,7485	0,4339	0	1
Company Size (1 if large company)	0,9335	0,2493	0	1
Low tech company	0,2236	0,4167	0	1
High tech company	0,0190	0,1364	0	1
Medium low-tech company	0,1504	0,3575	0	1
Medium high-tech company	0,0828	0,2757	0	1
Other	0,0762	0,2653	0	1
Knowledge intensive services company	0,1321	0,3386	0	1
High tech knowledge intensive services company	0,0868	0,2816	0	1
Low tech services company	0,2292	0,4204	0	1

Number of observations: 2998. Eight firms were excluded from the sample due to inconsistent information.

After normalizing the indicators on a scale of 0-10, the following average results are obtained:

Table 10 - Activity average score

Activity average score (Breadth and Depth)	Score (0-10 scale)	Level
Sourcing	**2,6**	**Low**
Collaboration	**1,3**	**Low**
Search	**4,1**	**Medium**
Protection	**0,8**	**Low**
OI Total	**2,3**	**Low**

A Spearman correlation matrix (Table A14) was used to investigate multicollinearity and found no value between the different activities to be over 0,4 threshold (Spithoven et al., 2013). For the aggregated indicators, several regressions were run excluding some of the separate activity variables

(for example, there were models run with the open innovation breadth indicator excluding one of the activities) and the consistency remained.

5.2. Regression results and marginal effects

Several regressions were run to test the hypothesis related to both dependent variables and the distinct open innovation practices. Results in all the regressions came out statistically significant. The positive and significant coefficients demonstrate that the variable contributes to increase the probability of improving the introduction of innovation (newmkt) or the success of these in terms of sales (turnmar). The marginal effects give a dimension of increased of the probability.

The following models were built and tested:

- Model 1 shows the probit regression related to the introduction of novelty in the overall open innovation indicator
- Model 2 shows the probit regression related to the introduction of novelty in the overall breadth indicator and the overall depth indicator.
- Model 5 shows the probit regression related to the introduction of novelty using the overall breadth indicator and splitting the open innovation depth practices into each of the four open innovation activities (Collaboration, Search, Sourcing, Protection).
- Model 6 shows the probit regression related to the introduction of novelty using the overall depth indicator and splitting the open innovation breadth practices into each of the four open innovation activities (Collaboration, Search, Sourcing, Protection).
- The same rationale was made in models 3 and 4 and then in models 7 and 8 but using a fractional probit regression.

Since both models are non-linear and so, since the coefficients magnitude analysis may lead to wrong conclusions, the average marginal effects (AME) are also calculated.

The p value shows the significance level which commonly used in statistics. In case the p value is significant compared to a chosen limit (usually 1%, 5%, 10%) which means that the probability that the improvement seen is due to the model's variables and not by chance and that thus we can reject the null hypothesis. As also extensively used in statistics a limit of 1% 5% and 10% was chosen from the chi-square test as a baseline. The pseudo R^2 is used in maximum likelihood estimations (MLEs) instead of the R^2 used in ordinary least squares (OLS). The main difference is that in an OLS regression model the parameters are found so that the sum of squares errors is minimized while in an MLE the estimation seeks to choose those estimates that maximize the probability of obtaining the observed probability (Cabrera, 1994). In a probit regression a pseudo R^2 means the proportion of error variance that is reduced by the model compared to the null hypothesis model (Cabrera, 1994).

In terms of model fit, all models have a p value of 0,000 which is a very good indication that the variables are mutually exclusive.

Table 11 shows the coefficients and gives us information on the positive or negative impact of each independent variables but not of its measure. To have a perception of the magnitude of effect of each variable Table 12 shows the marginal effects which represent the expected change in outcome probability associated with a discrete one unit increase in the indicator. Since we are conducting a probit regression the coefficients do not show the rate of change in the dependent variables as the independent variables change, but rather the rate of change in the log-odds as the independent variables change.

Table 11 - Probit and Fractional Probit regressions explaining innovation performance in Portuguese companies in the sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Probit newmkt	Probit newmkt	Probit newmkt	Probit newmkt	Fracreg turnmar	Fracreg turnmar	Fracreg turnmar	Fracreg turnmar
Oi Total	**0.147*** **				**0.049*** **			
	(0.018)				(0.011)			
OI Breadth		**0.139*** **	**0.150*** **			**0.044** **	**0.048*** **	
		(0.020)	(0.020)			(0.014)	(0.014)	
OI Depth		0.010		-0.004		0.006		0.004
		(0.019)		(0.022)		(0.013)		(0.015)
Collaboration Depth			**0.017***				0.007	
			(0.008)				(0.005)	
Search Depth			-0.001				-0.002	
			(0.013)				(0.009)	
Sourcing Depth			**-0.090*** **				**-0.035** **	
			(0.019)				(0.013)	
Collaboration Breadth				**0.061*** **				0.014
				(0.016)				(0.010)
Search Breadth				0.012				-0.005
				(0.008)				(0.006)
Protection Breadth				**0.135*** **				**0.056*** **
				(0.019)				(0.010)
Sourcing Breadth				**0.020***				0.010
				(0.010)				(0.006)
Part of a Group	0.041	0.037	0.006	0.043	**-0.096** **	**-0.097** **	**-0.110** **	**-0.091***
	(0.054)	(0.054)	(0.055)	(0.055)	(0.037)	(0.037)	(0.037)	(0.037)
R&D Intensity	**2.296*** **	**2.229*** **	**1.840*** **	**2.064*** **	**0.922*** **	**0.913*** **	**0.793*** **	**0.832*** **
	(0.469)	(0.465)	(0.466)	(0.473)	(0.228)	(0.229)	(0.235)	(0.229)
International Orientation	0.073	0.075	0.063	0.052	**0.105** **	**0.106** **	**0.100** **	**0.096***
	(0.057)	(0.057)	(0.057)	(0.057)	(0.039)	(0.039)	(0.039)	(0.039)
Size (1 if large company)	-0.120	-0.105	-0.066	-0.110	**0.163***	**0.167***	**0.186** **	**0.158***
	(0.101)	(0.101)	(0.102)	(0.102)	(0.070)	(0.070)	(0.069)	(0.070)
Constant	-0.200	**-0.315***	-0.242	-0.153	**-1.753*** **	**-1.788*** **	**-1.758*** **	**-1.700*** **
Observations	2998	2998	2998	2998	2998	2998	2998	2998
p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R-squared	0.043	0.046	0.053	0.056	0.019	0.019	0.021	0.023
Standard errors in parentheses								

Note:

There were seven sector control variables (p. 47) that were left out for presentation reasons although they were introduced in the model. They are excluded from the presentation as was the case in (Ebersberger et al., 2012)

* p<0.05 ** p<0.01 *** p<0.001"

Table 12 - Marginal effects for both dependent variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Probit newmkt	Probit newmkt	Probit newmkt	Probit newmkt	Fracreg turnmar	Fracreg turnmar	Fracreg turnmar	Fracreg turnmar
Oi Total	**0.056*** **				**0.007*** **			
	(0.007)				(0.002)			
OI Breadth		**0.052*** **	**0.056*** **			**0.007** **	**0.007*** **	
		(0.007)	(0.007)			(0.002)	(0.002)	
OI Depth		0.004		-0.002		0.001		0.001
		(0.007)		(0.008)		(0.002)		(0.002)
Collaboration Depth			**0.006***				0.001	
			(0.003)				(0.001)	
Search Depth			-0.000				-0.000	
			(0.005)				(0.001)	
Sourcing Depth			**-0.034*** **				**-0.005** **	
			(0.007)				(0.002)	
Collaboration Breadth				**0.023*** **				0.002
				(0.006)				(0.001)
Search Breadth				0.005				-0.001
				(0.003)				(0.001)
Protection Breadth				**0.051*** **				**0.009*** **
				(0.007)				(0.002)
Sourcing Breadth				**0.007***				0.002
				(0.004)				(0.001)
Part of a Group	0.015	0.014	0.002	0.016	**-0.015** **	**-0.015** **	**-0.017** **	**-0.014***
	(0.021)	(0.020)	(0.021)	(0.021)	(0.006)	(0.006)	(0.006)	(0.006)
R&D Intensity	**0.870*** **	**0.842*** **	**0.689*** **	**0.771*** **	**0.141*** **	**0.140*** **	**0.122*** **	**0.127*** **
	(0.176)	(0.174)	(0.174)	(0.175)	(0.035)	(0.035)	(0.036)	(0.035)
International Orientation	0.028	0.028	0.024	0.019	**0.016** **	**0.016** **	**0.015** **	**0.015***
	(0.022)	(0.021)	(0,021)	(0.021)	(0.006)	(0.006)	(0.006)	(0.006)
Size (1 if large company)	-0.045	-0.040	-0.025	-0.041	**0.025***	**0.026***	**0.028** **	**0.024***
	(0.038)	(0.038)	(0.038)	(0.038)	(0.011)	(0.011)	(0.011)	(0.011)
Observations	2998	2998	2998	2998	2998	2998	2998	2998
p value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R-squared	0.043	0.046	0.053	0.056	0.019	0.019	0.021	0.023
Standard errors in parentheses								

Note:

T There were seven sector control variables (p. 47) that were left out for presentation reasons although they were introduced in the model. They are excluded from the presentation as was the case in (Ebersberger et al., 2012)

* p<0.05 ** p<0.01 *** p<0.001"

5.2.1. Open innovation total, breadth, and depth and the introduction of novelty

In the regression analysis (Table 11), in model 1 it is possible to see that the overall open innovation indicator is statistically significant and has a positive effect on the tendency to introduce novel innovations. The marginal effects (Table 12) give an idea of the magnitude of increase or decrease (depending on the signal) - in percentage points - that an increase in each of the independent variables has on the probability of either introducing novelty to the market (newmkt), or of increasing the share of sales of these novelties in the total sales. The results show that an increase of 1 point in the score of the open innovation total indicator means an increase of 5% of the probability of introducing a new product/service. Overall, the marginal effects show that strategies that combine several elements result in having a greater probability of introducing market novelty more than each of the open innovation practices individually.

In model 2 the use of the total open innovation practices are broken down into its breadth component and its depth component. Open innovation breadth is significant and has a positive impact on novel innovativeness while open innovation depth not significant.

In the control variables, to be part of a group, company size and the international orientation of a firm appear to be insignificant for the introduction of new products to the market while R&D intensity has a positive impact both variables which is an indication that the internal capability of the companies to invest in R&D is still important for innovation performance. A 1% increase in R&D intensity increases the probability of introducing market novelty by 8,7%.

5.2.2. Open innovation breadth and depth activities and the introduction of novelty

In these models, the dependent variable is the same as in model 1 and 2 but each of the breadth and depth indicators is drilled down into each of the open innovation practices.

In the regression analysis (Table 11), in model 3 the depth activities are decomposed and it can be noted that Sourcing Depth actually has a negative impact on the probability of introducing novelty to the market while collaboration Depth has a positive one.

When separating the breadth activities in model 4 it is possible to see that all activities (except for search) have a positive impact on the probability of introducing novelty to the market. This means companies are more likely to introduce innovative products or services if they pursue collaboration arrangements, if they source the market for innovation and if they protect their innovation with IP-Protection activities (such as trademarks, patents, etc.). Companies that have a collaboration strategy

in place have an increase on the predicted probability of introducing new products or services of 2,2%, while companies that rely of protective strategies on their IP have an increase in probability of 5%.

In the control variables only the R&D intensity has a significantly positive impact on the introduction of novelty to the market.

5.2.3. Open innovation total, breadth, and depth and the share of innovative sales

In these models the dependent variable is the share of sales originated from the introduction of new products or services in the market (Turnmar).

In the regression analysis (Table 11), Model 5 is built to show an overall measure of open innovation while in model 4 they are separated in both breadth and depth. In model 5 it is possible to see that the open innovation overall indicator is highly significant and has a positive effect on generating innovative sales. When separating in both breadth and depth in Model 6, only breadth has a significant and positive effect, which is in line with the findings of the models related to the introduction of novelty.

As we can see by the marginal effects (Table 12) an increase of 1 point in the score of the open innovation total indicator means an increase of 0,7% of the probability of increasing one percentage point in the sales of innovative products on the overall sales.

In the control variables, similarly to model 1 and 2, R&D intensity has a significantly positive impact on the introduction of novelty to the market but, on the contrary to these models, international orientation and to be a SME has a significant positive impact. To be part of a group is also significant but contributing negatively to the performance of innovation introduced in the market in terms of sales. A 1% increase in R&D intensity increases the probability of generating innovative turnover by 14,1%. To be part of a group decreases the by 1,4% but, in turn, to be internationally oriented increases the probability of generating innovative turnover by 1,6%. To be a large company increases the probability of generating innovative turnover by 2,5%.

5.2.4. Open innovation breadth and depth activities and the share of innovative sales

In these models the dependent variable is the same as is models 5 and 6 but separating in each model the breadth and depth into each of its activities.

When separating the depth activities in model 7 it is possible to see that the only significant activity is Sourcing depth with a negative impact on novel innovative sales which is in line with the findings in terms of introduction of novelty to the market (model 3).

In model 8 only protection breadth is found to be significant and positive on novel innovative sales. This means that companies are more likely to increase sales of innovative products or services if they use protective measures on their intellectual property.

In the control variables, the results found are in line with the ones found on models 5 and 6.

5.2.5. Summary of the results

Since in Model 1 the overall open innovation indicator is positive and statistically significant, this means open innovation influences the propensity to start novel innovations and in model 5 the open innovation overall indicator is highly significant and has a positive effect on generating innovative sales. Thus H1 (The use of open innovation practices in Portuguese companies improves innovation performance) can be supported.

Since in Model 2 and Model 3 open innovation breadth is significant and has a positive impact on novel innovativeness, and in Model 6 and Model 7 open innovation breadth has a significant and positive effect, H2 (The breadth of open innovation practices in Portuguese companies improves innovation performance) can be supported.

Since in Model 2, Model 4, Model 6 and Model 8 open innovation depth is not significant, H3 (The depth of open innovation practices in Portuguese companies improves innovation performance) cannot be supported.

In Model 3 and Model 7 Search Depth is not significant and in Model 4 and Model 8 Search Breadth is not significant either. This means that H4 (The use of open innovation search - both in terms of breadth and depth - in Portuguese companies improves innovation performance) cannot be supported.

In Model 3 and Model 7 Sourcing Depth is significant and negative and in Model 4 and Model 8 Sourcing Breadth is only positive and significant for the introduction of novelty. This means that H5 (The use of open innovation sourcing - both in terms of breadth and depth - in Portuguese companies improves innovation performance) can only partially be supported.

In Model 3 and Model 7 Collaboration Depth significant and positive only for the introduction of novelty and in Model 4 and Model 8 Collaboration Breadth is only positive and significant for the introduction of novelty. This means that H6 (The use of open innovation collaboration - both in terms of breadth and depth - in Portuguese companies improves innovation performance) can partially be supported on the introduction of novelty as a measure of performance but not in the innovative sales share performance.

In Model 4 and Model 8 Protection Breadth is both positive and significant for both dependent variables. This means that H7 (The use of open innovation protection in Portuguese companies improves innovation performance) can be supported.

Table 13 - Summary of hypotheses results

Hypothesis	Result
H1: The use of OI practices in Portuguese firms improves innovation performance.	Supported
H2: The breadth of OI practices in Portuguese firms improves innovation performance.	Supported
H3: The depth of OI practices in Portuguese firms improves innovation performance.	Not supported
H4: The use of open innovation search (both in terms of breadth and depth) in Portuguese firms improves innovation performance.	Not supported
H5: The use of open innovation sourcing (both in terms of breadth and depth) in Portuguese firms improves innovation performance.	Partially supported
H6: The use of open innovation collaboration (both in terms of breadth and depth) in Portuguese firms improves innovation performance.	Partially supported
H7: The use of open innovation protection in Portuguese firms improves innovation performance.	Supported

6. Conclusion

Open innovation practices and especially its impact on innovation performance remains a subject of interest within the management studies due to its difficult of measuring and due to the context dependency of its outcomes.

The main conclusion of this work is the relevance of open innovation practices in Portuguese firms for their innovation performance which builds on former studies done in Portugal as will be discussed in the following chapter. As was shown in the results obtained, it was possible to validate that the use of open innovation practices by Portuguese firms improves their innovation performance. It was also possible to conclude that not all activities contribute to the improvement of innovation performance which leads to the conclusion that a broad strategical approach can have better innovation performance results, possibly due to the number of external factors (context dependency) that affect the open innovation activities.

Extending these conclusions, it is relevant to make a comparison to the main study done in Portugal concerning open innovation and subsequently a comparison to other EU countries also with comparable results.

6.1. Prevalence of open innovation in Portugal

There are certain conclusions that can be drawn from comparing the results obtained in this work to the ones on the main study on open innovation in Portugal by Teixeira & Lopes, (2012). Nevertheless the conclusions should be drawn with caution as the survey methodologies are different, the open innovation activities are not directly comparable and especially since the types of companies in their sample were chosen from an innovation dynamic pool of companies.

In this work's sample only 24% (4.1.1) of the firms had an overall OI score over 3 out of 10 which show a fairly low open innovation score (measured as an average of open innovation breadth and depth). These overall findings are in line with the overall findings of Teixeira & Lopes (2012) who found a low level of use of open innovation activities within the innovation processes. Also in line with Teixeira & Lopes (2012) findings it is possible to see that the inbound activities (search and sourcing) are much more prevalent than outbound activities.

In terms of activities performed by the innovative companies, there are certain signs that differ from the findings of Teixeira & Lopes, (2012). In their work the authors separate between "Search and Sourcing" which could be compared to the Search and Sourcing indicators in this work and "Transfer of technology to other organizations" which could be compared to the Protection indicator. The authors found that 84,3% used search and sourcing and that more than 50% used it more than sporadically. Of the innovative firms analyzed in the sample, 98% recurred to search activities although only 30% of these had a Search score (breadth and depth) over 5. In terms of Sourcing 75% of the firms reported

this activity but only 5% had a Sourcing score (breadth and depth) over 5. These results could at first depict a slight decrease in terms of use of these open innovation activities but since as the companies in this work's sample are randomly picked and do not belong to an innovative dynamic pool they could be in line with the findings (although it is not possible to make that conclusion). In terms of Protection, Teixeira & Lopes (2012) found that only 11,4% of firms had recurred to the transfer of knowledge and technology to other organizations while in this work's sample, 15% of the companies applied for a patent, apply for an utility model and registered an industrial design right potentially to then make it available to third party organizations. These findings are also in line with Carvalho & Moreira's (2015) findings for SME and that there is a low presence of protection activities.

6.2. Comparison of prevalence of open innovation with other countries

Since this work uses the framework that was presented by Ebersberger et al. (2011), a chapter is dedicated to the comparison of the results found for other European countries.

6.2.1. Introduction of novelty

Although the comparisons may require certain care in the analysis since the questions in the CIS are not always the same, there are some conclusions that can be drawn. Open innovation practices in Portugal have a positive effect on the introduction of market novelty aligned with Belgium, Denmark, and Norway (Austria did not show a statistically significant result). When drilling down into the breadth component, the findings for Portugal are aligned with these three countries in significance and signal. In terms of depth the findings are not statistically significant which is also in line with the findings of Ebersberger et al. (2011).

When analyzing each of the activities it is possible to see that Portugal, as Norway and Denmark, has each breadth activity contributing positively to the probability of introduction of market novelty. In terms of depth, where results varied more, collaboration has a positive effect which was not found in any of the other 4 countries and sourcing depth has a negative effect as in Belgium.

The findings on the positive effect of R&D intensity contrasts with the findings of Spithoven et al. (2013) in Belgium firms, that found no significance.

6.2.2. Share of sales of innovative products or services

It is possible to see that the positive influence found in Portugal on the probability of increasing the Share of sales of innovative products or services is in line with the findings for Austria, Belgium, Denmark, and Norway.

In terms of open innovation breadth and depth the findings for Portugal are aligned with Austria, Denmark, and Norway where breadth has a positive effect and depth a non-significant impact.

When analyzing each of the activities it is possible to see that Portugal is in line with Austria where only protection breadth has a significant and positive impact. In terms of depth, Portugal is aligned with Belgium where Sourcing depth has a negative impact on the probability of increasing the Share of sales of innovative products or services.

6.3. Limitations

This research had certain limitations as was already pointed out in the literature review. The concept of innovation performance can have different meanings depending on how the researchers decide to measure it and the information available. This fact limits the conclusions as there are several dimensions of performance that are being left out. The work done analyses innovation performance but does not look at open innovation from a cost/benefit perspective which constitutes a limitation as has been pointed out by Greco et al. (2015). Also, the data source used (CIS2016) is based on self-reported information. The construction of the open innovation (sourcing, collaboration and protection) indicators was based on the work of Ebersberger et al. (2011) and requires certain care when comparing the data to its work since the calculation methods were not available and were inferred from the CIS 2016 questionnaire.

In terms of the fitness of the model the Pseudo-R2 measures show a room for improvement on the model and values that are distant from the excellent fit according to the works of McFadden, (1977). Nevertheless the results obtained by Ebersberger et al. (2012) also fall short of the excellent fit threshold.

6.4. Recommendations for future work

Innovation performance can be measured in terms of output generated but it could also be measured in terms of different dimensions of impact such as the economic, financial, and human capital performance of the company and using different scales to the ones used (Moretti & Biancardi, 2020). To deepen this research, it would be of interest to explore innovation performance not only as a measure of output in terms of novelty and share sales of innovation.

Since the results of this work differs slightly with previous research in Portugal the main recommendation in terms of follow-up research is to have an in depth empirical study with further detailed questions on the practices of open innovation that can validate these new findings.

The findings presented in this work could be an indication that the approach to innovation of highly dynamic innovation firms, has extended to the rest of Portuguese companies' approach towards

innovation and it would be pertinent to validate and identify its root causes (e.g. management behavioral changes, ease of access to knowledge, public incentives).

Also relevant would be to follow a specific approach that separates the analysis in terms of size (following the work of Spithoven et al., 2013), sector, geographical location. Similarly applicable would be a comparative analysis of companies “born” in start-up incubators, where knowledge sharing is fomented from the very foundation, to companies of the same size and sector with a more traditional background and analyze the openness and the performance of innovation on these two types of companies.

Finally, an analysis on the possible change in preponderance of the internal R&D departments in the company’s ability to generate innovation internally could be useful to fully understand the consequences of open innovation in Portuguese firms.

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Appendix

Table A14 - Spearman's Correlation Matrix

	newmkt	turnmar	oitotal	oibreadth	oidepth	collaborationbreadth	collaborationdepth	searchbreadth	searchdepth	protectionbreadth	sourcingbreadth	sourcingdepth	Part of a group	R&D intensity	international orientation	size2	cae_agg2_lt	cae_agg2_ht	cae_agg2_mlt	cae_agg2_mht	cae_agg2_oth	cae_agg2_kis	cae_agg2_htkis	cae_agg2_lkis	cae_agg1_mi	cae_agg1_kbs	cae_agg1_oth
newmkt	1																										
turnmar	0,91*	1																									
oitotal	0,16*	0,12*	1																								
oibreadth	0,18*	0,15*	0,92*	1																							
oidepth	0,08*	0,05*	0,83*	0,58*	1																						
collaborationbreadth	0,17*	0,13*	0,66*	0,6*	0,54*	1																					
collaborationdepth	0,15*	0,12*	0,61*	0,45*	0,64*	0,74*	1																				
searchbreadth	0,1*	0,08*	0,64*	0,74*	0,33*	0,27*	0,17*	1																			
searchdepth	0,08*	0,06*	0,57*	0,43*	0,65*	0,28*	0,21*	0,4*	1																		
protectionbreadth	0,18*	0,17*	0,38*	0,44*	0,22*	0,23*	0,21*	0,18*	0,2*	1																	
sourcingbreadth	0,1*	0,08*	0,66*	0,7*	0,47*	0,36*	0,28*	0,22*	0,2*	0,18*	1																
sourcingdepth	-0,07*	-0,07*	0,31*	0,19*	0,49*	-0,02	-0,01	0,02	0,03	0	0,42*	1															
Part of a group	0,05*	0	0,19*	0,2*	0,12*	0,23*	0,21*	0,09*	0,07*	0,03	0,17*	-0,06*	1														
R&D intensity	0,2*	0,21*	0,28*	0,31*	0,16*	0,3*	0,26*	0,22*	0,2*	0,26*	0,13*	-0,2*	0,08*	1													
international_orientation	0,07*	0,08*	0,15*	0,13*	0,13*	0,11*	0,14*	0,07*	0,12*	0,15*	0,06*	-0,01	0,01	0,19*	1												
Size (1 if large company)	-0,05*	0	-0,13*	-0,15*	-0,08*	-0,17*	-0,15*	-0,07*	-0,04*	-0,02	-0,13*	0,05*	-0,28*	-0,05*	-0,04	1											
cae_agg2_lt	-0,04*	-0,04*	-0,07*	-0,07*	-0,04*	-0,11*	-0,07*	-0,06*	-0,04	-0,01	-0,02	0,07*	-0,13*	-0,12*	0,01	0,02	1										
cae_agg2_ht	0	0,01	0,08*	0,08*	0,06*	0,08*	0,07*	0,05*	0,05*	0,08*	0,06*	-0,02	0,09*	0,12*	0,05*	0,04*	-0,07*	1									
cae_agg2_mlt	-0,02	-0,02	-0,02	-0,02	-0,01	-0,01	0	0	-0,04*	-0,05*	-0,03	0,01	-0,07*	0	0,13*	0,01	-0,23*	-0,06*	1								
cae_agg2_mht	0,05*	0,05*	0,06*	0,05*	0,06*	0,05*	0,06*	0,03	0,06*	0,01	0,03	0	0,02	0,1*	0,15*	-0,11*	-0,16*	-0,04*	-0,13*	1							
cae_agg2_oth	0,03	0	0,05*	0,06*	0,03	0,05*	0,02	0,06*	0	0,03	0,02	0,01	0,08*	-0,03	-0,04*	-0,02	-0,15*	-0,04*	-0,12*	-0,09*	1						
cae_agg2_kis	-0,05*	-0,05*	0,05*	0,05*	0,03	0,07*	0,04*	0,04	0,02	-0,01	0,04*	-0,03	0,1*	0,05*	-0,21*	0	-0,21*	-0,05*	-0,16*	-0,12*	-0,11*	1					
cae_agg2_htkis	0,09*	0,13*	0,01	0,02	-0,02	0,06*	0,05*	0,02	0,04*	0,14*	-0,06*	-0,16*	0,03	0,3*	0,05*	-0,01	-0,16*	-0,04*	-0,13*	-0,09*	-0,09*	-0,12*	1				
cae_agg2_lkis	-0,01	-0,02	-0,06*	-0,06*	-0,03	-0,07*	-0,07*	-0,05*	-0,03	-0,09*	0	0,05*	0	-0,21*	-0,08*	0,05*	-0,29*	-0,08*	-0,23*	-0,16*	-0,16*	-0,21*	-0,17*	1			
cae_agg1_mi	-0,02	-0,01	-0,02	-0,03	0,01	-0,04*	-0,01	-0,02	-0,01	-0,01	0	0,06*	-0,12*	-0,01	0,2*	-0,03	0,56*	0,15*	0,44*	0,31*	-0,27*	-0,37*	-0,29*	-0,52*	1		
cae_agg1_kbs	0,01	0,02	-0,01	0	-0,02	0,02	0	-0,01	0,01	0	-0,01	-0,06*	0,08*	0,03	-0,18*	0,04*	-0,48*	-0,13*	-0,38*	-0,27*	-0,26*	0,43*	0,34*	0,61*	-0,86*	1	
cae_agg1_oth	0,03	0	0,05*	0,06*	0,03	0,05*	0,02	0,06*	0	0,03	0,02	0,01	0,08*	-0,03	-0,04*	-0,02	-0,15*	-0,04*	-0,12*	-0,09*	1*	-0,11*	-0,09*	-0,16*	-0,27*	-0,26*	1