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TESIS DOCTORAL

The role of cooperation breadth as a strategy for innovation: a study of openness in Spanish startups

El papel de la amplitud de cooperación como estrategia para la innovación: un estudio de la apertura de las *startups* españolas

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PhD DISSERTATION

The role of cooperation breadth as a strategy for innovation. A study of openness in Spanish startups.

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by

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If you want to go fast, go alone.

If you want to go far, go together.

(African proverb)

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Summary

Startups and incumbent firms both play important roles in generating innovations and economic growth, but they contribute to the innovation ecosystem and economic development in different ways. Between the innovation strategies, open innovation is taking a higher importance for both incumbent firms and startups. Literature states that startups' resources and capacities are different from incumbent firms, so there might exist differences on the use of open innovation strategies. In this context, this dissertation adopts a combination of theoretical perspectives (the resource-based view, with especial attention to intellectual propriety rights, the knowledge-based view, and the dynamic capabilities perspective) in order to develop a better understanding of open innovation in startups. I investigate how the diversity of external knowledge sources contributes to startups' innovation performance. In addressing this overarching research question, I present four separate empirical studies that deal with various facets of value creation and value capture from open innovation, with a special emphasis on startups. In testing these studies, I use the Spanish Technological Innovation Panel (PITEC). In particular, these studies address the following sub research questions:

1) Is there complementarity between cooperation breadth and R&D outsourcing breadth for innovation performance?
2) Are startups different from incumbent firms in terms of cooperation breadth and innovation performance?
3) Will startups benefit to a greater extent from cooperation breadth for radical innovation performance?
4) How openness and appropriation independently and jointly influence startups' radical innovation performance?

The first study examines the relationship between breadths of two different modes of external knowledge: R&D outsourcing and cooperation. Building upon transaction costs theory and the resource-based view, I deepen on the concept of breadth and I apply it to different open innovation strategies. I hypothesize an inverted-U relationship between outsourcing breadth and innovation performance, and a complementary relationship between R&D outsourcing and R&D cooperation. The empirical analysis confirms the first hypothesis, but also reveals an interesting result: the complementary effect of R&D cooperation varies with the level of R&D outsourcing breadth and it is not confirmed for low and medium levels of R&D outsourcing breadth. The results have important implications for theory on the selection of different modes of inbound open innovation and for managers and their cooperation and outsourcing strategies.

In study two I compare the open innovation strategy between startups and incumbent firms over a period of ten years (2004-2013). Using a sample of startups and incumbent Spanish firms, I find that they differ considerably, and that this has implications for management. Incumbent firms and startups differ in terms of their use of external cooperation activities as a source of innovation. The lack of financial and human resources of startups leads them to open their borders more than incumbent firms, and startups benefit from being flexible, as they have yet to implement routines. This boosts startups' radical innovation performance. This study contributes to understand the innovation ecosystem and to clarify the role of firms regarding the search of opportunities.

Study three examines the effect of being a startup and a high-tech startup on the relationship between cooperating with a diversity of partners and radical innovation performance. Startups are forced to open up their boundaries to overcome the liabilities of newness and smallness, and it far from being a limitation, it is an opportunity for innovation. I hypothesize that startups and, in particular, high-tech startups, benefit to a

greater extent from cooperation breadth. The findings confirm the hypotheses, so cooperation breadth triggers knowledge exploration and exploitation in startups. This study contributes to the link between open innovation and entrepreneurship theory, and points out that breadth is a mechanism to capture complementary assets. It also sheds light on the contingencies of open innovation strategy by proving that the technology intensity sector effect does not disappear when newness factor is taken into consideration.

Study four looks at how openness and appropriation strategy both independently and jointly influence radical innovation performance. Startups benefit from opening up towards external partners to overcome liability of smallness and newness. At the same time, combining collaborative innovation activities with due diligent appropriation strategy ensures they capture value created, suggesting complementarity between openness and appropriation on radical innovation performance. I test and find support for my propositions: Cooperation breadth draws an inverted-U shape, appropriation strategy is positively related to startups' radical innovation performance, and a complementary effect between openness and appropriation strategy exists, evidencing that using both strategies at the same time is better than the sum of both. It contributes to the recent debate about the trade-off between openness and appropriation.

The contributions of this dissertation to the field of open innovation can be summarized in terms of three main aspects. First, startups create and capture value from their innovations, contributing to the innovation ecosystem from their particular position. Second, startups need to open their boundaries to a bigger extent than other firms, so breadth is a mechanism to overcome their initial liabilities and access to complementary assets. Third, there is a complementary effect for startups between openness and their appropriation strategy. Additionally, this dissertation makes a contribution to the field of entrepreneurship theory in terms of three main aspects. First, it advances on how

entrepreneurial firms look for business opportunities through external partners as an innovation strategy for value creation. It entails that startups are more dynamic than incumbent firms to integrate heterogeneous external knowledge. Second, it explains how startups use external partners to gain more knowledge exploitation opportunities, using breadth as a mechanism to access complementary assets. Third, it sheds light on the importance of formal appropriation mechanisms for startups.

Concluding, in this dissertation I develop a framework to explain open innovation in the context of startups. The findings of the four empirical studies of this dissertation help to explain how startups create and capture value from external sources, and to which extent startups can benefit to a greater extent from an open innovation strategy. Overall, this dissertation contributes to the link between open innovation literature and entrepreneurship theory, and provides interesting implications for managers.

Resumen

Las *startups* y empresas establecidas juegan papeles muy importantes en la generación de innovaciones y crecimiento económico, pero contribuyen al ecosistema de innovación y desarrollo económico de modos diferentes. Entre las estrategias de innovación, la innovación abierta está tomando una mayor importancia para ambas, *startups* y empresas establecidas. La literatura afirma que los recursos y capacidades de las *startups* son distintos de los de las empresas establecidas, así que podrían existir diferencias en el uso de las estrategias de innovación abierta. En este contexto, esta tesis adopta una combinación de perspectivas teóricas (perspectiva de recursos y capacidades, con especial atención a los derechos de propiedad intelectual, la perspectiva basada en el conocimiento, y la perspectiva de capacidades dinámicas) para desarrollar una mejor comprensión de la innovación abierta en las *startups*. Yo investigo cómo la diversidad de fuentes externas de conocimiento contribuye al resultado de innovación de las *startups*. Para responder a esta pregunta de investigación general, presento separados, cuatro estudios empíricos que dirigen varias facetas de la creación y captura de valor en la innovación abierta, con especial énfasis en las *startups*. Para testar estos estudios, empleo el Panel de Innovación Tecnológica (PITEC). En particular, los estudios dirigen las siguientes sub-preguntas de investigación:

1) ¿Hay complementariedad entre la amplitud de cooperación y la amplitud de externalización de I+D para el resultado de innovación?
2) ¿Son las *startups* diferentes de las empresas establecidas en cuanto a la amplitud de cooperación y el resultado de innovación?
3) ¿Se beneficiarán las *startups* en una mayor extensión de la amplitud de cooperación para el resultado de innovación radical?

4) ¿Cómo influyen independiente y conjuntamente en el resultado de innovación radical de las *startups* la apertura y la apropiación?

El primer estudio examina la relación entre las amplitudes de dos diferentes modos de conocimiento externo: externalización de I+D y cooperación. Construyendo sobre la teoría de costes de transacción y la perspectiva basada en los recursos, profundizo en el concepto de amplitud y lo aplico a diferentes estrategias de innovación abierta. Planteo una relación con forma de U-invertida entre la amplitud de la externalización de I+D y el resultado de innovación; y una relación complementaria entre la externalización de I+D y la cooperación. Los análisis empíricos confirman la primera hipótesis, y revelan un resultado interesante: el efecto complementario de la cooperación para I+D varía con el nivel de amplitud de la externalización de I+D, y no es confirmado para niveles bajo a medio de amplitud de externalización de I+D. Los resultados tienen importantes implicaciones para la teoría en la selección de los diferentes modos de innovación abierta de entrada, y para los directivos y sus estrategias de cooperación y externalización.

En el estudio dos, comparo las estrategias de innovación abierta entre las *startups* y las empresas establecidas por un periodo de diez años (2004-2013). Usando una muestra española de *startups* y empresas establecidas, encuentro que difieren considerablemente, y ello tiene implicaciones para la dirección de las empresas. Las *startups* y las empresas establecidas difieren con relación al uso de las actividades de cooperación externa como fuente de innovación. La falta de recursos humanos y financieros de las *startups* les lleva a abrir sus fronteras más que las empresas establecidas; y las *startups* se benefician de ser flexibles, ya que no han implementado rutinas todavía. Esto aumenta el resultado de innovación radical de las *startups*. Este estudio contribuye a comprender el ecosistema de innovación y a clarificar el papel de las empresas con relación a la búsqueda de oportunidades.

El estudio tres examina el efecto de ser una *startup* y una *startup* de alta tecnología en la relación entre la cooperación con una diversidad de socios y el resultado de innovación radical. Las *startups* son forzadas a abrir sus límites para sobrellevar sus limitaciones de pequeñez y novedad, y ello, lejos de ser una limitación, es una oportunidad para la innovación. Planteo que las *startups* y, en particular, las *startups* de alta tecnología, se benefician con mayor extensión de la amplitud de cooperación. Los resultados confirman las hipótesis, así que la amplitud de cooperación dispara la exploración y explotación de conocimiento en las *startups*. Este estudio contribuye a la unión de la innovación abierta con la teoría de emprendimiento, y señala que la amplitud es un mecanismo para capturar activos complementarios. También aporta luz en las contingencias de la estrategia de innovación abierta, probando que el efecto de la intensidad tecnológica del sector no desaparece cuando el factor de novedad es tenido en consideración.

El estudio cuatro estudia cómo la apertura y la estrategia de apropiación de forma independiente y conjunta influyen en el resultado de innovación radical. Las *startups* se benefician de abrirse a socios externos para sobrellevar sus limitaciones. A su vez, combinar actividades de innovación colaborativa con la debida estrategia de apropiación asegura la captura del valor creado, sugiriendo complementariedad entre apertura y estrategia de apropiación para el resultado de innovación radical. Yo compruebo y encuentro apoyo para mis proposiciones: la amplitud de cooperación dibuja una forma de U-invertida, la estrategia de apropiación está positivamente relacionada con el resultado de innovación radical de las *startups*, y hay un efecto complementario entre apertura y apropiación, lo cual evidencia que el uso de ambas estrategias a la vez es mejor que la suma de ambas. Ello contribuye al reciente debate sobre la relación entre apertura y apropiación.

La contribución de esta tesis al campo de la innovación abierta puede ser resumida en tres aspectos principales. Primero, las *startups* crean y capturan valor de sus innovaciones, contribuyendo al ecosistema de innovación desde su posición. Segundo, las *startups* necesitas abrir sus fronteras con mayor extensión que otras empresas, de modo que la amplitud es un mecanismo para superar sus limitaciones iniciales y acceder a recursos complementarios. Tercero, hay un efecto complementario para las *startups* entre la apertura y su estrategia de apropiación. Además, esta tesis hace una contribución al campo de la teoría del emprendimiento en tres principales puntos. Primero, avanza en cómo las empresas emprendedoras buscan oportunidades a través de socios externos como una estrategia de innovación para la creación de valor; ello implica que las *startups* son más ágiles que las empresas establecidas para integrar conocimiento externo heterogéneo. Segundo, explica cómo las *startups* usan a los socios externos para ganar más oportunidades de explotación de conocimiento, usando la amplitud como mecanismo para acceder a recursos complementarios. Tercero, aporta luz en la importancia de los mecanismos de apropiación formal para las *startups*.

En conclusión, en esta tesis desarrollo un marco para explicar la innovación abierta en el contexto de las *startups*. Los resultados de los cuatro estudios empíricos de esta tesis ayudan a explicar cómo las *startups* crean y capturan valor de las fuentes externas, y cómo las *startups* pueden beneficiarse en una mayor extensión de una estrategia de innovación abierta. En general, esta tesis contribuye a unir la literatura de innovación abierta con la teoría del emprendimiento, y aporta interesantes implicaciones para los directivos.

Chapter 1: Introduction

1.1 Introduction

The goal of this dissertation is to understand the open innovation (OI) phenomenon in the context of startups. Innovation is one of the main motors of economic growth and wealth creation in a country (Gronum et al., 2012) and a source of sustained competitive advantage for firms (Danneels, 2002; Katila and Ahuja, 2002; Teece et al., 1997; Wang and Ahmed, 2007; Zobel, 2013). Startups and incumbent firms both play important roles in generating innovations and economic growth, but they contribute to the innovation ecosystem and economic development in different ways. This dissertation explores the differences in OI strategies between startups and incumbent firms, and examines the startups' features to create and appropriate value.

Most research on OI has focused on large and established firms, with a minor emphasis on Small and Medium Enterprises (SMEs) and startups. Implications of OI for startups are still neglected in mainstream studies and this thesis advances our knowledge on this relevant subtopic. From a Schumpeterian point of view, startups are a key driver in the production of innovation and economic change. They introduce innovations that changes the competitive rivalry in an industry, and thereby threaten the competitive advantage of established firms (Schumpeter, 1934). Startups are responsible for a sizable creation of revenues and jobs, as well as for their destruction (Davila et al., 2015).

Each year around 300,000 new firms are created in Spain (INE, 2016). However, startups also experience a high failure rate. In average, only 48.9% of these Spanish firms survived long enough to celebrate their 3 year anniversary (INE, 2016). Since startups are one of the main sources of innovation in Spain, it turns essential to understand their internal routines and innovation processes to advise managers how to success.

Startups' success depends on the deployment of efficient routines to create and capture value from new products. They suffer from the liabilities of smallness and newness (Stinchcombe, 1965), so they lack human and financial resources to bring new technologis and products to the market, and they lack reputation and legitimacy to be well-know in markets. As a result, adopting OI practices is a necessity for startups in order to overcome their liabilities (Spender et al., 2017). The OI paradigm provides a context to understand how startups contribute to innovation processes (Corvello et al., 2017). Among the different routines that explain some drivers of successful startups is the use of external resources, such as the degree of openness and the cooperation in the ecosystem where the new firm is involved (Eftekhari and Bogers, 2015), or the specific characteristics of their external networks (Allen et al., 2016; Neyens et al., 2010; Perez et al., 2013; Shan et al., 1994). Thereby, cooperation strategies are central for startups. Between the cooperation strategies, OI research has shown the relevance of an efficient degree of diversity of knowledge sources, known as breadth (e.g. Laursen and Salter, 2006, 2014; Leeuw et al., 2014; Oerlemans et al., 2013). This dissertation therefore focuses on cooperation breadth as a startups' mechanism of openness.

Startups might achieve greater benefits from cooperating with other agents than larger firms because they are less bureaucratic, more willing to take risks, and more agile in reacting to changing environments (Vanhaverbeke, 2017). The use of cooperation strategies lets startups preserve their creativity and flexibility, while mitigating their liabilities of smallness and newness (Ketchen et al., 2007). Startups are gradually adopting OI as part of their innovation strategy, but it is not thoughly implemented in Spanish startups.

The differences between incumbent firms and startups regarding their innovation strategies and cooperating activities are substantial because they have a different

endowment of resources and a different way to manage the external relationships. In particular, startups do not have a portfolio of innovation projects, their OI practices must be framed into their general innovation strategy and business model, their OI activities are managed by the entrepreneur, and cooperating activities depends on the bond ties of the entrepreneur (Vanhaverbeke, 2017). In other words, startups do not have a R&D department which is in charged of the external sourcing activities, but the entrepreneur is the person who manages all the cooperation activites of the firm, which define the startup's innovation model. Furthermore, startups do not have developed innovation routines yet nor have an extended base of knowledge as the incumbent firms have (Katila and Shane, 2005). It makes startups be more flexible and able to introduce changes to adapt to the environment (Criscuolo et al., 2012; Hyytinen et al., 2015; Katila and Shane, 2005). As a consequence of all these differences, it is necessary to develop a deeper understanding of OI in the conext of startups.

The aim of this dissertatin is to fill an important research gap in literature since OI scholars have underdeveloped the contribution of startups for the innovation performance. Similarly, I contribute to the entrepreneurship theory through the introduction of the concept of breadth in this research stream. My purpose is that this dissertation helps to understand why it is necessary a framework for the study of OI in startups, and to be a starting point for future studies on the specific topic, with the aim to stimulate a debate both for theory building scholars and for the manager.

In this context, this dissertation adopts a combination of theoretical perspectives in order to develop a better understanding of OI in startups. In doing so, I link entrepreneurship theory with OI research to shed light on how these two streams of literature can be married. I also employ different theoretical angles to discuss the startups' particularities and the underlying causes that explain how startups can create and appropriate value when

they cooperate with external knowledge sources. I acknowledge of the resource-based view (RBV) -with especial attention to intellectual propriety rights (IPRs)-, the knowledge-based view (KBV), and the dynamic capabilities (DC) perspective.

In the following, I shortly explain the OI paradigm, and outline the emerging literature and research gaps on OI. I then elucidate how and why startups are different from incumbent firms when cooperate with external knowledge sources. The discussion of these differences and the startups' processes to create and capture value enables the development of research questions that address the gaps in literature. Those research questions are debated along the four studies that consist this dissertation. Finally, I discuss the methodological design and I explain the sample used to test the hypotheses of this dissertation.

1.2 An approach to Open Innovation concept

Innovation is essential for firms to get a competitive advantage (Danneels, 2002; Katila and Ahuja, 2002; Teece et al., 1997; Wang and Ahmed, 2007; Zobel, 2013). Over time, firms have constantly been searching for ways to transform and advance their innovation strategies to generate a superior firm performance (Zobel, 2013). Between these strategies, the use of external knowledge or collaborative R&D networks have been outlined as a key element for successful innovation (Enkel, 2010). The use of external knowledge sources is not therefore a new element introduced by the OI paradigm, but it has several antecedents that sustain the importance of external knowledge for innovation (Chesbrough, 2006; Dahlander and Gann, 2010; Spithoven et al., 2013).

The evolutionary theory, proposed by Nelson and Winter (1982) represents one of the antecedents of OI. This theory includes elements of the theory of Schumpeter (1934), Alchian (1950), Hayek (1945), and Cyter and March (1963). From this perspective, the firm is viewed as an entity that seeks profits and whose main activity is to build –through organizational learning processes- and exploit value knowledge assets (Augier and Teece, 2009). Organizational routines are therefore modified as a result of firms' efforts to solve problems as well as by random events (Nelson and Winter, 1982). In other words, it happens an evolutionary process since firms' routines change through external search and learning (Augier and Teece, 2009). According to this theory, organizations actively search for technology outside their organizational boundaries.

OI also has its roots in other well-known theories that refer to external knowledge sources. In the theoretical framework of OI proposed by Dahlander and Gann (2010), they explained that OI is built on the theoretical bases of Teece (1986), Cohen and Levinthal (1990), March (1991), and others. For example, the absorptive capacity concept (Cohen and Levinthal, 1990) combines both internal and external knowledge since it highlights the importance of having an internal R&D base in order to absorb external knowledge. The strategic alliance perspective and the network theory (e.g. Ahuja, 2000; Burt, 1992; Granovetter, 1985; Stuart, 2000) have also evidenced the importance of external sources long before the term OI was coined.

The term open innovation was introduced by first time in 2003 when Henry Chesbrough published his book titled *Open Innovation: The New Imperative for Creating and Profiting from Technology*. His goal was to show a new innovation model that included both internal and external knowledge sources. Chesbrough (2003) underscored that firms have changed the way in which they conduct their innovative processes, from a closed model to an open innovation model. Over the last years, some erosion factors, such as

increased labour mobility, knowledge diffusion, the access of startups to venture capital, and the rise of the Internet (Chesbrough and Bogers, 2014; Chesbrough, 2003) have changed the innovation paradigm and the conditions in which firms operate (Bessant and Phillips, 2013; Chesbrough, 2003; Lee et al., 2010; van de Vrande et al., 2009). The new premises break the traditional innovation perspective where research and development (R&D) activities happened inside the firm to avoid that competitors could steal its ideas. The new OI model triggers the flow of knowledge between different agents, and looks for all the parties can benefit from that knowledge.

OI is defined as "a distributed innovation process that involves purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model" (Chesbrough and Bogers, 2014, p. 12). To understand the concept, let's analyse each of its elements. First, OI is a distributed innovation process. It refers to the basic idea of innovation, which was described by Dosi (1988) as a process of search, discovery, experimentation, development, imitation, and adoption of new products, processes, and organizational environments. Moreover, this innovation process is distributed, highlighting the idea of external knowledge search, as well as the engagement in external relationships.

Second, OI involves different flows of knowledge. Knowledge can flow outside-in or inside-out, generating the different dimensions of OI. The outside-in or inbound OI is referred to a process where firms try to monitor their environment to interiorize external technology and knowledge (Spithoven et al., 2011). In other words, inbound OI represents the internal use of external knowledge (Huizingh, 2010). This process enriches the firm's own knowledge base because the organization is open to external sources (Chesbrough, 2012), absorbing and integrating knowledge from suppliers, customers and other agents (Enkel et al., 2009). The inside-out process is also called outbound OI, and it is defined

as the external exploitation of internal knowledge (Huizingh, 2010). It is referred to the benefits that firms get when they go to the market with their ideas, sell intellectual propriety rights, or transfer ideas to the environment (Enkel et al., 2009). Ideas that the firm has not used, go outside for other companies to use them (Chesbrough, 2012). Finally, when knowledge flows are both inside-out and outside-in, the process is called coupled OI (Gassmann and Enkel, 2004). Here, two (or more) partners purposely exchange their knowledge through co-creation and commercialisation activities (Bogers, 2011).

Third, the flows of knowledge are 'purposively' managed, so those flows are firm controlled. It allows to differentiate OI from other streams of literature, such as knowledge spillovers, which are inevitable and no intended results of R&D activities. Spillovers are used without permission by other firms, which avoid the organization to benefit from them. In an OI model, spillovers are transformed into inside-out knowledge flows, so they are purposively managed by the firm (Chesbrough and Bogers, 2014). In this way, firms can benefit from their spillovers, so organizations manage and monitor all their flows of knowledge.

Fourth, OI can be performed through pecuniary or non-pecuniary mechanisms. When the OI concept emerged, it was only linked to pecuniary mechanisms because OI was applied in large industrial firms (Piller and West, 2014). Dahlander and Gann (2010) proposed an analytical model of OI consisted of two dimensions: 1) inbound - outbound, 2) pecuniary – non-pecuniary. Pecuniary modes are those in which there is an exchange of money. An example of non-pecuniary mechanisms are assimilation and revelation.

The last element of OI is the business model. The business model is key to understand the OI concept as it is the responsible for placing the innovation process in the

organizational realm and it describes how value is created inside the value network and how value is captured by the firms involved (Chesbrough and Bogers, 2014). The business model distinguishes OI from other streams of literature, such as the open software sources or user innovation. While OI involves value capture, open sources do not capture the value created because they are only focused on value creation in the supply chain (Chesbrough, 2006).

OI is therefore based on knowledge and on the idea of an interconnected world, where organizations cannot only depend on their own capacity to innovate, but also on exploiting others' knowledge (Heap, 2010), to the same extent that other firms can benefit from the firm's technology. Accordingly, firms explore and exploit external knowledge to enhance their innovation performance since external sourcing might have a mediator effect on firm performance, especially in knowledge-intensive firms (Vrontis et al., 2017). The rapid changes in technology lead firms to use external knowledge together with the firm's internal knowledge and skills (Tsai, 2009), and it requires a significant effort in the creation of new routines and structures that support the change (Bessant and Phillips, 2013). The transformation into an OI model has become a need to maintain a competitive advantage and cope with the changes in the context. In the current globalized world of aggressive competition and fast pace of change, OI strategies become a key element for new product development and firm survival. OI is a response to a new reality and it is a new paradigm to explain the firms' innovation process.

Kuhn (1962) claimed that a change of paradigm happens when there are anomalies in the current paradigm, so it shows insuperable problems, and it is needed to rebuild it. In the case of the innovation paradigm, the closed innovation model showed some problems to explain the current innovation processes in firms because firms get involved with external agents in R&D activities, so the closed innovation model is experiencing a crisis. The

erosion factors outlined above are the core causes of why the innovation paradigm is changing, and shifting from a closed to an open model. On this basis, Chesbrough (2006) justified through two examples that OI is the new paradigm of innovation. First, traditional studies on innovation do not consider the indirect effects of knowledge, while OI specifically includes them as a consequence of the business model. Thus, knowledge spillovers are not a cost for the firms, but an opportunity to expand the business. Second, contrary to the closed innovation model where firms accumulated intellectual property assets, even when they did not add value to the firm; in the OI model, intellectual propriety is an asset that generates value for the business. Hence, most of scholars consider OI as a new paradigm, which can be used as a base for future research.

Nevertheless, the OI idea has also received several critics. Following to Chesbrough and Bogers (2014), these critics can be split into two lines: first, those who claim that OI is not a new phenomenon (Mowery, 2009; Trott and Hartmann, 2009, 2013); second, those who criticise the lack of coherence in the OI theoretical framework, so OI would explain a new idea, but it can be explained with already developed concepts (Groen and Linton, 2010).

Regarding the first critic, Mowery (2009) considered that many elements of the OI framework were already presented in the US industrial research of late XIX and beginning XX centuries. He even argued that the innovation strategy exception could be the closed innovation model rather than the open innovation model, which has been practiced over years. Trott and Hartmann (2009) explained that organizations have always had open innovation processes, so there is not a change from closed to open innovation models. They summarized their idea with the statement ‘old wine in new bottles’, where the authors considered that OI is only a trend and that it does not contribute with new concepts. This argument is explained in depth in a revisited paper (Trott and Hartmann,

2013), where the authors focused on the closed innovation model premises, and they stated that the closed innovation model did never exist, and the firms have always been open to external sources. Paraphrasing to Trott and Hartmann, Heap (2010) said the OI is 'new clothes for old practices'. With that sentence, the author refers to the idea that many OI practices was already present time ago, but he does not deny a novelty element of OI. The OI paradigm does not reject that its elements have already existed I a previous paradigm, but the new notion of the OI paradigm allows to combine them into a complementary way to manage the innovation process (Cassiman and Valentini, 2011; Chesbrough and Bogers, 2014).

The second critic is about the lack of coherence in the OI theoretical framework. The absence of this framework makes difficult to compare and validate the results about the effects of firms' openness. Groen and Linton (2010) wondered whether OI is a research field or, instead, a communication barrier to the theory development, so OI inhibits the communication between scholars from different academic streams. As an answer, Chesbrough and Bogers (2014) pointed out that OI is a different research stream, focused on the creation of new products, services and processes, and it involves a high number of actors, which provides value in utilizing the term OI as differentiated to the management of the supply chain.

However, the idea that the OI paradigm is lacking an underlying analytical framework remains in numerous studies. For example, Dahlander and Gann (2010) underscored that in OI literature, numerous definitions are used, but they do not show coherence inside an analytical framework. That absence of theoretical grounding has lead numerous scholars to claim for an OI theoretical development (Elmquist et al., 2009; Kovács et al., 2014), or for the application of an existing theoretical framework (Alexy et al., 2016; Enkel,

2010; Hsieh et al., 2016; Randhawa et al., 2016; van de Vrande et al., 2010; Vanhaverbeke and Cloodt, 2014; West and Bogers, 2017).

Despite the critics, the OI paradigm has largely been adopted in academia. Chesbrough (2012) outlined that when he first published his seminal book in 2003, the words 'open' and 'innovation' had no meaning together. However, ten years later he repeated the search in *Google* and he got 483 million links. The importance of the topic is therefore overwhelming. OI has been revitalized and new research lines around this topic are emerging. In an attempt to gather the main research lines in OI and identify research opportunities, some scholars are written comprehensive literature reviews of OI (e.g. Kovács et al., 2014; Randhawa et al., 2016; West and Bogers, 2017). For example, Randhawa et al. (2016) revealed three main areas within the OI research: 1) firm-centric aspects of OI, 2) networks management, and 3) the role of users and communities in OI. The former topic has notably predominated in research. West and Bogers (2017) summarized some opportunities research in OI, which includes networks forms of collaboration, as well as the use of OI by small and new firms.

In this dissertation, I analyse the OI phenomenon in the context of startups, linking OI to the entrepreneurship theory, and framing my argumentation on the RBV –with especial attention to IPRs-, KBV as knowledge becomes a crucial resource for innovation, and the DC perspective as an extension of the RBV. In particular, I focus on cooperation breadth as a mechanism for startups to create value, and how they can capture value when cooperate with external knowledge sources. In the following section, I briefly explain how openness in startups can be understood from these different theoretical perspectives.

1.3 External knowledge for startups

Startups play a key role in the innovation ecosystem of a country. A well-known definition of startup is those of Blank (2010), who defined a startup as a company, partnership or temporary organization designed to search for a repeatable and scalable business model. However, literature has used the term in different ways and there is no consensus in its definition. For example, one criteria is the age of the firm, so some authors consider startups to those firms with less than one year old (Cook et al., 2012), other scholars include those firms with a maximum of three years old (Bhalla and Terjesen, 2013; Bosma et al.2004; Laursen and Salter, 2006), or a maximum of six years old (Presutti et al., 2007), while other consider startups to those firms with less than ten years old (Davila and Foster, 2005). Instead of the firm age, other studies have focused on new firms backed by venture capital (Gruber et al., 2008). Taking into consideration that variety of approaches, Alberti and Pizzurno (2017, p. 53) defined a start-up as a "a few-year-old business which is not yet established in the industry and in the market and could more easily fail".

Indeed, startups are highly vulnerable and they fight against the liabilities of smallness and newness (Stinchcombe, 1965). Because of their small size, startups suffer a structural lack of human and financial resources that hinders the likelihood of bringing a new technology or product into the market (Neyens et al., 2010; Spender et al., 2017). Technology startups often need substantial resources to fund early stages of the innovation processes, but the newness of their technologies makes the innovation processes highly speculative and with an uncertain outcome (Baum and Silverman, 2004). Because of their newness, startups lack reputation and legitimacy, which is obtained through experience (Neyens et al., 2010). That lack of experience leads to operate using immature and unrefined routines, and with a lack of employee commitment, knowledge

of their environment, and working relationships with customers and suppliers (Baum and Silverman, 2004).

To overcome those liabilities, startups open their boundaries to external sources and create business relationships (Battistella et al., 2017; Bhalla and Terjesen, 2013; Bogers, 2011; Eisenhardt and Schoonhoven, 1996; Neyens et al., 2010). Startups' success depends on the creation of relationships with complementary assets (Anderson and Parker, 2013) and many startups fail because they lack complementary assets, such as market access, distribution infrastructures, operational expertise, strategic and technical know-how, and funds for supporting R&D and development processes (Battistella et al., 2017).

Strategic alliance literature and entrepreneurship theory suggest that cooperation with external partners is important for startups and their innovation activities, for example to acquire resources (Hite and Hesterly, 2001), to get access to complementary assets (Colombo et al., 2006; Marx and Hsu, 2015), to enhance the strategic position and legitimacy (Eisenhardt and Schoonhoven, 1996), to improve the market power of startups (Eisenhardt and Schoonhoven, 1996), and to provide functional activities (Gruber et al., 2010). Although these studies contribute to literature and remark the relevance of external knowledge, they do not completely explain the flows of knowledge in startups for their innovative processes, and the specific internal routines that startups need to deploy to search, capture, absorb and exploit external knowledge. For example, the entrepreneurship theory does not explicitly consider the effects of investing in complementary technologies (Anderson and Parker, 2013). The OI paradigm provides a context to understand how startups contribute to the innovation processes (Corvello et al., 2017) and to the innovation ecosystem (Usman and Vanhaverbeke, 2017).

Despite the importance of OI for startups, OI literature has mainly focused on large and established firms, with some scholars recently researching on SMEs (Brunswicker and Vanhaverbeke, 2015) and startups (Alberti and Pizzurno, 2017; Spender et al., 2017; Usman and Vanhaverbeke, 2017; Zobel et al., 2016). OI scholars have underlined the important role of external actors for the innovation process of new firms and have remarked the need for future studies to focus on startups (Bogers et al., 2016; Brunswicker and Van De Vrande, 2014; Eftekhari and Bogers, 2015). As a result of that research need, Corvello et al. (2017) have edited a special issue on startups and open innovation. That special issue includes 8 studies that stimulate the discussion on managing startups in an OI context. Between these studies, Spender et al. (2017) reviewed a set of papers to build a map of the state of the art at the intersection between startups and OI. Usman and Vanhaverbeke (2017) illustrated how startups successfully organize and manage OI with large companies; and Alberti and Pizzurno (2017) also focused on the relationship between startups and large firms, and studied the role of startups in OI networks as depending by 'knowledge leaks' as unintended knowledge flows. All these studies advance on the understanding of knowledge flows in startups, but they highlight that there is room for more research. In this dissertation I focus on the cooperation breadth as a strategy of knowledge flows between the startup and different external sources.

Startups are powerful engines of knowledge creation (Spender et al., 2017). Knowledge can come from different sources. Each type of external source have a different knowledge base that combined with the own base of knowledge of the firm, result in a different knowledge recombination (Teece, 1986). For example, cooperating with suppliers can serve as a mean to access technical and specific resources and knowledge that new firms need, which contributes to identify and solve technological problems (Tsai, 2009; Tsai and Hsieh, 2009), accelerating the innovation process (Nieto and Santamaría, 2007);

customers help to identify new product tendencies because they are more willing to provide timely feedback on a firm's product (Xue et al., 2016), avoiding the failure on product design (Leeuw et al., 2014; Tsai, 2009; Tsai and Hsieh, 2009), and providing new insights into new business opportunities for technological development beyond existing products and markets (Brunswicker and Vanhaverbeke, 2015); and universities are relevant sources for pioneering high-tech entrepreneurial firms (Gans and Stern, 2003) because their goal is to explore and develop new knowledge since they own an extent knowledge base that supports the innovative process (Un et al. 2010) and provide novel scientific knowledge with high potential for future (Tsai and Wang, 2009). Because of these differences, cooperating with a diversity of knowledge sources will bring a higher variety of knowledge and more possibilities for innovation to the firm. On this basis, an essential part of literature studying the impact of different external knowledge flows is the called breadth of external sources (Bahemia and Squire, 2010; Collins and Riley, 2013; Laursen and Salter, 2006, 2014; Leeuw et al., 2014; Leiponen and Helfat, 2010; Oerlemans et al., 2013; Rothaermel and Deeds, 2006). Breadth refers to the extent that firms access different external knowledge sources, such as customers, suppliers, competitors, universities and research centres (Zobel, 2013). Laursen and Salter (2014) defined cooperation breadth as the number of different types of sources with which the firm cooperates.

OI research has shown the relevance of an efficient degree of sources breadth on the innovation processes. For example, external breadth provides access to distinct skills and knowledge (Pangarkar and Wu, 2013) and to more diverse information and capabilities (Baum et al., 2000), which should lead to more radical innovations; cooperation breadth helps startups in their innovation processes in terms of risk and autonomy (Pangarkar and Wu, 2013), and it offers more opportunities for learning (Fuerst and Zettinig, 2015;

Pangarkar and Wu, 2013), and to exploit possible complementarities and synergies (Belderbos et al., 2006; Nieto and Santamaría, 2007). However, a high cooperation breadth also have some drawbacks, such as high transaction costs due to the efforts to control and manage the relationships (Faems et al., 2008; Gulati and Singh, 1998), a poor allocation of managerial attention (Laursen and Salter, 2006; Ocasio, 1997), and the difficulties in managing and absorbing the external ideas (Koput, 1997; Laursen and Salter, 2006).

A highly cited paper on the study of openness is Laursen and Salter's (2006) work. Although the authors did not focus on startups in their study, they incorporated a control variable to monitor for the effect of startups. However, it resulted not to be significant in any of the regressions regarding radical and incremental innovation. Although OI literature provides a background to explain knowledge flows between firms, it cannot simply be applied to startups because there are clear differences between startups and large firms, and between startups and small and medium firms (SMEs) (Usman and Vanhaverbeke, 2017). In this dissertation I analyse the cooperation sources breadth from the angle of startups. For that purpose, I link OI concepts to different theories, but focusing on the particularities of startups. While OI can be linked to different theoretical perspectives (Vanhaverbeke and Cloodt, 2014), the consideration of the particular features of startups is needed, otherwise we would fail to explain the application of OI in the startups context. Thereby, in this dissertation I link the OI paradigm to the entrepreneurships theory, explaining the particularities of startups in external knowledge sources breadth, and basing my arguments in the RBV –with especial attention to IPRs-, the KBV, as knowledge becomes a crucial resource for innovation; and the DC perspective as an extension of the RBV.

The entrepreneurship theory has recognized the role of startups in identifying business opportunities. Startups are recognized by their innovative capabilities and they are labelled as entrepreneurial firms (Neyens et al., 2010). Entrepreneurs often see business opportunities that other firms do not see (Burgelman and Hitt, 2007) and they recognize the value of new information that they happen to receive (Shane, 2000). In other words, startups might recognise business opportunities that are in front of other organizations, but they do not realise. In this way, external sources might be a source for business opportunities for startups, so they discover the business opportunity in a complementary way to their partners. Having business relationships bring the possibility to discover new business opportunities (Bhushan and Pandey, 2015). The diversity of external relationships or cooperation breadth gives startups more variety of resources and opportunities to create and exploit value and impact on their performances.

The RBV is focused on the factors that are key for firms to get a competitive advantage, creating a bundle of resources and capacities that distinguishes a firm from others (Mahoney and Pandian, 1992), and that are crucial to explain firm's profitability (Amit and Schoemaker, 1993). Barney (1991) argued that these resources must, by definition, be scarce, valuable, inimitable, and without equivalent substitutes. The RBV suggests that startups try to accumulate intangible resources to pursue their entrepreneurial activities and success (Lee et al., 2001). However, startups might have difficulties in getting a sustainable competitive advantage because they do not own and control a broad pool of resources within their boundaries. In other words, their initial resources endowment might not be enough to compete against incumbent firms. The startups' vulnerable strategic position leads them to form strategic alliances (Eisenhardt and Schoonhoven, 1996).

The RBV can be applied to the OI context, so the scarce, valuable, inimitable, and without equivalent substitutes are created in a cooperative way since knowledge from different

agents is brought together to create value (Vanhaverbeke and Cloodt, 2014). OI combines both internal and external resources, so firms integrate external knowledge into the development of their own technologies. Collaborating firms that combine resources in unique ways may realize a competitive advantage over others that compete on the basis of a stand-alone strategy (Vanhaverbeke and Cloodt, 2014, p. 265). External sources are therefore considered essential in the startups' innovation processes. Startups can acquire the resources that they lack (Hite and Hesterly, 2001) or get access to complementary assets (Colombo et al., 2006), reaching a sustainable competitive advantage.

The inimitable element of the resources leads to the development of appropriation mechanisms to protect their innovations and capture the rents from those innovations. IPRs are crucial in an open context to avoid intentionally or unintentionally allowing partners to collect all the benefits derived from their innovations (Pisano, 2006; Teece, 1986). Laursen and Salter (2014) explained that the creation of innovations requires some openness to get new knowledge, but the commercialization of the innovation requires certain protection to let firms capture the returns from their innovations. The link between OI and the appropriation strategy is relevant for startups since they are highly vulnerable to unintended knowledge spillovers. Their lack of resources makes them to be over-dependent of their partners and it increases the risk of opportunistic behaviour (Granovetter, 1985; Villena et al., 2011). Having IPRs would diminish it (Laursen and Salter, 2014; Teece, 2000). Moreover, IPRs are not only a mean to protect the inventions, but they also perform as a signal of quality or innovation capabilities (Baum and Silverman, 2004; Miozzo et al., 2016) that can help startups to attract more partners and connect with partners with complementary assets (Colombo et al., 2006; Teece, 1986; Wang et al., 2015). Thereby, startups have their own motivation to use IPRs when cooperate with external sources.

The KBV considers the creation of knowledge as the most strategically important resource of the firm (Grant, 1996), which triggers value creation. Hence, the main role of a firm is the generation, integration, and utilisation of knowledge (Grant, 1996; Kogut and Zander, 1992). Startups are powerful engines of knowledge creation (Spender et al., 2017), despite their initial endowment limitations. Knowledge might come from the firm itself, so it would emerge from the firm thanks to their own R&D activities; or from external partners. Knowledge accessing provides the predominant motive for alliance formation, especially within the knowledge-intensive sectors (Grant and Baden-Fuller, 2004). Integrate diverse knowledge inputs increases the opportunities for new knowledge combinations (Salge et al., 2012). Hence, cooperate with a diversity of knowledge sources would increase the discovery of new opportunities. On this basis, knowledge from external partners is especially relevant for startups, which are looking for new business opportunities.

OI cannot be understood without the theoretical angles of absorptive capacity (Vanhaverbeke et al., 2008) since firms need to integrate external knowledge. Cohen and Levinthal (1990, p. 128) defined the absorptive capacity as 'the ability to recognize the value of new information, assimilate it, and apply it to commercial ends'. Hence, absorptive capacity has a potential value for inbound open innovation activities. However, in order to absorb external knowledge, firms need a prior related knowledge base to assimilate that knowledge (Cohen and Levinthal, 1990) and it might be a caveat for the startups. Since startups do not have an extent base of knowledge due to their newness, they might experience difficulties when they cooperate with external agents. As a consequence, the negative effects of cooperation might be more severe for startups than for other firms. Although this dissertation does not specifically address the absorptive capacity interplay, it is included as a control variable in our studies.

An extent of the RBV is the DC perspective. Compared to the RBV, the DC perspective takes into account firms' external factors, and it explains situations in which there is a change in the firm's environment and the RBV fails to explain. The DC perspective focuses on firms' capacities to create, integrate and reconfigure their resources to respond to the rapidly changing environment (Teece et al., 1997). The DC perspective can help to explain OI since it explains how firms obtain an innovation-based competitive advantage in open environments where resources are widely available and transferable (Zobel, 2013). The DC perspective could be especially useful to explain the startups' success. Startups have been described as being more flexible than incumbent firms (Hyytinen et al., 2015; Katila and Shane, 2005), and do not suffer from structural inertia (Criscuolo et al., 2012). They have demonstrated to be highly innovative because they do not have formal and rigid routines that block their innovation processes. Hence, startups might be endowed of an internal structure that is accurate to face the environment changes.

To sum up, startups' features and purposes perform a special role when applying different theory frameworks to the OI context. For this reason, in this dissertation I analyse startups as a particular phenomenon on the employ of a diversity of external knowledge sources.

1.4 Research questions

The objective of this dissertation is to provide a better understanding of the OI phenomenon, in particular, of the cooperation breadth, in the context of startups. I study how startups may benefit from defining specific knowledge source strategies, that is, how startups use a diversity of knowledge sources to create and appropriate the value from their innovations, and so enhancing their innovation performance. As I have mentioned before, the mainstream of OI studies have neglected the analysis of the particularities of

startups in the study of the OI phenomenon. Despite the importance of startups for the innovation system of most of the countries, researchers have barely account for a framework that addresses the particularities of startups when applying OI strategies. Since the differences between startups and other types of firms are substantial, the OI principles cannot be directedly applied to startups and drive to the same conclusions. Some research streams, such as the entrepreneurship theory, the RBV, the KBV, and the DC perspective, have analysed the use of external resources by startups, but these research streams do not completely explain the startups' flows of knowledge in the current innovation ecosystem since they do not frame the innovation strategy, which includes the use of external sources, as an integral part of the business model of a firm. The OI paradigm provides a better framework to understand the current innovation ecosystem and the firms' innovation strategies, but startups' features should be taken into consideration. Accordingly, this dissertation contributes to the OI literature by studying their implications for startups, but also to the entrepreneurship literature since I introduce some concepts, such as cooperation breadth or the consideration of the OI activities as part of the business model of a startup, into the entrepreneurship theory.

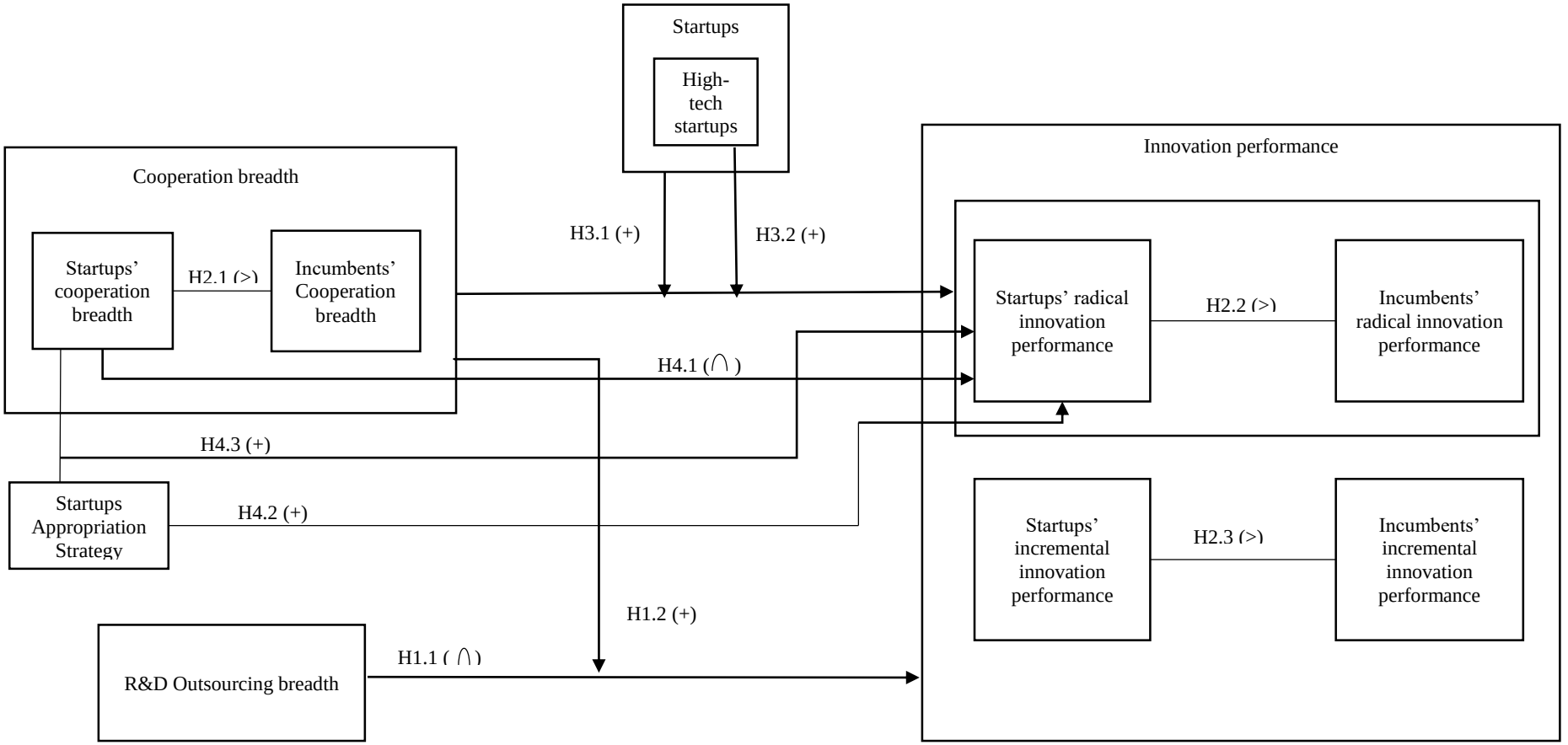
After a thorough literature review and the identification of that relevant research gap, I pose the overarching research question of this dissertation as follows:

Will the diversity of external sources of knowledge contribute to the performance of start-ups?

In addressing this overarching research question, I implemented four separate studies that address various facets of OI in the context of startups. These studies go from the general concept of breadth for all firms to the particular analysis of a sample of startups. The first study deepens on the concept of breadth, so I study different types of inbound open

innovation in terms of breadth and their complementarity for the innovation performance, controlling by startups. From this study, I observe the preponderance of cooperation breadth over R&D outsourcing breadth, and a positive impact of startups on innovation performance, so it leads to a comparative analysis of cooperation breadth and innovation performance on the second study. The second study analyses the differences between startups and incumbent firms in terms of cooperation breadth and innovation performance since it has not been studied in literature yet. Once differences have been tested and checked that the bigger differences are in cooperation breadth and radical innovation performance, in the third study I only focus on these two variables. I analyse whether startups benefit to a greater extent from cooperation breadth for radical innovation performance. If startups have a higher cooperation breadth, it might be because its use creates more value for startups. Finally, I focus on startups and investigate their cooperative innovation processes and value appropriation strategies for radical innovation performance, as well as their complementaries. The openness and appropriation strategies are crucial issue for startups, forming the innovation strategy. The use of both at the same time is determining to know how they influences the radical innovation performance. The four studies place a different emphasis on the underlying theories that support the processes of value creation and value appropriation in startups. Each study will answer to a specific subquestions and provide unique insights into the overarching research question. Figure 1.1 gives an overview of the dissertation, so it summarises the hypotheses of the four studies, and in Table 1.1 there is a summary of the research questions of this dissertation. In the following, the four studies are introduced in more detail.

Figure 1.1 Dissertation overview



Source: Own elaborated.

Table 1.1 Summary of research questions

Study	Research question
Overarching question	Will the diversity of external sources of knowledge contribute to the performance of startups?
1	Is there complementarity between cooperation breadth and R&D outsourcing breadth for innovation performance?
2	Are startups different from incumbent firms in terms of cooperation breadth and innovation performance?
3	Will startups benefit to a greater extent from cooperation breadth for radical innovation performance?
4	How openness and appropriation independently and jointly influence startups' radical innovation performance?

Source: Own elaborated

Study 1 – Modes of inbound knowledge breadth. Are cooperation and R&D outsourcing really complementary?

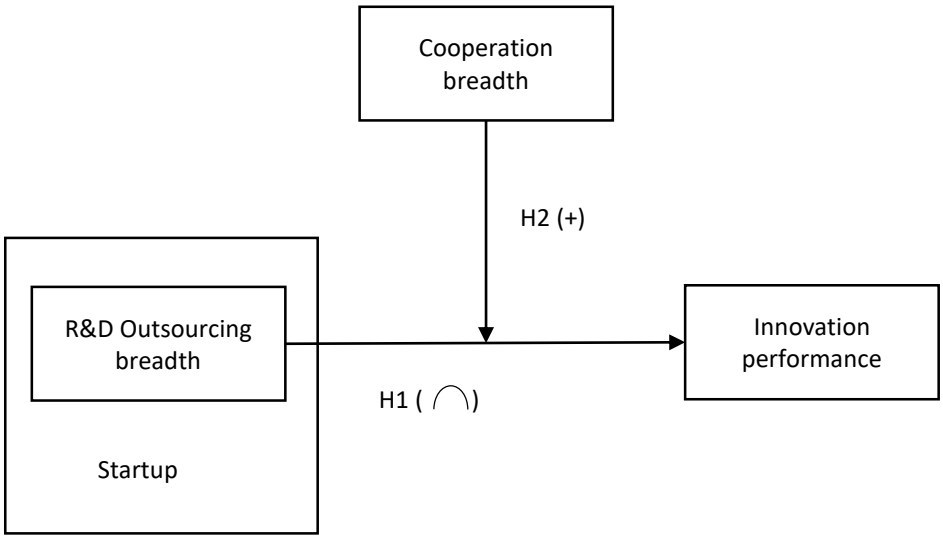
The first study examines the relationship between breadths of two different modes of external knowledge: R&D outsourcing and cooperation. They are the two main inbound innovation strategies as the former is the main example of a pecuniary inbound innovation strategy involving the acquisition of external knowledge, while the latter is the most common non-pecuniary sourcing strategy used by firms to absorb external knowledge into their innovation processes (Chesbrough and Bogers, 2014; Dahnlander and Gann, 2010; Tsai and Wang, 2008, 2009). R&D outsourcing and cooperation are two different strategies to integrate external technology, and they are utilized in a different way as R&D outsourcing is usually performed to reduce costs, reinforce specialization, and achieve economies of scale, while cooperation is motivated by strategic rather than cost considerations. Most of the research has examined the 'make' or 'buy' trade-off and the complementarity or substitutability between internal and external R&D (Andries and Thorwarth, 2014; Audretsch et al., 1996; Berchicci, 2013; Hagedoorn and Wang, 2012; Lokshin et al., 2008; Love and Roper, 2001, 2009; McIvor, 2009; Piga and Vivarelli,

2003, 2004; Schmiedeberg, 2008; Veugelers and Cassiman, 1999), but it has barely been analysed the interplay between different OI strategies. The study of the interaction of these two inbound OI strategies is relevant since firms may create mutual relational capital that generates synergies and economies of scale and scope. The research question of this study is as follows:

Is there complementarity between cooperation breadth and R&D outsourcing breadth for innovation performance?

Building upon transaction costs literature and the resource-based view I hypothesise an inverted-U relationship between outsourcing breadth and innovation performance and a complementary relationship between R&D outsourcing and R&D cooperation. Figure 1.2 summarises the model.

Figure 1.2 Model in Study 1



Source: Own elaborated

The model is tested on a large sample based on CIS survey for Spain. The empirical analysis confirms the U-inverted relationship between outsourcing breadth and

innovation, but also reveals an interesting result: the complementary effect of R&D cooperation varies with the level of R&D outsourcing breadth and it is not confirmed for low and medium levels of R&D outsourcing breadth. I also find that the variable control of startups is positively significant for innovation performance.

This study contributes to understand the concept of breadth and addresses the combination of different OI strategies, rather than analysing each of them in a separate way. Furthermore, the significant coefficient for startups suggests that startups play a singular role in the generation of innovations and it should be investigated.

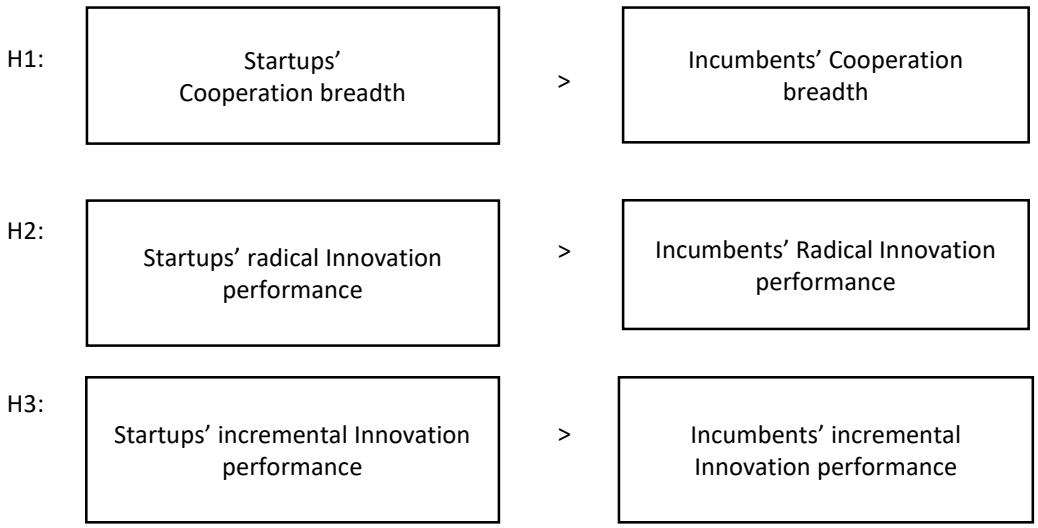
Study 2 – Open innovation and the comparison between startups and incumbent firms in Spain

Study two compares the OI strategy between startups and incumbent firms. Startups and incumbent firms both play important roles in generating innovations and economic growth, but they contribute to the innovation ecosystem and economic development in different ways. Startups are assumed to be more innovative than established firms (Criscuolo et al., 2012), but few research addresses this comparison. Katila and Shane (2005) found that startups contribute to markets where diversity in approaches to innovation is high, while incumbent firms operate in markets where innovation routines are standardised. And Criscuolo et al. (2012) found that startups have higher returns to innovation in both, manufacturing and services, and also a major likelihood of product innovations. In order to understand the innovation ecosystem, I extent this research stream and study how both types of firm can contribute to the economic prospects from their specific positions, and then benefit from these prospects in terms of cooperation breadth and different types of innovation. Therefore, the research question of this study is as follows:

Are startups different from incumbent firms in terms of cooperation breadth and innovation performance?

Basing my arguments in the RBV and the DC perspective, as well as in the entrepreneurship theory, I justify that there are notable differences between startups and incumbent firms in terms of resource endowments, external cooperation and innovative capabilities for reaching high innovation performance. Figure 1.3 summarises the t-test of this study.

Figure 1.3 Models in Study 2



Source: Own elaborated

Using a sample of startups and incumbent Spanish firms over a period of ten years (2004-2013), I find that they differ considerably. Incumbent firms and startups differ in terms of their use of external cooperation activities as a source of innovation. The lack of financial and human resources of startups leads them to open their borders more than incumbent firms, and startups benefit from being flexible, as they have yet to implement routines. This boosts startups' innovation performance.

The study extents previous research on the differences between startups and incumbent firms, and contributes to understand the role of each type of firm on the innovation ecosystem, which generates important implications for management.

Study 3 – Do startups benefit more from opening to external sources? An analysis of the role of startups for radical innovation performance

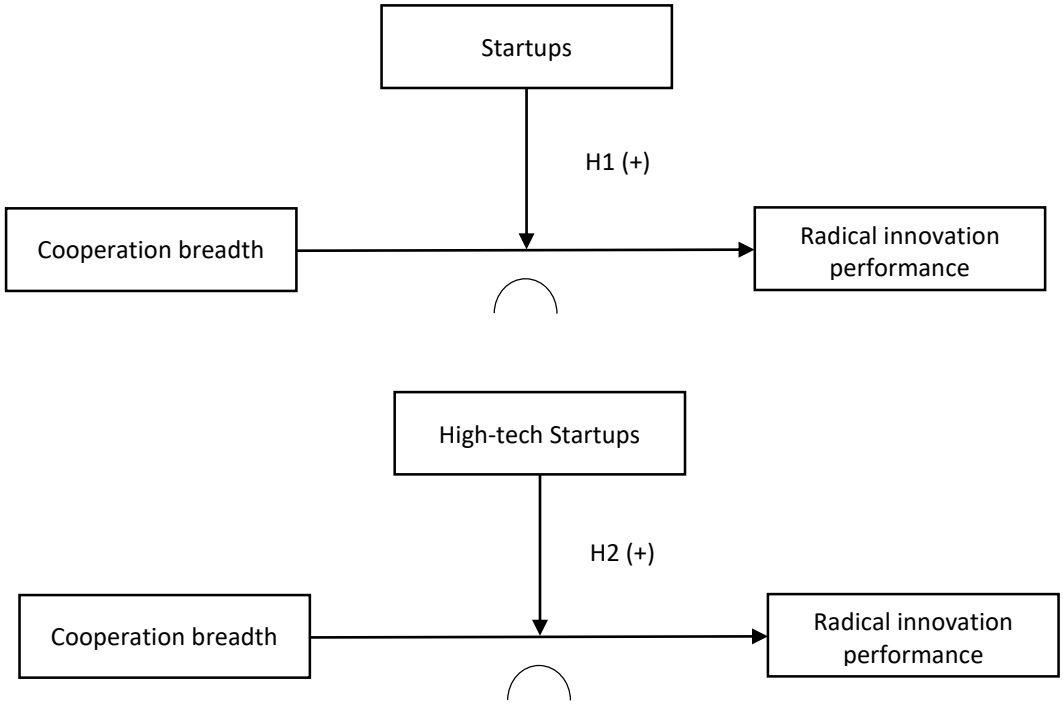
Study 3 investigates the contribution of startups and high-tech startups in the analysis of the impact of cooperate breadth on radical innovation performance. Engaging in relationships with external sources is key for all types of firms, but it might become of special relevance for startups, which are forced to open up their boundaries to overcome the liabilities of newness and smallness (Usman and Vanhaverbeke, 2017). The differences in extracting the benefits from OI could also be dependent on some contingencies, such as the industrial sector in which the firm operates (Huizingh, 2010). To our knowledge, no previous studies have examined whether startups and high-tech startups may benefit to a greater extent from defining specific knowledge source strategies. I therefore discuss how startups related to other firms successfully explore and exploit business opportunities when they cooperate with a diversity of partners. Thereby, the study addresses the following research question:

Will startups benefit to a greater extent from cooperation breadth for radical innovation performance?

Basing my arguments on the KBV I discuss that cooperation breadth brings more diverse knowledge inputs to identify opportunities and enhances innovation performance, and provide access to market to exploit opportunities and increase the likelihood of startups'

performance. I hypothesise that startups and, in particular, high-tech startups, benefit to a greater extent from cooperation breadth. Figure 1.4 shows the models used in this study.

Figure 1.4 Models in Study 3



Source: Own elaborated

Using data from the Spanish Innovation Technology Panel (PITEC) from 2004 to 2013, I find that the contribution of cooperation breadth is higher in startups, in particular, in high-tech startups. Startups are forced to open up their boundaries to overcome the liabilities of newness and smallness, and it far from being a limitation, it is an opportunity for innovation. This positive effect in intensified in high-tech sectors since knowledge intensity increases and it is more needed to access to a diversity of knowledge sources.

This study contributes to the link between OI and entrepreneurship theory, evidencing the usefulness of applying the concept of breadth on the explanation of startups' innovation processes. It also deepens on the contingencies on OI strategies and contrast previous

literature that argued that the effect of the technology intensity sector tend to disappear when smallness factor is taken into consideration.

Study 4 – The paradox of openness in startups

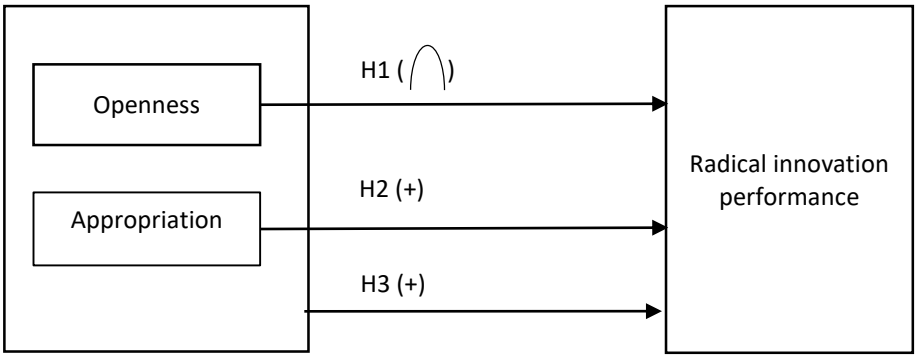
To shed light and clarify how both openness in the value creating process, and appropriation strategy as part of the value capturing process interrelate and influence the startups' radical innovative performance, this study focuses on the impact of cooperation breadth and the appropriation strategy on radical innovation performance of startups, and analyses the complementarity between them. Openness and appropriation are two key elements of the startups' innovation strategy. Recent studies are analysing the interplay between openness and the appropriation strategy of the firm, called the "openness paradox" (Arora et al., 2016; Huang et al., 2014; Jensen and Webster, 2009; Laursen and Salter, 2014; Miozzo et al., 2016; Zobel et al., 2016), but with the exception of Zobel et al. (2016), they do not focus on startups. Since we have justified that startups are different from incumbent firms, it is necessary to investigate these two strategies for startups. Hence, the research question of this study is as follows:

How openness and appropriation independently and jointly influence startups' radical innovation performance?

In this study I argue that cooperating with external partners is a key source for the innovation process of a startup because it helps startups to overcome their liability of smallness and newness. At the same time, combining collaborative innovation activities with due diligent appropriation strategy ensures they capture value created, suggesting complementarity between openness and appropriation on innovation performance. Based

on Spanish data from 2004 to 2013, I test and find support for my propositions: Cooperation breadth draws an inverted-U shape with startups' innovation performance, startups' appropriation strategy is positively related to the innovation performance, and a complementary effect between openness and appropriation strategy exists. Figure 1.5 summarises the model.

Figure 1.5 Model in Study 4



Source: Own elaborated

Startups can benefit from using both strategies at the same time since formal appropriation mechanisms reduce the likelihood of partners' opportunistic behaviours. At the same time, formal appropriation mechanisms also help startups to attract more partners and connect with partners with complementary assets, thus, getting a complementary effect when startups use both strategies. Hence, I evidence that using both strategies at the same time is better than the sum of both.

This study contributes to literature by explaining how startups use their openness strategy to create value, and how they can benefit from IPRs to capture the value of their innovations, and so enhance their radical innovation performance. It also contributes to

the recent debate about the trade-off between openness and appropriation, evidencing a complementary effect.

1.5 Research design

This dissertation uses secondary data from the database Spanish Technological Innovation Panel (PITEC), collected by the Spanish National Statistics Institute (INE), in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). The survey was implemented in 2003 and it is based on the annual Spanish responses to the Community Innovation Survey (CIS), whose method and types of questions are described in Oslo Manual (OECD, 2005).

CIS data has been used in numerous academic papers across Europe, for example, in Germany (Grimpe and Kaiser, 2010), Belgium (Cassiman and Veugelers, 2002, 2006; Spithoven et al., 2011), the United Kingdom (Laursen and Salter, 2006, 2014); and in other non-European countries, such as Taiwan (Tsai and Hsieh, 2009; Tsai and Wang, 2009). In Spain, PITEC is a well-established research tool, and has been used in previous studies (e.g. Escribano et al., 2009; Gimenez-Fernandez and Sandulli, 2016; Vega Jurado et al., 2010). CIS data has also been used in the context of startups (Colombelli et al., 2016; Criscuolo et al., 2012). Though in some countries, the Innovation Survey do not consider firms with less than 10 employees, PITEC do not suffer from this limitation since it includes all size firms, allowing the study of the startup phenomenon.

The database has broad sector coverage since it includes firms from all sectors of the Statistical Classification of Economic Activities in the European Community (NACE),

being representative of the population of Spanish firms. PITEC divides these industries according to the NACE code using a two-digit code, except when there are many firms in an industry and the firm's activity is defined at three digits or when there are just a few firms, in which case activities are regrouped with others.

Data are collected on a yearly base from 2003. PITEC started with two samples of firms: a sample of big firms (200 or more employees), and a sample of firms with internal R&D investment. In 2004 and 2005, the second sample was enlarged. Moreover, the 2004 sample also included small and medium-size firms (less than 200 employees), firms with external R&D expenditure, others without internal R&D investment, and a representative sample of small and medium-size firms and no innovation expenses. In this dissertation we are mainly focus on a sample of startups, which are defined in the survey as firms of new creation or they were during the two last years.

The current survey is 16 pages long and it includes four pages appendix of definitions and examples. In 2004 PITEC introduced some important changes in the questionnaire, affecting variables related to cooperation with external sources for technology innovation, which are central variables in our dissertation. Due to these limitations, this dissertation takes as focus year 2004; and I use longitudinal data from 2004 to 2013 to test my hypotheses. Since I analyse the OI phenomenon, I focus on firms that intended to have an innovation activity, even failed. The sample and description of the variables used in each model is provided in each study. The statistical technique used to test the different hypotheses is also explained in each study.

Although all the studies of this dissertation are based on secondary data, I undertook some interviews with international startups to understand the internal processes of their open innovation activities. However, those interviews are not included in this dissertation. In

spite of it, they have informed the application of the theoretical argumentations and managerial implications.

1.6 Dissertation outline

The remainder of this dissertation is structured as follows. Chapters 2, 3, 4, and 5 deal with one of the four research sub-questions respectively. Chapter 2 deepens on the concept of breadth. Chapter 3 explains the differences between startups and incumbent firms regarding the cooperation breadth and the innovation performance. Chapter 4 investigates the contribution of cooperation breadth for startups for radical innovation performance. Chapter 5 presents an integrative perspective of startups' openness and appropriation strategy, studying the complementarity between them. Finally, Chapter 6 revisits the overall research question and summarizes the main findings of the four studies. This Chapter also discusses the implications for theory and practice, lays out some limitations of this dissertation, and provides directions for future research.

References

Ahuja, G., 2000. Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study. Adm. Sci. Q. 45.

Alberti, F.G., Pizzurno, E., 2017. Oops, I did it again! Knowledge leaks in open innovation networks with start-ups. Eur. J. Innov. Manag. 20, 50–79. doi:10.1108/EJIM-11-2015-0116

Alchian, A.A., 1950. Uncertainty, Evolution, and Economic Theory. J. Polit. Econ. 58.

Alexy, O., Bascavusoglu-Moreau, E., Salter, A.J., 2016. Toward an aspiration-level theory of open innovation. Ind. Corp. Change 25, 289–306. doi:10.1093/icc/dtw003

Allen, T.J., Gloor, P.A., Fronzetti Colladon, A., Woerner, S.L., Raz, O., 2016. The power of reciprocal knowledge sharing relationships for startup success. J. Small Bus. Enterp. Dev. 23, 636–651. doi:10.1108/JSBED-08-2015-0110

Amit, R., Schoemaker, P.J.H., 1993. Strategic Assets and Organizational Rent. Strateg. Manag. J. 14, 33–46. doi:10.2307/2486548

Anderson, E.G., Parker, G.G., 2013. Integration and Cospecialization of Emerging Complementary Technologies by Startups. Prod. Oper. Manag. 22, 1356–1373. doi:10.1111/j.1937-5956.2012.01415.x

Andries, P., Thorwarth, S., 2014. Should Firms Outsource their Basic Research? The Impact of Firm Size on In-House versus Outsourced R&D Productivity. Creat. Innov. Manag. 23, 303–317. doi:10.1111/caim.12073

Arora, A., Athreye, S., Huang, C., 2016. The paradox of openness revisited: Collaborative innovation and patenting by UK innovators. Res. Policy 45, 1352–1361. doi:10.1016/j.respol.2016.03.019

Audretsch, D.B., Menkveld, A.J., Thurik, A.R., 1996. The Decision Between Internal and External R & D. J. Institutional Theor. Econ. JITE Z. Für Gesamte Staatswiss. 152, 519–530.

Augier, M., Teece, D.J., 2009. Dynamic Capabilities and the Role of Managers in Business Strategy and Economic Performance. Organ. Sci. 20, 410–421. doi:10.1287/orsc.1090.0424

Bahemia, H., Squire, B., 2010. A Contingent Perspective Of Open Innovation In New Product Development Projects. Int. J. Innov. Manag. Ijim 14, 603–627.

Barney, J., 1991. Firm Resources and Sustained Competitive Advantage. J. Manag. 17, 99.

Battistella, C., Toni, A.F.D., Pessot, E., 2017. Open accelerators for start-ups success: a case study. Eur. J. Innov. Manag. 20, 80–111. doi:10.1108/EJIM-10-2015-0113

Baum, J. a. C., Calabrese, T., Silverman, B.S., 2000. Don't go it alone : Alliance network composition and startups' performance in canadian biotechnology. Strateg. Manag. J. 21, 267–294.

Baum, J.A.C., Silverman, B.S., 2004. Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. J. Bus. Ventur., Evolutionary approaches to entrepreneurship: Honoring Howard Aldrich 19, 411–436. doi:10.1016/S0883-9026(03)00038-7

Belderbos, R., Carree, M., Lokshin, B., 2006. Complementarity in R&D Cooperation Strategies. Rev. Ind. Organ. 28, 401–426. doi:10.1007/s11151-006-9102-z

Berchicci, L., 2013. Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance. Res. Policy 42, 117–127. doi:10.1016/j.respol.2012.04.017

Bessant, J., Phillips, W., 2013. Innovation management and dynamic capability, in: Harland, C., Nassimbeni, G., and Schneller, E. (Eds) The SAGE Handbook of Strategic Supply Management. SAGE.

Bhalla, A., Terjesen, S., 2013. Cannot make do without you: Outsourcing by knowledge-intensive new firms in supplier networks. Ind. Mark. Manag., Managing Key Supplier Relationships 42, 166–179. doi:10.1016/j.indmarman.2012.12.005

Bhushan, B., Pandey, S., 2015. Exploring the dynamics of network characteristics for Indian high technology entrepreneurial firms. J. Glob. Entrep. Res. 5, 1–20. doi:http://0-dx.doi.org.cisne.sim.ucm.es/10.1186/s40497-015-0029-4

Blank, S., 2010. What's A Startup? First Principles. Steve Blank.

Bogers, M., 2011. The open innovation paradox: knowledge sharing and protection in R&D collaborations. Eur. J. Innov. Manag. 14, 93–117. doi:10.1108/14601061111104715

Bogers, M., Zobel, A.-K., Afuah, A., Almirall, E., Brunswicker, S., Dahlander, L., Frederiksen, L., Gawer, A., Gruber, M., Haefliger, S., Hagedoorn, J., Hilgers, D., Laursen, K., Magnusson, M.G., Majchrzak, A., McCarthy, I.P., Moeslein, K.M., Nambisan, S., Piller, F.T., Radziwon, A., Rossi-Lamastra, C., Sims, J., Wal, A.L.J.T., 2016. The open innovation research landscape: established perspectives and emerging themes across different levels of analysis. Ind. Innov. 0, 1–33. doi:10.1080/13662716.2016.1240068

Bosma, N., Praag, M. van, Thurik, R., Wit, G. de, 2004. The Value of Human and Social Capital Investments for the Business Performance of Startups. Small Bus. Econ. 23, 227–236. doi:10.1023/B:SBEJ.0000032032.21192.72

Brunswicker, S., Van De Vrande, V., 2014. Exploring Open Innovation in Small and Medium-Sized Enterprises, in: New Frontiers in Open Innovation. Oxford University Press, Oxford.

Brunswicker, S., Vanhaverbeke, W., 2015. Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators. J. Small Bus. Manag. 53, 1241–1263. doi:10.1111/jsbm.12120

Burgelman, R.A., Hitt, M.A., 2007. Entrepreneurial actions, innovation, and appropriability. Strateg. Entrep. J. 1, 349–352. doi:10.1002/sej.28

Burt, R., 1992. Structural Holes: The Social Structure of Competition. Harv. Univ. Press Camb. MA.

Cassiman, B., Valentini, G., 2011. What is open innovation, really?

Cassiman, B., Veugelers, R., 2006. In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition. Manag. Sci. 52, 68–82. doi:10.1287/mnsc.1050.0470

Cassiman, B., Veugelers, R., 2002. Complementarity in the Innovation Strategy: Internal R&D, External Technology Acquisition and Cooperation (SSRN Scholarly Paper No. ID 308601). Social Science Research Network, Rochester, NY.

Chesbrough, H., 2012. Open Innovation: Where We've Been and Where We're Going. Res.-Technol. Manag. 55, 20–27. doi:10.5437/08956308X5504085

Chesbrough, H., 2006. Open Innovation: A new paradigm for understanding industrial innovation, in: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), Open Innovation: Researching a New Paradigm. Oxford University Press, Oxford.

Chesbrough, H., 2006. Open Business Models: How To Thrive In The New Innovation Landscape. Harvard Business Press.

Chesbrough, H., Bogers, M., 2014. Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation, in: New Frontiers in Open Innovation. Oxford University Press, Oxford, pp. 3–28.

Chesbrough, H.W., 2003. Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business Press.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: A new perspective on learning and innovation. Adm. Sci. Q. 35, 128–152. doi:10.2307/2393553

Collins, J., Riley, J., 2013. Alliance Portfolio Diversity and Firm Performance: Examining Moderators. J. Bus. Manag. 19, 35–50.

Colombelli, A., Krafft, J., Vivarelli, M., 2016. To be born is not enough: the key role of innovative start-ups. Small Bus. Econ. 1–15. doi:10.1007/s11187-016-9716-y

Colombo, M.G., Grilli, L., Piva, E., 2006. In search of complementary assets: The determinants of alliance formation of high-tech start-ups. Res. Policy, Special issue commemorating the 20th Anniversary of David Teece's article, "Profiting from Innovation", in Research Policy 35, 1166–1199. doi:10.1016/j.respol.2006.09.002

Cook, R., Campbell, D., Kelly, C., 2012. Survival Rates of New Firms: An Exploratory Study. Small Bus. Inst. J. 8, 35–42.

Corvello, V., Grimaldi, M., Rippa, P., 2017. Start-ups and open innovation. Eur. J. Innov. Manag. 20, 2–3.

Criscuolo, P., Nicolaou, N., Salter, A., 2012. The elixir (or burden) of youth? Exploring differences in innovation between start-ups and established firms. Res. Policy 41, 319–333. doi:10.1016/j.respol.2011.12.001

Cyter, R.M., March, J.G., 1963. A Behavioral Theory of the firm. Prentice-Hall Englewood Cliffs N. Y.

Dahlander, L., Gann, D.M., 2010. How open is innovation? Res. Policy 39, 699–709. doi:10.1016/j.respol.2010.01.013

Danneels, E., 2002. The dynamics of product innovation and firm competences. Strateg. Manag. J. 23, 1095–1121. doi:10.1002/smj.275

Davila, A., Foster, G., 2005. Management Accounting Systems Adoption Decisions: Evidence and Performance Implications from Early-Stage/Startup Companies. Account. Rev. 80, 1039–1068. doi:10.2308/accr.2005.80.4.1039

Davila, A., Foster, G., He, X., Shimizu, C., 2015. The Rise and Fall of Startups: Creation and Destruction of Revenue and Jobs by Young Companies. Australian Journal of Management 40 (1):6–35. https://doi.org/10.1177/0312896214525793.

Dosi, G., 1988. Sources, Procedures, and Microeconomic Effects of Innovation. J. Econ. Lit. 26, 1120–71.

Eftekhari, N., Bogers, M., 2015. Open for Entrepreneurship: How Open Innovation Can Foster New Venture Creation. Creat. Innov. Manag. 24, 574–584. doi:10.1111/caim.12136

Eisenhardt, K.M., Schoonhoven, C.B., 1996. Resource-Based View of Strategic Alliance Formation: Strategic and Social Effects in Entrepreneurial Firms. Organ. Sci. 7, 136–150.

Elmquist, M., Fredberg, T., Ollila, S., 2009. Exploring the field of open innovation. Eur. J. Innov. Manag. 12, 326–345. doi:http://0-dx.doi.org.cisne.sim.ucm.es/10.1108/14601060910974219

Enkel, E., 2010. Attributes required for profiting from open innovation in networks. Int. J. Technol. Manag. 52, 344–371. doi:10.1504/IJTM.2010.035980

Enkel, E., Gassmann, O., Chesbrough, H., 2009. Open R&D and open innovation: exploring the phenomenon. RD Manag. 39, 311–316. doi:10.1111/j.1467-9310.2009.00570.x

Escribano, A., Fosfuri, A., Tribó, J.A., 2009. Managing external knowledge flows: The moderating role of absorptive capacity. Res. Policy 38, 96–105. doi:10.1016/j.respol.2008.10.022

Faems, D., Janssens, M., Madhok, A., Looy, B.V., 2008. Toward an Integrative Perspective on Alliance Governance: Connecting Contract Design, Trust Dynamics, and Contract Application. Acad. Manage. J. 51, 1053–1078.

Fuerst, S., Zettinig, P., 2015. Knowledge creation dynamics within the international new venture. Eur. Bus. Rev. 27, 182–213. doi:10.1108/EBR-03-2013-0036

Gans, J.S., Stern, S., 2003. The product market and the market for “ideas”: commercialization strategies for technology entrepreneurs. Res. Policy, Special Issue on Technology Entrepreneurship and Contact Information for corresponding authors 32, 333–350. doi:10.1016/S0048-7333(02)00103-8

Gassmann, O., Enkel, E., 2004. Towards a Theory of Open Innovation: Three Core Process Archetypes, in: In: Proceedings of the R&D Management Conference (RADMA). Sessimbra. pp. 8–9.

Gimenez-Fernandez, E.M., Sandulli, F.D., 2016. Modes of inbound knowledge flows: are cooperation and outsourcing really complementary? Ind. Innov. 0, 1–22. doi:10.1080/13662716.2016.1266928

Granovetter, M., 1985. Economic Action and Social Structure: The Problem of Embeddedness. Am. J. Sociol. 91, 481–510. doi:10.1086/228311

Grant, R.M., 1996. Toward a knowledge-based theory of the firm. Strateg. Manag. J. 17, 109–122. doi:10.1002/smj.4250171110

Grant, R.M., Baden-Fuller, C., 2004. A Knowledge Accessing Theory of Strategic Alliances. J. Manag. Stud. 41, 61–84. doi:10.1111/j.1467-6486.2004.00421.x

Grimpe, C., Kaiser, U., 2010. Balancing Internal and External Knowledge Acquisition: The Gains and Pains from R&D Outsourcing. J. Manag. Stud. 47, 1483–1509. doi:10.1111/j.1467-6486.2010.00946.x

Groen, A.J., Linton, J.D., 2010. Is open innovation a field of study or a communication barrier to theory development? Technovation 30, 554. doi:10.1016/j.technovation.2010.09.002

Gronum, S., Verreynne, M.-L., Kastelle, T., 2012. The Role of Networks in Small and Medium-Sized Enterprise Innovation and Firm Performance. J. Small Bus. Manag. 50, 257–282. doi:10.1111/j.1540-627X.2012.00353.x

Gruber, M., Heinemann, F., Brettel, M., Hungeling, S., 2010. Configurations of resources and capabilities and their performance implications: an exploratory study on technology ventures. Strateg. Manag. J. 31, 1337–1356. doi:10.1002/smj.865

Gruber, M., MacMillan, I.C., Thompson, J.D., 2008. Look Before You Leap: Market Opportunity Identification in Emerging Technology Firms. Manag. Sci. 54, 1652–1665. doi:10.1287/mnsc.1080.0877

Gulati, R., Singh, H., 1998. The Architecture of Cooperation: Managing Coordination Costs and Appropriation Concerns in Strategic Alliances. Adm. Sci. Q. 43, 781. doi:10.2307/2393616

Hagedoorn, J., Wang, N., 2012. Is there complementarity or substitutability between internal and external R&D strategies? Res. Policy, Special Section on Sustainability Transitions 41, 1072–1083. doi:10.1016/j.respol.2012.02.012

Hayek, F.A., 1945. The Use of Knowledge in Society (SSRN Scholarly Paper No. ID 1505216). Social Science Research Network, Rochester, NY.

Heap, J., 2010. Open Innovation. Manag. Serv. 54, 26–27.

Ketchen, D.J., Ireland, R.D., Snow, C.C., 2007. Strategic entrepreneurship, collaborative innovation, and wealth creation. Strat.Entrepreneurship J. 1, 371–385. doi:10.1002/sej.20

Hite, J.M., Hesterly, W.S., 2001. The evolution of firm networks: from emergence to early growth of the firm. Strateg. Manag. J. 22, 275–286. doi:10.1002/smj.156

Hsieh, C.-T., Huang, H.-C., Lee, W.-L., 2016. Using transaction cost economics to explain open innovation in start-ups. Manag. Decis. 54, 2133–2156. doi:10.1108/MD-01-2016-0012

Hsu, D.H., Ziedonis, R.H., 2013. Resources as dual sources of advantage: Implications for valuing entrepreneurial-firm patents. Strateg. Manag. J. 34, 761–781. doi:10.1002/smj.2037

Huang, F., Rice, J., Galvin, P., Martin, N., 2014. Openness and Appropriation: Empirical Evidence From Australian Businesses. IEEE Trans. Eng. Manag. 61, 488–498. doi:10.1109/TEM.2014.2320995

Huizingh, E.K.R.E., 2010. Open innovation: State of the art and future perspectives. Technovation 31, 2–9. doi:10.1016/j.technovation.2010.10.002

Hyytinen, A., Pajarinen, M., Rouvinen, P., 2015. Does innovativeness reduce startup survival rates? J. Bus. Ventur. doi:10.1016/j.jbusvent.2014.10.001

INE, 2016. Instituto Nacional de Estadística. (National Statistics Institute) [WWW Document]. URL http://www.ine.es/jaxi/menu.do?type=pcaxis&path=%2Ft37%2Fp204&file=inebase&L=0 (accessed 1.18.17).

Jensen, P.H., Webster, E., 2009. Knowledge management: does capture impede creation? Ind. Corp. Change 18, 701–727. doi:10.1093/icc/dtp025

Katila, R., Ahuja, G., 2002. Something Old, Something New: A Longitudinal Study of Search Behavior and New Product Introduction. Acad. Manage. J. 45, 1183–1194. doi:10.2307/3069433

Katila, R., Shane, S., 2005. When Does Lack of Resources Make New Firms Innovative? Acad. Manage. J. 48, 814–829. doi:10.5465/AMJ.2005.18803924

Kogut, B., Zander, U., 1992. Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology. Organ. Sci. 3, 383–397. doi:10.1287/orsc.3.3.383

Koput, K.W., 1997. A Chaotic Model of Innovative Search: Some Answers, Many Questions. Organ. Sci. 8, 528–542. doi:10.1287/orsc.8.5.528

Kovács, A., Van Looy, B., Cassiman, B., 2014. Exploring the scope of open innovation: A bibliometric review of a decade of research [WWW Document]. URL https://lirias.kuleuven.be/handle/123456789/439281 (accessed 7.2.14).

Kuhn, T.S., 1962. The Structure of Scientific Revolutions. University of Chicago Press, Chicago.

Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. Strateg. Manag. J. 27, 131–150. doi:10.1002/smj.507

Laursen, K., Salter, A.J., 2014. The paradox of openness: Appropriability, external search and collaboration. Res. Policy, Open Innovation: New Insights and Evidence 43, 867–878. doi:10.1016/j.respol.2013.10.004

Lee, C., Lee, K., Pennings, J.M., 2001. Internal capabilities, external networks, and performance: a study on technology-based ventures. Strateg. Manag. J. 22, 615–640. doi:10.1002/smj.181

Lee, S., Park, G., Yoon, B., Park, J., 2010. Open innovation in SMEs—An intermediated network model. Res. Policy 39, 290–300. doi:10.1016/j.respol.2009.12.009

Leeuw, T., Lokshin, B., Duysters, G., 2014. Returns to alliance portfolio diversity: The relative effects of partner diversity on firm's innovative performance and productivity. J. Bus. Res. 67, 1839–1849. doi:10.1016/j.jbusres.2013.12.005

Leiponen, A., Helfat, C.E., 2010. Innovation objectives, knowledge sources, and the benefits of breadth. Strateg. Manag. J. 31, 224–236. doi:10.1002/smj.807

Lokshin, B., Belderbos, R., Carree, M., 2008. The Productivity Effects of Internal and External R&D: Evidence from a Dynamic Panel Data Model*. Oxf. Bull. Econ. Stat. 70, 399–413. doi:10.1111/j.1468-0084.2008.00503.x

Love, J.H., Roper, S., 2009. Organizing the Innovation Process: Complementarities in Innovation Networking. Ind. Innov. 16, 273–290. doi:10.1080/13662710902923776

Love, J.H., Roper, S., 2001. Outsourcing in the innovation process: Locational and strategic determinants. Pap. Reg. Sci. 80, 317–336. doi:10.1111/j.1435-5597.2001.tb01802.x

Mahoney, J.T., Pandian, J.R., 1992. The resource-based view within the conversation of strategic management. Strateg. Manag. J. 13, 363–380. doi:10.1002/smj.4250130505

March, J.G., 1991. Exploration and Exploitation in Organizational Learning. Organ. Sci. 2, 71–87. doi:10.1287/orsc.2.1.71

Marx, M., Hsu, D.H., 2015. Strategic switchbacks: Dynamic commercialization strategies for technology entrepreneurs. Res. Policy 44, 1815–1826. doi:10.1016/j.respol.2015.06.016

McIvor, R., 2009. How the transaction cost and resource-based theories of the firm inform outsourcing evaluation. J. Oper. Manag. 27, 45–63. doi:10.1016/j.jom.2008.03.004

Miozzo, M., Desyllas, P., Lee, H., Miles, I., 2016. Innovation collaboration and appropriability by knowledge-intensive business services firms. Res. Policy 45, 1337–1351. doi:10.1016/j.respol.2016.03.018

Mowery, D.C., 2009. Plus ca change: Industrial R&D in the "third industrial revolution." Ind. Corp. Change 18, 1–50. doi:10.1093/icc/dtn049

Nelson, R.R., Winter, S.G., 1982. The Schumpeterian Tradeoff Revisited. Am. Econ. Rev. 72, 114–132.

Neyens, I., Faems, D., Sels, L., 2010. The impact of continuous and discontinuous alliance strategies on startup innovation performance. Int. J. Technol. Manag. 52, 392–410. doi:10.1504/IJTM.2010.035982

Nieto, M.J., Santamaría, L., 2007. The importance of diverse collaborative networks for the novelty of product innovation. Technovation 27, 367–377. doi:10.1016/j.technovation.2006.10.001

Ocasio, W., 1997. Towards an attention-based view of the firm. Strateg. Manag. J. 18, 187–206.

OECD, 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd ed. Paris: Organisation for Economic Co-operation and Development.

Oerlemans, L.A.G., Knoben, J., Pretorius, M.W., 2013. Alliance portfolio diversity, radical and incremental innovation: The moderating role of technology management. Technovation 33, 234–246. doi:10.1016/j.technovation.2013.02.004

Pangarkar, N., Wu, J., 2013. Alliance formation, partner diversity, and performance of Singapore startups. Asia Pac. J. Manag. 30, 791–807. doi:10.1007/s10490-012-9305-9

Perez, L., Whitelock, J., Florin, J., 2013. Learning about customers: Managing B2B alliances between small technology startups and industry leaders. Eur. J. Mark. 47, 431–462. doi:http://0-dx.doi.org.cisne.sim.ucm.es/10.1108/03090561311297409

Piga, C., Vivarelli, M., 2003. Sample selection in estimating the determinants of cooperative R&D. Appl. Econ. Lett. 10, 243–246. doi:10.1080/1350485022000044156

Piga, C.A., Vivarelli, M., 2004. Internal and External R&D: A Sample Selection Approach*. Oxf. Bull. Econ. Stat. 66, 457–482. doi:10.1111/j.1468-0084.2004.00089.x

Piller, F.T., West, J., 2014. Firms, Users, and Innnovation. An Interactive Model of Coupled Open Innovation, in: New Frontiers in Open Innovation. Oxford University Press.

Pisano, G., 2006. Profiting from innovation and the intellectual property revolution. Res. Policy, Special issue commemorating the 20th Anniversary of David Teece's article, "Profiting from Innovation", in Research Policy 35, 1122–1130. doi:10.1016/j.respol.2006.09.008

Presutti, M., Boari, C., Fratocchi, L., 2007. Knowledge acquisition and the foreign development of high-tech start-ups: A social capital approach. Int. Bus. Rev. 16, 23–46. doi:10.1016/j.ibusrev.2006.12.004

Randhawa, K., Wilden, R., Hohberger, J., 2016. A Bibliometric Review of Open Innovation: Setting a Research Agenda. J. Prod. Innov. Manag. 33, 750–772. doi:10.1111/jpim.12312

Rothaermel, F.T., Deeds, D.L., 2006. Alliance type, alliance experience and alliance management capability in high-technology ventures. J. Bus. Ventur., Entrepreneurship and Strategic Alliances 21, 429–460. doi:10.1016/j.jbusvent.2005.02.006

Salge, T.O., Bohné, T.M., Farchi, T., Piening, E.P., 2012. Harnessing the Value of Open Innovation:: The Moderating Role of Innovation Management. Int. J. Innov. Manag. 16, 1240005–1.

Schmiedeberg, C., 2008. Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. Res. Policy 37, 1492–1503. doi:10.1016/j.respol.2008.07.008

Schumpeter, J.A., 1934. The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle. Transaction Publishers.

Shan, W., Walker, G., Kogut, B., 1994. Interfirm cooperation and startup innovation in the biotechnology industry. Strateg. Manag. J. 15, 387–394. doi:10.1002/smj.4250150505

Shane, S., 2000. Prior Knowledge and the Discovery of Entrepreneurial Opportunities. Organ. Sci. 11, 448–469.

Spender, J.-C., Corvello, V., Grimaldi, M., Rippa, P., 2017. Startups and open innovation: a review of the literature. Eur. J. Innov. Manag. 20, 4–30. doi:10.1108/EJIM-12-2015-0131

Spithoven, A., Clarysse, B., Knockaert, M., 2011. Building absorptive capacity to organise inbound open innovation in traditional industries. Technovation 31, 10–21. doi:10.1016/j.technovation.2010.10.003

Spithoven, A., Vanhaverbeke, W., Roijakkers, N., 2013. Open innovation practices in SMEs and large enterprises. Small Bus. Econ. 41, 537–562. doi:10.1007/s11187-012-9453-9

Stinchcombe, A.L., 1965. Organizations and social structure. Handb. Organ. 44, 142–193.

Stuart, T.E., 2000. Interorganizational alliances and the performance of firms: a study of growth and innovation rates in a high-technology industry. Strateg. Manag. J. 21, 791–811. doi:10.1002/1097-0266(200008)21:8<791::AID-SMJ121>3.0.CO;2-K

Teece, D.J., 2000. Managing Intellectual Capital: Organizational, Strategic, and Policy Dimensions. OUP Oxford.

Teece, D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Res. Policy 15, 285–305. doi:10.1016/0048-7333(86)90027-2

Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strateg. Manag. J. 18, 509–533.

Trott, P., Hartmann, D., 2013. Open innovation : old ideas in a fancy tuxedo remedy a false dichotomy, in: Tidd, J. (Ed.), Open Innovation Research, Management and Practice. Imperial College Press, London, pp. 359–386.

Trott, P., Hartmann, D., 2009. WHY "OPEN INNOVATION" IS OLD WINE IN NEW BOTTLES. Int. J. Innov. Manag. 13, 715–736. doi:10.1142/S1363919609002509

Tsai, K.-H., 2009. Collaborative networks and product innovation performance: Toward a contingency perspective. Res. Policy 38, 765–778. doi:10.1016/j.respol.2008.12.012

Tsai, K.-H., Hsieh, M.-H., 2009. How different types of partners influence innovative product sales: Does technological capacity matter? J. Bus. Res. 62, 1321–1328. doi:10.1016/j.jbusres.2009.01.003

Tsai, Kuen-Hung, and Jiann-Chyuan Wang. 2008. "External Technology Acquisition and Firm Performance: A Longitudinal Study." *Journal of Business Venturing* 23 (1):91–112. https://doi.org/10.1016/j.jbusvent.2005.07.002.

Tsai, K.-H., Wang, J.-C., 2009. External technology sourcing and innovation performance in LMT sectors: An analysis based on the Taiwanese Technological Innovation Survey. Res. Policy, Special Issue: Innovation in Low-and Meduim-Technology Industries 38, 518–526. doi:10.1016/j.respol.2008.10.007

Un, C.A., Cuervo-Cazurra, A., Asakawa, K., 2010. R&D Collaborations and Product Innovation. J. Prod. Innov. Manag. 27, 673–689. doi:10.1111/j.1540-5885.2010.00744.x

Usman, M., Vanhaverbeke, W., 2017. How start-ups successfully organize and manage open innovation with large companies. Eur. J. Innov. Manag. 20, 171–186. doi:10.1108/EJIM-07-2016-0066

van de Vrande, V., de Jong, J.P.J., Vanhaverbeke, W., de Rochemont, M., 2009. Open innovation in SMEs: Trends, motives and management challenges. Technovation 29, 423–437. doi:10.1016/j.technovation.2008.10.001

van de Vrande, V., Vanhaverbeke, W., Gassmann, O., 2010. Broadening the scope of open innovation: past research, current state and future directions. Int. J. Technol. Manag. 52, 221–235. doi:10.1504/IJTM.2010.035974

Vanhaverbeke, W. 2017. *Managing Open Innovation in SMEs*. Camdridge University Press.

Vanhaverbeke, W., Cloodt, M., 2014. Theories of the Firm and Open Innovation, in: In Henry Chesbrough, Wim Vanhaverbeke and Joel West, Eds., New Frontiers in Open Innovation. Oxford University Press, Oxford, pp. 256–278.

Vanhaverbeke, W., Van de Vrande, V., Cloodt, M., 2008. Connecting Absorptive Capacity and Open Innovation (SSRN Scholarly Paper No. ID 1091265). Social Science Research Network, Rochester, NY.

Vega Jurado, J., Manjarrés Henríquez, L., Gutiérrez Gracia, A., 2010. Cooperation with scientific agents and firm's innovative performance. Presented at the 13th Conference of the International Schumpeter Society: Innovation, Organisation, Sustainability and Crises, Aalborg (Denmark).

Veugelers, R., Cassiman, B., 1999. Make and buy in innovation strategies: evidence from Belgian manufacturing firms. Res. Policy 28, 63–80. doi:10.1016/S0048-7333(98)00106-1

Villena, V.H., Revilla, E., Choi, T.Y., 2011. The dark side of buyer–supplier relationships: A social capital perspective. J. Oper. Manag. 29, 561–576. doi:10.1016/j.jom.2010.09.001

Vrontis, D., Thrassou, A., Santoro, G., Papa, A., 2017. Ambidexterity, external knowledge and performance in knowledge-intensive firms. J Technol Transf 42, 374–388. https://doi.org/10.1007/s10961-016-9502-7

Wang, B., Subramanian, A.M., Chai, K.H., 2015. Patent strategy in exploration and exploitation alliances: The case of biotechnology start-ups, in: 2015 Portland International Conference on Management of Engineering and Technology (PICMET). Presented at the 2015 Portland International Conference on Management of Engineering and Technology (PICMET), pp. 1054–1060. doi:10.1109/PICMET.2015.7273153

Wang, C.L., Ahmed, P.K., 2007. Dynamic capabilities: A review and research agenda. Int. J. Manag. Rev. 9, 31–51. doi:10.1111/j.1468-2370.2007.00201.x

West, J., Bogers, M., 2017. Open innovation: current status and research opportunities. Innovation 19, 43–50. doi:10.1080/14479338.2016.1258995

Xue, J., Wang, P., Ma, X., Peng, Y., 2016. External networks and entrepreneurial orientation. Presented at the Academy of Managment Annual Meeting, Anaheim, California.

Zobel, A.-K., 2013. Open Innovation: A dynamic Capabilities Perspective. Maastricht University, Maastricht.

Zobel, A.-K., Balsmeier, B., Chesbrough, H., 2016. Does patenting help or hinder open innovation? Evidence from new entrants in the solar industry. Ind. Corp. Change 25, 307–331. doi:10.1093/icc/dtw005

Chapter 2: Modes of inbound knowledge breadth. Are cooperation and R&D outsourcing really complementary?

2.1 Introduction

This study analyses the impact of R&D outsourcing breadth, as well as the moderator effect of cooperation on innovation performance. R&D outsourcing and cooperation are two different strategies to integrate external technology. R&D Outsourcing is usually performed to reduce costs, reinforce specialization, and achieve economies of scale, while collaboration is motivated by strategic rather than cost considerations (Gooroochurn and Hanley 2007; Narula 2001). As a result, outsourcing, compared to collaboration, is less common in basic research (Andries and Thorwarth 2014), and is frequently used in non-core activities where knowledge is explicit and less complex (Spithoven and Teirlinck 2015; Weigelt 2009), and for more incremental innovation (Stanko and Olleros 2013). I believe that it is essential to examine the dynamic between outsourcing and cooperation strategies, taking into account their different natures and goals.

Most of the research has examined the 'make' or 'buy' trade-off and the complementarity or substitutability between internal and external R&D (Andries and Thorwarth 2014; Audretsch, Menkveld and Thurik 1996; Berchicci 2013; Lokshin, Belderbos and Carree 2008; Hagedoorn and Wang 2012; Love and Roper 2001, 2009; McIvor 2009; Piga and Vivarelli 2003, 2004; Schmiedeberg 2008; Veugelers and Cassiman 1999). While valuable, this strand of research does not answer several questions related to the best selection models to define the inbound open innovation strategy for a diversity of external knowledge sources.

Open Innovation (OI) has been defined as 'a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model'

(Chesbrough and Bogers 2014:17). Accordingly, different openness strategies constitute the OI paradigm (Dahlander and Gann 2010). Among these strategies, outsourcing and cooperation play key roles in inbound flows of knowledge and in-bound OI.

A number of papers have analysed R&D outsourcing and R&D cooperation in a common framework (Dhont-Peltraut and Pfister 2011; Holl and Rama 2014; Tsai and Wang 2008, 2009), but they do not consider the interrelation between these strategies. Firms frequently combine these two modes of in-bound OI and only some scholars have examining the complementarities of R&D cooperation and R&D outsourcing (Grimpe and Kaiser 2010; Lin, Hsiao and Lin 2013; Teirlinck and Spithoven 2011, 2013), considering it from different perspectives. For example, while Grimpe and Kaiser (2010) focused on external resources from partner variety and experience; Teirlinck and Spithoven (2011, 2013) analysed firms' internal resources in terms of research managers and R&D experts; and Lin et al. (2013) made a methodological contribution by considering a method that combined adoption and productivity approaches. Though much progress has been made, research comparing different modes of in-bound OI still has a long way to go (Bahemia and Squire 2010).

This research explores this comparatively underexplored research field by focusing on R&D cooperation and R&D outsourcing, and underpinning the analysis of their complementarities through the concept of external knowledge source breadth. Breadth refers to the extent that 'firms access different external knowledge sources' (Zobel 2013: 68), such as customers, suppliers, competitors, universities, research centres, etc. Breadth is an essential part of literature studying the impact of inbound knowledge flows (Laursen and Salter 2006; Rothaermel and Deeds 2006; Bahemia and Squire 2010; Leiponen and Helfat 2010; Oerlemans, Knoben and Pretorius 2013; Collins and Riley 2013; Leeuw, Lokshin and Duysters 2014). Breadth has been mainly studied for cooperation activities,

but it can be also conceptualized for R&D outsourcing strategies. Some studies have considered the "broadness" of outsourcing by the number of different activities (Gilley and Rasheed 2000), but outsourcing breadth in terms of number of different external sources has barely been analysed. Therefore, my first contribution is to analyse the impact of R&D outsourcing on innovation performance by measuring it in the same manner as for cooperation, in terms of breadth.

Secondly, I study the moderator effect of cooperation breadth on the relationship between outsourcing breadth and the innovative performance of the firm. The paper offers a new perspective with regard to the traditional 'buy', 'make' or 'ally' trade-off because I examine the effects of the interaction of two open innovation strategies in terms of breadth —cooperation breadth and R&D outsourcing breadth. This is important because firms may create mutual relational capital that generates synergies and economies of scale and scope. Because the paper focuses more on the learning process and relational capabilities arising from the exposure to different sources of knowledge, I do not consider sourcing depth.

I test the model on a large CIS data set of Spanish firms. This research uses pooled data from a longitudinal sample to evaluate the impact of different inbound OI strategies breadths on firm innovative performance. I found that there is a U-inverted relationship between outsourcing breadth and innovation performance and a complementary relationship between R&D outsourcing and R&D cooperation, but that the complementary effect of R&D cooperation varies with the level of R&D outsourcing breadth, and is not confirmed for low and medium levels of R&D outsourcing breadth.

The remainder of this paper is structured as follows. In the next section I review the theoretical background of inbound OI strategies, and I develop my hypotheses in Section

3. The fourth section describes methodology, and in the fifth section I present the statistical method and the results of the analyses. I then discuss the findings. I conclude with implications and directions for future research.

2.2 Literature background

Theoretical literature has emphasized that different openness strategies exist. Dahnlander and Gann (2010) and Chesbrough and Bogers (2014) identified two main inbound strategies: sourcing and acquiring. Sourcing is a non-pecuniary type of openness, in which firms use and absorb external knowledge into their innovation processes; while acquiring is a pecuniary inbound innovation involving the acquisition of external knowledge, which is then integrated into the innovation process. In the same way, Tsai and Wang (2008, 2009) argued that there are two ways to access external technology: quasi-external activities such as technology cooperation, and fully external activities, i.e., market procurement, such as R&D outsourcing and licensing.

R&D outsourcing refers to the purchase by an enterprise of creative work performed by other enterprises or by public or private research organizations to increase the stock of knowledge for developing new and improved products and processes (OECD 2005). Consequently, the transformation of potential knowledge into realized knowledge is made by an external firm that transfers it together with its exploitation rights to the payer firm in the manner contractually specified (Grimpe and Kaiser 2010). Firms with few resources and looking for low risk and low cost knowledge exchange employ R&D outsourcing (Gassmann, Enkel and Chesbrough 2010), and many firms tend to outsource non-core activities (Gilley and Raseed 2000; Mudambi and Tallman 2010; Narula 2001), as these activities are relatively standardized (Teirlinck and Spithoven 2013), involve

explicit knowledge and entail low levels of complexity and uncertainty (Howells, Gagliardi and Malik 2008). R&D outsourcing is considered the most basic inbound OI strategy. Firms do not enter into long relationships with the R&D suppliers but temporary contracts for a previously specified purpose (Grimpe and Kaiser 2010), where firms can change suppliers when new or cost-effective technologies are available in the market (Gilley and Rasheed 2000). Although firms that incorporate outsourced knowledge into their innovation processes may encounter coordination and communication challenges arising from R&D outsourcing activities (Tsai and Wang 2009), especially, if R&D outsourcing breadth increases, the interdependence between partners is minimum (Narula 2001).

Compared to R&D outsourcing, collaboration is considered a more open strategy of knowledge sharing (Chesbrough, 2012; Teirlinck and Spithoven 2008), where knowledge exchange is more complex and tacit (Teirlinck and Spithoven 2013). R&D cooperation usually focuses on a common project for a medium period of time, where partners share common objectives in the development of a specific technology (Hagedoorn 1993; Trombini and Comacchio 2012). Here, the transformation of valuable knowledge is made jointly by the firm and the partner, so a higher degree of learning is likely to occur (Fey and Birkinshaw 2005). The governance cost of the 'ally' mode is higher than the 'buy' mode because cooperation involves specialized assets (Williamson 1991). In addition, the opportunity cost of cooperation is potentially higher than in R&D outsourcing because the R&D outcome is uncertain (Holmstrom 1989) and firms cannot observe partners behavior (Oxley 1997), who are often engaged in attempts to outlearn each other (Khanna, Gulati and Nohria 1998) since knowledge-based assets are imperfectly protected (Cohen, Nelson and Walsh 2002). To succeed in joint innovation, improve firm performance and ensure survival chances (Mitsuhashi and Greve 2009), firm's technologies or knowledge

bases must 'fit' (Baum, Cowan and Jonard. 2010). Cooperation and R&D outsourcing differs in terms of availability and training of research managers and R&D experts (Teirlinck and Spithoven 2013). Cooperation may require more advanced management capabilities (Lane and Lubatkin 1998), and it changes the internal cost structure of the firm (Kale and Singh 2009). Table 2.1 summarizes the differences between R&D outsourcing and cooperation.

Table 2.1 R&D outsourcing and cooperation features

Dimension	R&D Outsourcing	Cooperation
Relationship duration	Short-term relationship	Medium- or long-term relationship
Knowledge	Explicit	Tacit
Learning	Low	High
Transaction costs	Low - medium	Medium - high
Asset specificity	Low	High

Source: Own elaborated.

2.3 Conceptual framework and hypotheses

2.3.1 R&D outsourcing breadth

Firms get a competitive advantage through their abilities to integrate, build and reconfigure internal and external competences (Teece et al., 1997). In other words, firms can sense, seize and reconfigure opportunities for resources alterations internally or externally (di Stefano et al., 2010). The capabilities and strategies required to recombine resources from outside and inside the firm are likely to be different from those found in traditional R&D settings (Dahlander and Gann, 2010).

Openness breadth refers to the extent to which 'firms access different external knowledge sources', such as customers, suppliers, competitors, universities, research centres, etc. (Zobel 2013: 68). However, this dimension has been unexplored in outsourcing empirical

literature. Various scholars have pointed to the existence of a curvilinear relationship (inverted U-shape) between outsourcing intensity and firm performance (Kotabe and Mol 2009; Kotabe, Mol, Murray and Parente 2012; Leachman, Pegels and Shin 2005; Rothaermel, Hitt and Jobe 2006; Grimpe and Kaiser 2010; Berchicci 2013). Focusing on innovation literature, Grimpe and Kaiser (2010) studied the benefits and challenges of R&D outsourcing, discovering an inverse U-shaped relationship between R&D outsourcing and innovation performance. They argued that the effects of R&D outsourcing on innovation performance is initially positive because it allows access to valuable resources not available internally, fostering greater efficiency, lowering costs and boosting their innovation processes. However, with greater intensities of R&D outsourcing, the returns from additional R&D outsourcing become negative because of the dilution of firm-specific resources, the weakening of innovative capabilities, and the increasing need for management attention. Berchicci (2013) also noted that R&D outsourcing is positively related to innovation performance but only up to a point, because excessive outsourcing increases search, coordinating and monitoring costs and could generate a risk of external knowledge dependence. Graphically speaking, this implies that the benefits of outsourcing intensity on innovation creates an inverted U-shape. In these studies, R&D outsourcing has been measured in different ways, such as R&D external expenditures (Grimpe and Kaiser 2010) or number of activities (Berchicci 2013).

I extend that strand of research and consider that outsourcing breadth is likely to have an effect on the performance of the firm's overall OI strategy. Prior research has shown that knowledge search breadth brings greater innovation (Rothaermel and Deeds 2006; Bahemia and Squire 2010; Leiponen and Helfat 2010; Zobel 2013) because it pools the efforts of diverse knowledge sources and it enhances the potential for new products and a better matching of products and consumer preferences (Almirall and Casadesus-

Masanell 2010). Some studies have also shown that performance decreases when firms open their innovation process to many external knowledge sources (Laursen and Salter 2006; Rothaermel and Deeds 2006). I propose that an inverted U-shaped relationship exists between R&D outsourcing breadth and firms' innovative performance.

The benefits of R&D outsourcing breadth can be summarized through Cui, Loch, Grosmann and He (2012)'s motivations to outsource: (1) economical motivation to reduce internal R&D investment (factory and premise costs) (2) industrial motivation, as outsourcing decreases firms' innovative processes cadence and market cycle; (3) market motivation as outsourcing breadth could open new markets or lead to better understanding of current market needs; (4) technological motivation since a greater variety of outsourcing firms provides new technologies with the potential for radical innovations; (5) strategic motivation as non-core activities are outsourced to specialized outsourcers who know market regulations, standards and structures, so firms are able to focus on their core competencies; and (6) organizational motivation as increased outsourcing breadth reveals and overcomes internal barriers and rigidities, and encourages organizational change and innovation.

However, increased outsourcing breadth also entails certain challenges. First, it is difficult to find the 'right' outsourcer (Tsai and Wang 2009) whose technology meets the firm's competitive strategy and is reliable (Hoecht and Trott 2006; Howells et al. 2008; Sen and MacPherson 2009). Second, communication problems increases with outsourcing breadth because firms may lack the expertise related to that area and being unable to communicate professionally with outsourcers. Third, outsourcers can sell their technologies to competitors (Tsai and Wang 2009) and extend them across the whole industry (Hoecht and Trott 2006), so it does not provide a competitive advantage for the firm. Finally, outsourcing breadth creates a risk of external dependency (Rothaermel et al. 2006) since

firms acquire external technology rather than internally developing it (Tsai and Wang 2009; Wang, Roijjakers and Vanhaverbeke 2013), reducing their knowledge base in all areas and thereby damaging firms' absorptive capacity (Cohen and Levinthal 1990).

Therefore, R&D outsourcing breadth provides immediate access to different technologies and knowledge with few bureaucratic costs, reducing firms' innovative process time and the costs and risks of internal R&D. However, higher levels of R&D outsourcing breadth increase transaction costs and the risks of depending on external outsourcers. Hence, I propose that:

Hypothesis 1.1: *There is an inverted U-shaped relationship between R&D outsourcing breadth and innovation performance.*

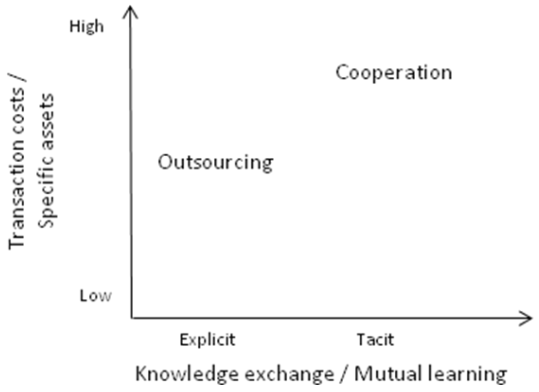
2.3.2 The moderator role of cooperation

The impact of cooperation on innovation performance has received considerable attention in literature. Apart from the direct effect of cooperation breadth on the chances of positive innovation outcomes (Chesbrough and Appleyard 2007; Leiponen and Helfat 2010; Zobel 2013), I expect cooperation to have moderating effects on the relationship between R&D outsourcing breadth and firms' innovation performance. I therefore focus on the effect of the joint adoption of cooperation breadth and R&D outsourcing breadth on innovation performance.

The RBV can be applied to the OI context, so the scarce, valuable, inimitable, and without equivalent substitutes are created along with other agents or used in a complementary way. In other words, knowledge from different agents is brought together to create value (Vanhaverbeke and Cloodt, 2014). OI combines both internal and external resources, so

firms integrate external knowledge into the development of their own technologies. Collaborating firms that combine resources in unique ways may realize a competitive advantage over others that compete on the basis of a stand-alone strategy (Vanhaverbeke and Cloodt, 2014, p. 265). Over the last years, Transaction Costs Economy (TCE) and the Resource-based view (RBV) have converged somewhat in the explanation of knowledge flows because of their complementary roles and co-evolution (Spithoven and Teirlinck 2015). Basing my arguments on TCE and RBV, I consider that cooperation moderates the relationship between R&D outsourcing and innovation performance through two mechanisms: absorptive capacity and relational capability. The framework weights the balance between transaction costs and asset specificity, and the type of knowledge transferred and mutual learning. Figure 2.1 illustrates these quantities and places OI strategies in a matrix.

Figure 2.1 OI strategies for knowledge transfer



Source: Own elaborated

First, cooperation might help to absorb the knowledge from contracts, generating new recombinations. The potential for new recombinations is based on the idea of taper

integration, developed by Rothaermel et al. (2006), who affirmed that a firm creates synergy through simultaneously accomplishing vertical integration and strategic outsourcing. As a result, taper integration may reduce transaction costs, enhance strategic flexibility, increase access to diverse sources of knowledge, integrate tacit knowledge and complementary assets, and thereby enhance the development of new products and increases a firm's product portfolio. Grimpe and Kaiser (2010) argued that cooperation may mitigate the negative effects from over-outsourcing on innovation performance. One reason for that behaviour was partner variety, which increases the likelihood of accessing novel and unique knowledge that could be redeployed within a firm. Since each OI strategy has its unique advantages and drawbacks, an adequate combination will enhance firms' flexibility and innovation (Spithoven and Teirlinck 2015). Thus, a base of R&D from cooperation, do not fully eliminate the risk of external dependence and it may create new recombinations since different types of knowledge are combined, suggesting a complementary effect between OI breadth strategies.

Second, cooperation breadth generates an external relationship management capability—a 'relational capital' that can mitigate the problems of contract formation. Many firms invest in specific assets to manage cooperative activities, creating a dedicated alliance management department (Kale, Dyer and Singh 2002; Kale and Singh 2007, 2009; Sampson 2005; Schilke and Goerzen 2010), or a specific committee consisting of members of each part of a collaborative agreement (Hagedoorn and Hesen 2007). In this regard, another reason for the positive moderator role of cooperation, according to Grimpe and Kaiser (2010), is increased experience, as the experience of collaborating with a large variety of partners facilitates the interactions with outsourcers and makes firms recognize superior resource deployments more easily. The synergetic effect between OI breadth strategies comes up when a high degree of partner diversity is used

by both strategies. The potential for misunderstanding and costly miscommunication is mitigated as firms get more experience in R&D outsourcing and cooperation.

Firms create a relational capital that can be used by both strategies. The relational capital provided by cooperative activities, which are based on mutual trust and interaction and curb opportunistic and disloyal behaviours (Gulati 1998), creates a basis for learning and know-how transfer (Kale, Singh and Perlmutter 2000) that facilitates external knowledge acquisitions. Poppo and Zenger (2002) assert that the interdependence between partners as a consequence of a relational governance improves the exchange outcome. When combining cooperation breadth with R&D outsourcing breadth, firms could benefit from economies of scale and scope.

Overall, combining R&D outsourcing breadth with cooperation could contribute to the adoption of economies of scale and scope in building relational capital, at the same time that using both breadth strategies enhances the likelihood of new combinations. Thus, cooperation breadth positively moderates the relationship between R&D outsourcing breadth and innovation performance, avoiding the negative effects of over-openness in R&D outsourcing:

Hypothesis 1.2: T*he relationship between R&D outsourcing breadth and innovation performance is positively moderated by cooperation breadth.*

2.4 Methodology

2.4.1 Sample

I test the model on a representative sample of Spanish firms from the database Spanish Technological Innovation Panel (PITEC), collected by the Spanish National Statistics Institute (INE). The survey was implemented in 2003 and it is based on the annual Spanish responses to the Community Innovation Survey (CIS), whose method and types of questions are described in Oslo Manual (OECD 2005). CIS data has been used in numerous academic papers across Europe, for example, in Germany (Grimpe and Kaiser 2010), Belgium (Cassiman and Veugelers 2002, 2006; Spithoven, Clarysse and Knockaert 2011), the United Kingdom (Laursen and Salter 2006); and in other non-European countries, such as Taiwan (Tsai and Hsieh 2009; Tsai and Wang 2009). In Spain, PITEC is a well-established research tool, and has been used in previous longitudinal studies (e.g., Escribano, Fosfuri and Tribó 2009; Sandulli, Fernandez-Menendez, Rodriguez-Duarte and Lopez-Sanchez 2012; Un, Cuervo-Cazurra and Asakawa 2010; Vega-Jurado, Manjarrés-Henríquez and Gutiérrez-Gracia 2010).

The database has broad sector coverage, and includes both manufacturing and service sectors. PITEC divides these industries according to the standard National Classification of Economic Activities (CNAE) code, using a two-digit code, except when there are many firms in an industry and the firm's activity is defined at three digits or when there are just a few firms, in which case activities are regrouped with others.

In the survey, firms are asked to indicate whether they have been able to achieve a product innovation. Product innovation include both technologically new products, which refer to 'goods and services that differ significantly in their characteristics or intended uses from products previously produced by the firm' (OECD 2005:48); and technologically

improved products, which 'occur through changes in materials, components and other characteristics that enhance performance' (OECD 2005:48). The questionnaire asks then firms to assert what share of their sales can be ascribed to innovations new to the market and which are new to the firm. In the questionnaire there are a series of questions about external acquisition of technology and the sources of knowledge for innovation. In 2004 PITEC introduced some changes in the questionnaire, affecting variables related to cooperation and external sources for technology innovation, which are central variables in the model. Due to these limitations, I have not considered the data from the 2003 survey, and use only pooled longitudinal data from 2004 to 2012. I have used pooled data instead of panel data because maximum likelihood estimations –used for the Tobit analysis- might introduce biases (Lopez 2011). In addition, observations produce change due to mergers, disclosure, etc., that could mislead (Baum and Silverman 2004; Teirlinck, Dumon and Spithoven 2010). In total, and due to some missing data, I consider a subsample of 61,430 observations.

2.4.2 Measures

Dependent variable

Though there are different forms through which firm innovation performance can be assessed, I use product innovation as a proxy to indicate the innovative performance by firms as it has been traditionally used in literature (Belderbos, Carree and Lokshin 2004; Faems, van Looy and Debackere 2005; Faems, de Visser, Andries and van Looy 2010; Nieto and Santamaria 2007). I measure product innovation performance (*Newprod*) as proportion relative to the turnover of new or strongly improved products that the company introduced to the market and that were new to the market or to the firm. New products to

the market or to the firm are mutually exclusive since they add up to 100%, so Newprod ranges from 0 to 100.

Independent variables

The study analyses the impact of two inbound OI strategies on the innovation performance of the firm: cooperation breadth and R&D outsourcing breadth. First, cooperation breadth refers to agreements with a diversity of external sources—suppliers, customers, public sector customers, competitors, consultants, universities and research centres. I consider that partner diversity must be considered to measure cooperative agreements since it has been proven to have an impact on innovation performance (Laursen and Salter 2006; Oerlemans et al. 2013). Following the methodology of Laursen and Salter (2006), the variable cooperation breadth (*coop*) is constructed as the addition of seven sources of collaboration. Thus, each of the seven sources is coded as a binary variable, 0 being no use and 1 being use of the knowledge source. Subsequently, the seven sources are added up so that each firm gets a 0 when no collaboration sources are used, and a firm gets the value of 7 when all collaboration sources are used.

Second, in the survey, firms are asked whether they have acquired external R&D, that is, if they have outsourced-in R&D technology. As cooperation, R&D outsourcing is also measured in terms of diversity of outsourcers. Thus, R&D outsourcing breadth (*out*) is constructed as the addition of six sources of outsourcing: firms, research centres, public sector, universities, no governmental organizations, and other international organizations. Each of the six sources is coded as a binary variable, 0 being no use and 1 being use of the knowledge source. Again, the six sources are added up so that each firm gets a 0 when

no outsourcing sources are used, and a firm gets the value of 6 when all outsourcing sources are used.

Considering the U-inverted shape of R&D outsourcing breadth, I square the variable outsourcing (*out2*). I include the interaction variables among cooperation breadth and R&D outsourcing breadth (*coop_out*), and the interaction between cooperation breadth and R&D outsourcing breadth squared (*coop_out2*) to test the impact of a joint adoption of these OI strategies on the innovation performance.

Control variables

In order to rule out possible alternative explanations to those formally hypothesized, the model includes the following control variables. Previous research has discussed that firm age has a positive (Tsai et al. 2011; Wang et al. 2013) or negative (Wang and Li-Ying 2014) impact on innovation. To clarify inconsistent findings I include firm age (*Logage*), which is measured as the logarithm of the number of years between the foundation of the firm and the observation year. I also control for firm size (*Logsize*) as it has been argued to be relevant for firms' innovative behaviour (Berchicci 2013; Cassiman and Veugelers 2002). This variable is measured by the logarithm of the total number of employees. As scholars consider internal R&D to be crucial for innovation (Lin et al. 2013; Schmiedeberg 2008), I include firm's internal R&D efforts (*Intrd*), measured as the proportion of its internal innovation expenses. Another input variable that might affect innovation performance is the firm's patent activity (*Pat*) (Faems et al. 2005). I measured it as a dummy variable that takes the value of 1 if the firm has applied for a patent. To reflect that the results are not simple reflecting R&D outsourcing intensity, but indeed the breadth of it, I include a control variable for R&D outsourcing investment (*Outintensity*).

It is measured as the share of R&D external expenses. Openness to external sources has been recognized to be crucial for startup firms to overcome their liabilities of newness and smallness (Bogers 2011; Neyens, Faems and Sels 2010), so I include a dummy variable to indicate whether the firm is a startup. The survey asks if the firm were of new creation that year or the two previous year and, as previous studies (Laursen and Salter 2006), I use that question to measure the variable startup *(Startup)*.

We have included a sector variable control (*CNAE*) to test if there are differences across manufacturing industry sectors since previous studies (Tsai 2009; Veugelers 1997; Wang et al. 2013) have indicated that it is necessary to correct the fixed industry effects. Finally, I have created dummy variables (*Year*) to control the possible bias of the observation year (Un et al. 2010; Wang et al. 2013). Controlling time-varying effects is necessary in a rapidly changing environment such as technology and innovation, and to check if the economic crisis impact on results. The year 2004 was the default. A short description of the variables used to test the model and their references are included in Table 2.2.

Table 2.2 Variable description

Variable	Description	References
Newprod	Proportion relative to turnover of new or strongly improved products that the company introduced to the market and that were new to the market or to the firm.	Belderbos et al. (2004); Faems et al. (2005, 2010); Nieto and Santamaria (2007)
Coop	Addition of seven sources of collaboration: suppliers, customers, public sector customers, competitors, consultants, universities, and research centres.	Laursen and Salter (2006)
Out	Addition of six sources of outsourcing: firms, research centres, public sector, universities, no governmental organizations, and other international organizations.	Extended from Laursen and Salter (2006)
Coop_out	Interaction between *coop* and *out* variables.	-
Coop_out2	Interaction between *coop* and *out* square variables.	-
Age	Natural logarithm of the number of years between the foundation of the firm and the observation year.	Tsai et al. (2011); Wang et al. (2013); Wang and Li-Ying (2014)
Size	Natural logarithm of the total number of employees.	Berchicci (2013); Cassiman and Veugelers (2002)
Intrd	Proportion of firm's internal innovation expenses.	Lin et al. (2013); Schmiedeberg (2008)
Pat	Dummy variable for firm's application of patents.	Faems et al. (2005)
Outintensity	Share of R&D external expenses.	Grimpe and Kaiser (2010)
Startup	Dummy variable to indicate whether the firm is of new creation	Laursen and Salter (2006)
CNAE	A set of dummy variables for the CNAE sectors, the Spanish equivalent of SIC codes.	Un et al. (2010)
Year	A set of dummy variables for the observation year.	Un et al. (2010); Wang et al. (2013)

2.5 Statistical method and results

This study uses pooled data from 2004 to 2012 to test the hypotheses. Table 2.3 summarizes the number of observations included per year and it reports the basic statistics of the variables used in the analysis (except industry and year dummies)[1]. The data reveals interesting points. Along the nine-year period the firms' turnover from new or strongly improved products that were new to the market or to the firm (*newprod*) does not form a linear pattern but attained its maximum values from 2005 to 2010 and the lowest in 2004

[1] The average of firms in high-tech sectors is 14.12%. By size, 12% of observations are microfirms (less than 10 employess; 38% of observations are small firms (between 10 and 50 employees); 30% of observations are medium firms (between 50 and 250 employees); and 20% of observations are large firms (more than 250 employees).

and 2011-2012. The cooperation breadth variable (*coop*) increases throughout the period (from 0.79 to 1.02), excluding the year 2004, when it was higher (0.89) than for subsequent years. R&D outsourcing breadth (*out*) was considerable higher in 2004 (0.51) and quite similar through the rest of the periods (around 0.43). R&D outsourcing intensity (*outintensity*) forms a similar pattern. It could be that firms are moving from R&D outsourcing to R&D cooperation, instead of looking for complementary behaviours. I also calculated means and standard deviations only for firms that stated they follow an open innovation strategy (not reported for the sake of brevity) and I found that due to the fact that many firms do not have any R&D partner, the reported levels of breadth are low. If I only look to firms that reported cooperation breadth, the breadth average is 2.6; and for those which reported R&D outsourcing breadth, the breadth average is 1.4.

Correlation coefficients of the major variables used in the model are reported in Table 2.4. Note that R&D outsourcing breadth and cooperation breadth are positively related, which might suggest a complementarity between them. Moreover, both, R&D outsourcing breadth and cooperation breadth are positively related to the innovation performance. All the control variables are also positively related to innovation performance, except for outsourcing intensity. This study follows the procedure suggested by Friedrich (1982) to reduce or eliminate any bias resulting from multicollinearity because of interaction terms. This procedure first standardizes the independent variables, and then forms the cross-product terms. In addition, a VIF (variance inflation factor) test is used to evaluate the effect of multicollinearity. Only the VIF for the variable interaction variables exceed 10, but since it is constructed through the interaction of two standardized variables, I do not believe it contaminates the results; the VIFs for the rest of variables are smaller than 10.

Table 2.3 Means and standard deviations of major variables used in the analysis

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012
Obs.	5,506	7,503	7,515	7,325	7,158	7,112	7,069	6,310	5,932
Newprod	22.22	28.04	26.58	26.08	28.42	28.77	28.93	25.77	22.78
	(32.29)	(37.16)	(36.26)	(35.99)	(37.03)	(36.98)	(37.04)	(36.20)	(34.62)
Coop	0.89	0.79	0.81	0.83	0.88	0.9	0.95	1.01	1.02
	(1.53)	(1.44)	(1.49)	(1.55)	(1.58)	(1.62)	(1.68)	(1.75)	(1.70)
Out	0.51	0.44	0.44	0.44	0.42	0.41	0.41	0.44	0.43
	(0.77)	(0.74)	(0.75)	(0.77)	(0.77)	(0.77)	(0.78)	(0.80)	(0.81)
Age	22.49	21.7	22.65	23.79	25.07	26.22	27.32	28.46	29.46
	(19.91)	(19.76)	(19.76)	(20.02)	(20.51)	(20.61)	(20.64)	(21.00)	(20.81)
Size	304.39	263.70	282.76	307.74	322.24	327.90	331.56	357.95	358.72
	(1322.62)	(1191.11)	(1308.41)	(1493.45)	(1555.89)	(1637.40)	(1576.09)	(1699.63)	(1769.78)
Pat	0.21	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13
	(0.40)	(0.36)	(0.35)	(0.34)	(0.34)	(0.33)	(0.33)	(0.34)	(0.34)
Intrd	65.80	59.25	54.82	52.65	52.07	49.21	47.26	51.94	54.77
	(40.68)	(39.64)	(42.35)	(42.01)	(42.40)	(42.61)	(42.88)	(43.03)	(43.12)
Outintensity	14.56	9.34	10.14	10.20	9.79	9.48	9.12	9.54	9.00
	(27.63)	(20.31)	(22.37)	(22.02)	(21.53)	(21.48)	(20.91)	(21.81)	(21.03)
Startup	0.04	0.03	0.01	0.003	0.00	0.00	0.00	0.00	0.001
	(0.19)	(0.17)	(0.10)	(0.05)	(0.01)	(0.01)	(0.03)	(0.03)	(0.04)

Note: The figures in parentheses are standard deviations.

Table 2.4. Correlation coefficients of major variables used in the model

	Newprod	Coop	Out	Logage	Logsize	Pat	Intrd	Outintensity
Newprod								
p-value								
Coop	0.088							
p-value	*0.000*							
Out	0.047	0.408						
p-value	*0.000*	*0.000*						
Logage	-0.102	-0.006	0.022					
p-value	*0.000*	*0.131*	*0.000*					
Logsize	-0.077	0.145	0.108	0.376				
p-value	*0.000*	*0.000*	*0.000*	*0.000*				
Pat	0.089	0.212	0.213	-0.008	0.062			
p-value	*0.000*	*0.000*	*0.000*	*0.043*	*0.000*			
Intrd	0.111	0.168	0.089	-0.073	-0.073	0.143		
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		
Outintensity	-0.003	0.104	0.459	0.015	0.051	0.041	-0.214	
p-value	*0.402*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	
Startup	0.093	0.021	0.015	-0.281	-0.093	0.030	0.040	0.006
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.166*

Note: This table omits the correlation coefficients of industry and time-effect dummies.

The econometric model that will be used to test the hypothesis is based on a (double) censored dependent variable—innovative performance—, which is measured as a percentage of turnover and therefore by definition ranges between 0 and 100, and a set of independent variables that represent OI strategies breadth and its interaction, and control variables. Following Laursen and Salter (2006), a censored Tobit model is applied. This model was proposed by James Tobin (1958) to estimate relationships between variables when there is either left- or right- censoring or both left-censored and right-censored in the dependent variable. In this case, the sample is both-side censored, the lower limit is 0, and the upper limit 100, since the dependent variable ranges between those values. The latent model would be as follows:

$$y^*_i = Newprod = \beta_0 + \beta_1 Coop + \beta_2 Out + \beta_3 Out2 + \beta_4\, Coop*Out + \beta_5 Coop*Out2 + \beta_6 Age + \beta_7 Sise(ln) + \beta_8 Intrd + \beta_9 Outintensity + \beta_{10} Startup + \beta_{11} CNAEdummies + \beta_{12} Yeardummies + \varepsilon,\ \varepsilon \sim N(0, \sigma^2)$$

However, the assumption of normality of residuals in the model is not satisfied. To address this problem, Laursen and Salter (2006) assumed a lognormal distribution for the residuals of the Tobit model. I also apply this approach and I introduce a latent variable, *lnnewprod*, as a logarithmic transformation of an observed measure of product innovation, lnnewprod = ln(1+newprod)[2].

Sample selection poses a potential problem with this analysis and data, because I can only analyse those firms that answered the questionnaire. As a result, selective reporting may bias the results (Heckman 1979). I use Heckman selection model in two-steps to control for a possible sample selection bias in the continuous dependent variable. I first define a

[2] Note: The lognormal transformation does not change the signs, nor the significance for the key variables' parameters in the subsequent estimations.

dependent variable with a dummy value: 1 if the firm made product innovations; 0, if the firms did not make any new product. I then use the Probit model to estimate the model parameters, including the independent and control variables of the model, and a dummy variable indicating if the firm bought machinery, equipment and software, as corrected term. This latter variable could impact the introduction of new products to market as they are basic assets for the innovation process, but not in the amount of innovation because they are fixed assets. The process of this calculation is omitted for the sake of brevity. The inverse of Mills-ratio indicates that the null hypothesis is not significant at 95% of confidence (Υ= 0.124, p>0.10), thus the results do not suffer from sample-selection bias.

The results of the Tobit regression can be found in Table 2.5. First, we estimate Model I, which contains the control variables (for reasons of space I do not include all results from industry and year dummy variables in the table). Model II contains the direct effects of OI strategies breadth—cooperation and outsourcing—on product innovation. Finally, in Model III I introduce the interaction terms between the OI strategies breadth for different levels of outsourcing breadth.

The estimators of model II shows R&D outsourcing breadth behaviour, drawing an inverted-U shape related to innovation performance since the parameter for R&D outsourcing breadth variable (*Out*) is significant and positive (β=0.395, p<0.01), and the parameter for outsourcing squared (*Out2*) is significant as well and it is negative (β=-0.283, p<0.01). Hence, it supports the first hypothesis that there is an inverted U-shaped relationship between R&D outsourcing breadth and innovation performance. I also verified that cooperation breadth is positively related to innovation performance (β=0.343, p<0.01) as suggested in the literature (Leiponen and Helfat 2010).

The estimation of Model III shows the interaction coefficients between cooperation breadth and R&D outsourcing breadth. I hypothesized that the relationship between R&D outsourcing breadth and innovation performance is positively moderated by cooperation breadth (Hypothesis 1.2). The results show that between medium and high levels of R&D outsourcing, the relationship between R&D outsourcing breadth and innovation performance is positively moderated by cooperation breadth since the parameter Coop_Out2 is significant and positive (β=0.047, $p<0.05$), hence there are increasing returns to innovation performance. However, for low to medium levels of R&D outsourcing, the model reveals that the relationship between R&D outsourcing breadth and innovation performance is negatively moderated by cooperation breadth since the parameter Coop_Out is significant and negative (β=-0.107, $p<0.01$); hence there are decreasing returns to innovation performance when both strategies are combined. Thereby, the hypothesis that cooperation positively moderates the relationship between R&D outsourcing breadth and innovation performance is partially confirmed.

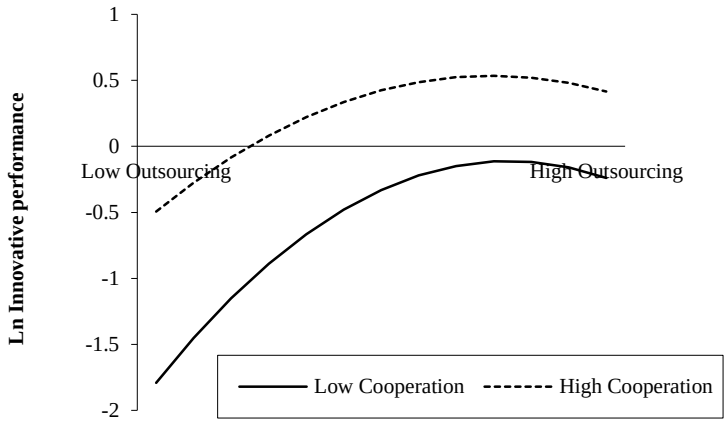
Figure 2.2 shows interactive effect of R&D outsourcing breadth and cooperation breadth on innovative performance for different levels of breadth. The chart shows that between low to medium levels of R&D outsourcing breadth, the contribution of cooperation breadth to innovation performance diminishes. It suggests that at this level of R&D outsourcing breadth, the OI strategies analysed are substitutes. In contrast, the figure shows that the contribution of cooperation breadth increases when the level of R&D outsourcing breadth is medium to high. Hence, cooperation breadth enhances innovation performance, suggesting that in this case, cooperation breadth and R&D outsourcing have complementary effects. These findings highlight the complexity of understanding the relationship between the breadths of different strategies of openness in shaping firms' innovative performance.

Table 2.5. Tobit regression, explaining innovation performance across Spanish firms.

Model	I		II		III	
Indepen Var.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Logage	-0.115***	0.020	-0.107***	0.020	-0.107***	0.020
Logsize	0.009	0.009	-0.040***	0.010	-0.039***	0.010
Pat	1.017***	0.038	0.809***	0.038	0.807***	0.038
Intrd	0.011***	0.000	0.009***	0.000	0.008***	0.000
Outintensity	0.004***	0.001	-0.003***	0.001	-0.003***	0.001
Startup	2.430***	0.147	2.347***	0.146	2.338***	0.146
Coop			0.343***	0.015	0.378***	0.016
Out			0.395***	0.034	0.409***	0.038
Out2			-0.283***	0.030	-0.255***	0.039
Coop_Out					-0.107***	0.024
Coop_Out2					0.047**	0.021
Industry dummies	Yes		Yes		Yes	
Time-effect dummies	Yes		Yes		Yes	
_cons	-1.477	0.153	0.124	0.152	0.144	0.152
/sigma	2.990	0.014	2.960	0.013	2.960	0.013
No. of obs	61430		61430		61430	
No. of left-censored obs	20896		20896		20896	
No. of right-censored obs	8410		8410		8410	
Log likelihood	-107194.93		-106742.10		-106724.35	
Chi-square	6090.97***		6696.32***		7031.82***	
Pseudo R^2	0.0276		0.0317		0.0319	

One-tailed t-test applied. * p < 0.10; ** p < 0.05; *** p < 0.01

Figure 2,2. Interactive effects between cooperation and R&D outsourcing



Of the control variables, the age of the firm has a negative effect on innovation performance since along the three models its parameter (*Logage*) is significant and negative. It suggests that older organizations may have greater resistance to new ideas. Applying for patents has a positive impact on innovation performance. Being a startup also resulted to be significant, suggesting that startups might be more innovative. The parameters for industry dummies are partially significant; in particular, there is a positive relationship with those related to textile and shoe industries, electronic equipment and information systems; and a negative relationship with plumbing industry and construction. Time effects may have an influence on innovation performance since year dummy coefficients are all significant and positive, except for 2012.

To ensure the robustness of the above findings, this study also runs different estimates for different samples (not reported for the sake of brevity). Because the sample includes data relative to some years after the financial crisis, I first exclude the initial year (2004) in the estimation, and then the final year (2012). The results of the Tobit regressions and the adjusted-R^2 and Chi-squared values indicate that the models fit to data (adj-R^2=0.0320, χ^2=6425.90, p<0.01; adj-R^2=0.0317, χ^2=6384.32, p<0.01, respectively); the estimated coefficients for outsourcing and outsourcing square are significant and show an U-inverted shape (out, β=0.426, p<0.01; out2, β=-0.273, p<0.01; out, β=0.419, p<0.01; out2, β=-0.263, p<0.01respectively), and the interaction effect are significant and their signs are the same as those presented in Table 2.5 (Coop_out, β=-0.110, p<0.01; Coop_out2, β=0.050, p<0.05; Coop_out, β=-0.102, p<0.01; Coop_out2, β=0. 043, p<0.10, respectively).

Second, although Haans et al. (2016) justified that testing for moderation in U-shaped relationships should include both the interaction term and its square, some researchers argue that adding the squared terms and later the interaction between the squared terms

to the model would overemphasize the effect of outliers in the estimates. To check that the introduction of the interaction with the squared term does not bias the results, I run the model without that squared interaction term. Results remain the same (adj-R^2=0.0319, χ^2=7026.94, p<0.01; out, β=0.374, p<0.01; out2, β=-0.209, p<0.01; Coop_out, β=-0.059, p<0.01).

I also checked the robustness of the results by running separate regressions for high-tech and low-tech sectors (Luker and Lyons 1997). Both models fit to data (adj-R^2=0.0167, χ^2=539.45, p<0.01; adj-R^2=0.0219, χ^2=4116.45, p<0.01, respectively), and in both cases, outsourcing draws an inverted-U shape (out, β=0.324, p<0.01; out2, β=-0.213, p<0.01; β=0.500, p<0.01; out2, β=-0.370, p<0.01, respectively), but I only found a significant interaction effect for low-tech firms (Coop_out, β=-0.111, p<0.01; Coop_out2, β=0.064, p<0.01). This might be due to the fact that firms behave differently with respect to their outsourcing strategy. Thus, the impact of outsourcing breadth is stronger for low-tech firms, while this effect is flatter for high-tech companies, impeding the sharing of relational capital between R&D outsourcing and cooperation. This result is in line with previous literature as firms with higher R&D capacity are better able to improve their innovative outcome through investing more in cooperation activities and relatively less in R&D outsourcing (Berchicci 2013).

2.6 Discussion

The aim of this study was to analyse the impact of R&D outsourcing breadth, as well as the moderator effect of cooperation on innovation performance. External knowledge sources are increasingly being used in firms' innovative processes (Laursen and Salter 2006). While most of literature has mainly studied breadth in cooperative activities

(Collins and Riley 2013; Faems et al. 2005; Laursen and Salter 2006; Leeuw et al. 2014; Oerlemans et al. 2013; Rothaermel and Deeds 2006), this study evidenced that sourcing breadth can be also useful to analyse the impact of R&D outsourcing. The results showed that there is an inverted U-shaped relationship between R&D outsourcing breadth and the innovation performance of a firm. It means it is beneficial for firms since it avoids risks about uncertain R&D, decreases internal research costs and accelerates the innovation process (Baloh, Jha and Awazu 2008; Gilley and Rasheed 2000; Howells et al. 2008; Rundquist and Halila 2010; Tsai and Wang 2009). That said, investing too much in external technology acquisition could create an external dependence (Rothaermel et al. 2006), which prevents firms from developing their own internal R&D and absorbing external knowledge.

Firms frequently use multiple strategies at the same time and this fact has barely been analysed by OI scholars. Open innovation is not just a single strategy of external technology access, but a framework for multiple strategies. I consider that an OI framework must cover different strategies because each strategy has its own features. Hence, this paper focused on the combination of the breadth of two main strategies used by Spanish firms: cooperation and R&D outsourcing. I proposed that a positive moderator role of cooperation breadth in the relationship between R&D outsourcing breadth and innovation performance. Grimpe and Kaiser (2010) tested that the relationship between R&D outsourcing intensity and innovation performance is positively moderated by the breadth of formal R&D collaborations. I went a step further since the model considered both strategies in terms of breadth. Hence, I argued that cooperation breadth moderates the relationship between R&D outsourcing breadth and innovation performance through two mechanisms: absorptive capacity and relational capital. I found that cooperation moderates positively that relationship, but not in all situations. It was only true for

medium to high levels of R&D outsourcing breadth. When firms develop the capacities to simultaneously manage different OI strategies, they are able to benefit from the breadth of both strategies. The synergetic effect of the joint adoption of cooperation breadth and R&D outsourcing breadth allow firms to improve innovation outcomes. The negative effect of cooperation between low and medium levels of R&D outsourcing breadth could be due to a dynamic in which the lower transactions costs of R&D outsourcing breadth make it a viable option that outweighs the benefits of diverse tacit knowledge from cooperation, though with higher cooperation costs due to co-specialized asset investments and coordination and control costs. Cooperation breadth and R&D outsourcing breadth require a different management approach. Therefore, it provokes a substitutive effect between OI strategies. Another explanation could be that between low and medium levels of R&D outsourcing breadth, it is difficult to build shared relational capital from cooperation breadth because common relationships are less likely to be found and these strategies are therefore substitutes.

The results of the control variables suggest that the older the firm, the more reluctant it is to introduce new products. This can be explained by the fact that older firms tend to focus solely on mature areas in which they have extensive knowledge, rather than seeking out innovative opportunities (Tsai, Hsieh and Hultink 2011). Laursen and Salter (2006) considered that startups could influence the innovation performance, but they did not find any influence. This study found a significant effect of startups, and it shows that startups perform a positive influence on innovation performance. It highlights the innovative role of startups for economic growth and wealth creation (Schumpeter 1934), and points out the use of external knowledge flows for startups. The extent of innovative performance is also dependent on the industry sector; in particular, it is more intense for electronic equipment and information systems.

2.7 Conclusion

This study focused on two different OI strategies—cooperation breadth and R&D outsourcing breadth—, and empirically analysed the relationship between R&D outsourcing breadth and innovation performance, and the moderator role of cooperation breadth on that relationship, in order to explain the synergetic impact of its combination. By studying breadth in R&D outsourcing and the moderator role of cooperation, I contribute to the OI literature in the following ways. First, literature has mainly studied breadth in cooperative activities. This study measured R&D outsourcing in terms of breadth, in an analogous manner to that used for cooperation breadth. I found that R&D outsourcing breadth formed an inverted-U relationship with innovative performance. Second, this paper offers another perspective with regard to the traditional 'buy', 'make' or 'ally' trade-off. While previous research has addressed their single impact on innovation performance (e.g. Laursen and Salter 2006; Leiponen and Helfat 2010), I compared and combined both R&D strategies—cooperation breadth and R&D outsourcing breadth—in a same model. Firms use different strategies at the same time, but empirical research barely analyse the interaction effect between strategies. A significant contribution of this paper is the study of the interrelationships between outsourcing and cooperation. Measuring both variables in terms of breadth allow us to discover the synergies between them. The findings revealed that the impact of cooperation breadth on the relationship between R&D outsourcing breadth and innovation performance depends on the level of R&D outsourcing breadth. The combination of these strategies has a negative effect on innovation performance between low and medium levels of R&D outsourcing breadth because these strategies might be substitutes. However, between medium to high levels of R&D outsourcing breadth, cooperation exerts a positive effect because firms build relational capital that can be used by both

strategies, generating economies of scale and scope. Future research literature should consider not only the combination of OI strategies, but also the level of breadth of each strategy.

This study has also some implications for practitioners. First, it is clear that the positive impact of OI strategies for innovation outcome, and thus R&D external relationships, must be an integral part of the business model for new product development. Nevertheless, I have evidenced an inverted U-shaped relation between R&D outsourcing breadth and innovation performance, so managers should not surpass a certain level of R&D outsourcing breadth. Doing so increases the risk of external dependence, blocks the creation of firms' knowledge base and hampers the firms' absorptive capacity, and as a result, harms the innovation outcome. Next, the interaction of different OI strategies does not always exhibit complementarities. As the research shows, there is a potential for diseconomies in OI combining deployment between low to medium levels of outsourcing breadth. Hence, it may take time for managers to develop capacities to deal with a combination of OI strategies because of the costs and managerial capacities needed to deal with a joint adoption of different innovation strategies. Finally, in an era of open innovation, policy makers should also design targeted policies that boost knowledge flows between firms. Currently, incentives for collaboration are given to big and high-intensive R&D firms (Barge-Gil 2010), but policies should also be focused on small and medium firms because I found that these kind of firms are more innovative and they are also implementing OI strategies.

Although this study reveals some interesting points, it has several limitations. First, the analysis of secondary data, such as PITEC, does not let the researcher take into account observations other than those included in the externally pre-established questionnaire. The use of primary data would have introduced the benefits of direct observational

methods research (Laursen and Salter 2006). In particular, I compared OI strategies breadths basing my arguments on costs, asset specificity, type of knowledge and learning considerations, but these characteristics could not be directly observed. Using a questionnaire would improve the analysis of different OI strategies, and other constructs could be used to measure these variables. In the same manner, I considered a restrictive definition of relational capital because PITEC did not provide information for a broader concept, such as the one used in Capello and Faggian (2005). Second, I have examined R&D outcomes through a percentage of new products as related to turnover. Future research could consider other innovative performances, such as process innovation or focus on the distinction between incremental and radical innovations. Third, PITEC has been anonymized to avoid the identification of firms. This limits the analyses as I could only consider pooled data. Fourth, the goal was not meant to be exhaustive in the discussion of inbound OI strategies, although it would have been possible to make more fine-grained, within-category distinctions. For example, some studies (Tsai and Wang 2009), also include licensing as a market procurement practice, but licenses resulted no to be moderatedly used in Spanish firms, and data do not provide information about the breadth of licenses. Fifth, it would be desirable to use sampling frames other than just Spanish firms to extend the validity of the findings.

This study also raises some interesting issues for future research. When firms embrace OI strategies they should consider not only the benefits associated with them but also their drawbacks. In particular, companies should ask themselves whether they have the resources and organizational capabilities to manage not only a particular strategy, but several strategies at the same time. Firms' deficiencies in successfully managing OI strategies underscore the need to develop organizational capabilities. These capacities may be complementary when firms combine OI strategies. Research on the joint adoption

of OI strategies is almost non-existent. Thereby, one fruitful area for future research may be to focus on factors that may be complementary to OI strategies. Another interesting are for future research would be the analysis of the open innovation phenomenon in the context of startups. The study evidenced that startups perform a positive impact on innovation performance, but most of open innovation literature has focused on large and established firms. Some scant literature are recently suggesting that small firms may even benefit to a greater extent from open innovation strategies (Brunswicker and Vanhaverbeke 2015), but few studies have analysed open innovation in startups. Startups could benefit to a bigger extent of openness because they use external knowledge to overcome their liabilities of smallness and newness (Neyes et al. 2010). In particular, future studies could deepen in the understanding of openness in startups and their motivation to use external sources, and compare startups with established firms.

References

Almirall, E., Casadesus-Masanell, R., 2010. Open Versus Closed Innovation: A Model of Discovery and Divergence. ACAD MANAGE REV 35, 27–47.

Andries, P., Thorwarth, S., 2014. Should Firms Outsource their Basic Research? The Impact of Firm Size on In-House versus Outsourced R&D Productivity. Creativity and Innovation Management 23, 303–317. https://doi.org/10.1111/caim.12073

Audretsch, D.B., Menkveld, A.J., Thurik, A.R., 1996. The Decision Between Internal and External R & D. Journal of Institutional and Theoretical Economics (JITE) / Zeitschrift für die gesamte Staatswissenschaft 152, 519–530.

Bahemia, H., Squire, B., 2010. A Contingent Perspective Of Open Innovation In New Product Development Projects. International Journal of Innovation Management (ijim) 14, 603–627.

Baloh, P., Sanjeev Jha, Yukika Awazu, 2008. Building strategic partnerships for managing innovation outsourcing. Strat Outs 1, 100–121. https://doi.org/10.1108/17538290810897138

Barge-Gil, A., 2010. Open, Semi-Open and Closed Innovators: Towards an Explanation of Degree of Openness. Industry and Innovation 17, 577–607. https://doi.org/10.1080/13662716.2010.530839

Baum, J.A.C., Cowan, R., Jonard, N., 2010. Network-Independent Partner Selection and the Evolution of Innovation Networks. Management Science 56, 2094–2110. https://doi.org/10.1287/mnsc.1100.1229

Baum, J.A.C., Silverman, B.S., 2004. Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. Journal of Business Venturing, Evolutionary approaches to entrepreneurship: Honoring Howard Aldrich 19, 411–436. https://doi.org/10.1016/S0883-9026(03)00038-7

Belderbos, R., Carree, M., Lokshin, B., 2004. Cooperative R&D and firm performance. Research Policy 33, 1477–1492. https://doi.org/10.1016/j.respol.2004.07.003

Berchicci, L., 2013. Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance. Research Policy 42, 117–127. https://doi.org/10.1016/j.respol.2012.04.017

Bogers, M., 2011. The open innovation paradox: knowledge sharing and protection in R&D collaborations. Euro Jrnl of Inn Mnagmnt 14, 93–117. https://doi.org/10.1108/14601061111104715

Brunswicker, S., Vanhaverbeke, W., 2015. Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators. Journal of Small Business Management 53, 1241–1263. https://doi.org/10.1111/jsbm.12120

Capello, R., Faggian, A., 2005. Collective Learning and Relational Capital in Local Innovation Processes. Regional Studies 39, 75–87. https://doi.org/10.1080/0034340052000320851

Cassiman, B., Veugelers, R., 2006. In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition. Management Science 52, 68–82. https://doi.org/10.1287/mnsc.1050.0470

Cassiman, B., Veugelers, R., 2002. Complementarity in the Innovation Strategy: Internal R&D, External Technology Acquisition and Cooperation (SSRN Scholarly Paper No. ID 308601). Social Science Research Network, Rochester, NY.

Chesbrough, H., 2012. Open Innovation: Where We've Been and Where We're Going. Research-Technology Management 55, 20–27. https://doi.org/10.5437/08956308X5504085

Chesbrough, H., Appleyard, M., 2007. Open Innovation and Strategy. Business Administration Faculty Publications and Presentations.

Chesbrough, H., Bogers, M., 2014. Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation, in: New Frontiers in Open Innovation. Oxford University Press, Oxford, pp. 3–28.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly 35, 128–152. https://doi.org/10.2307/2393553

Cohen, W.M., Nelson, R.R., Walsh, J.P., 2002. Links and Impacts: The Influence of Public Research on Industrial R&D. Management Science 48, 1–23. https://doi.org/10.1287/mnsc.48.1.1.14273

Collins, J., Riley, J., 2013. Alliance Portfolio Diversity and Firm Performance: Examining Moderators. Journal of Business and Management 19, 35–50.

Cui, Z., Loch, C., Grossmann, B., He, R., 2012. How Provider Selection and Management Contribute to Successful Innovation Outsourcing: An Empirical Study at Siemens. Production and Operations Management 21, 29–48. https://doi.org/10.1111/j.1937-5956.2011.01237.x

Dahlander, L., Gann, D.M., 2010. How open is innovation? Research Policy 39, 699–709. https://doi.org/10.1016/j.respol.2010.01.013

Dhont-Peltrault, E., Pfister, E., 2011. R&D cooperation versus R&D subcontracting: empirical evidence from French survey data. Economics of Innovation and New Technology 20, 309–341. https://doi.org/10.1080/10438591003669743

Escribano, A., Fosfuri, A., Tribó, J.A., 2009. Managing external knowledge flows: The moderating role of absorptive capacity. Research Policy 38, 96–105. https://doi.org/10.1016/j.respol.2008.10.022

Faems, D., De Visser, M., Andries, P., Van Looy, B., 2010. Technology Alliance Portfolios and Financial Performance: Value-Enhancing and Cost-Increasing Effects of Open Innovation*. Journal of Product Innovation Management 27, 785–796. https://doi.org/10.1111/j.1540-5885.2010.00752.x

Faems, D., Van Looy, B., Debackere, K., 2005. Interorganizational Collaboration and Innovation: Toward a Portfolio Approach*. Journal of Product Innovation Management 22, 238–250. https://doi.org/10.1111/j.0737-6782.2005.00120.x

Fey, C.F., Birkinshaw, J., 2005. External Sources of Knowledge, Governance Mode, and R&D Performance. Journal of Management 31, 597–621. https://doi.org/10.1177/0149206304272346

Friedrich, R.J., 1982. In Defense of Multiplicative Terms in Multiple Regression Equations. American Journal of Political Science 26, 797–833. https://doi.org/10.2307/2110973

Gassmann, O., Enkel, E., Chesbrough, H., 2010. The future of open innovation. R&D Management 40, 213–221. https://doi.org/10.1111/j.1467-9310.2010.00605.x

Gilley, K.M., Rasheed, A., 2000. Making More by Doing Less: An Analysis of Outsourcing and its Effects on Firm Performance. Journal of Management 26, 763–790. https://doi.org/10.1177/014920630002600408

Gooroochurn, N., Hanley, A., 2007. A tale of two literatures: Transaction costs and property rights in innovation outsourcing. Research Policy 36, 1483–1495. https://doi.org/10.1016/j.respol.2007.07.001

Grimpe, C., Kaiser, U., 2010. Balancing Internal and External Knowledge Acquisition: The Gains and Pains from R&D Outsourcing. Journal of Management Studies 47, 1483–1509. https://doi.org/10.1111/j.1467-6486.2010.00946.x

Gulati, R., 1998. Alliances and networks. Strategic Management Journal 19, 293–317. https://doi.org/10.1002/(SICI)1097-0266(199804)19:4<293::AID-SMJ982>3.0.CO;2-M

Haans, R.F.J., Pieters, C., He, Z.-L., 2016. Thinking about U: Theorizing and testing U- and inverted U-shaped relationships in strategy research. Strat. Mgmt. J. 37, 1177–1195. https://doi.org/10.1002/smj.2399

Hagedoorn, J., 1993. Understanding the rationale of strategic technology partnering: Nterorganizational modes of cooperation and sectoral differences. Strat. Mgmt. J. 14, 371–385. https://doi.org/10.1002/smj.4250140505

Hagedoorn, J., Hesen, G., 2007. Contract Law and the Governance of Inter-Firm Technology Partnerships – An Analysis of Different Modes of Partnering and Their Contractual Implications*. Journal of Management Studies 44, 342–366. https://doi.org/10.1111/j.1467-6486.2006.00679.x

Hagedoorn, J., Wang, N., 2012. Is there complementarity or substitutability between internal and external R&D strategies? Research Policy, Special Section on Sustainability Transitions 41, 1072–1083. https://doi.org/10.1016/j.respol.2012.02.012

Heckman, J.J., 1979. Sample Selection Bias as a Specification Error. Econometrica 47, 153–161. https://doi.org/10.2307/1912352

Hoecht, A., Trott, P., 2006. Innovation risks of strategic outsourcing. Technovation 26, 672–681. https://doi.org/10.1016/j.technovation.2005.02.004

Holl, A., Rama, R., 2014. Foreign Subsidiaries and Technology Sourcing in Spain. Industry and Innovation 21, 43–64. https://doi.org/10.1080/13662716.2014.879254

Holmstrom, B., 1989. Agency costs and innovation. Journal of Economic Behavior & Organization 12, 305–327. https://doi.org/10.1016/0167-2681(89)90025-5

Howells, J., Gagliardi, D., Malik, K., 2008. The growth and management of R&D outsourcing: evidence from UK pharmaceuticals. R&D Management 38, 205–219. https://doi.org/10.1111/j.1467-9310.2008.00508.x

Kale, P., Dyer, J.H., Singh, H., 2002. Alliance capability, stock market response, and long-term alliance success: the role of the alliance function. Strat. Mgmt. J. 23, 747–767. https://doi.org/10.1002/smj.248

Kale, P., Singh, H., 2009. Managing Strategic Alliances: What Do We Know Now, and Where Do We Go From Here? ACAD MANAGE PERSPECT 23, 45–62. https://doi.org/10.5465/AMP.2009.43479263

Kale, P., Singh, H., 2007. Building firm capabilities through learning: the role of the alliance learning process in alliance capability and firm-level alliance success. Strat. Mgmt. J. 28, 981–1000. https://doi.org/10.1002/smj.616

Kale, P., Singh, H., Perlmutter, H., 2000. Learning and protection of proprietary assets in strategic alliances: building relational capital. Strategic Management Journal 21, 217–237. https://doi.org/10.1002/(SICI)1097-0266(200003)21:3<217::AID-SMJ95>3.0.CO;2-Y

Khanna, T., Gulati, R., Nohria, N., 1998. The Dynamics of Learning Alliances: Competition, Cooperation, and Relative Scope. Strategic Management Journal 19, 193–210.

Kotabe, M., Mol, M.J., 2009. Outsourcing and financial performance: A negative curvilinear effect. Journal of Purchasing and Supply Management 15, 205–213. https://doi.org/10.1016/j.pursup.2009.04.001

Kotabe, M., Mol, M.J., Murray, J.Y., Parente, R., 2012. Outsourcing and its implications for market success: negative curvilinearity, firm resources, and competition. J. of the Acad. Mark. Sci. 40, 329–346. https://doi.org/10.1007/s11747-011-0276-z

Lane, P.J., Lubatkin, M., 1998. Relative absorptive capacity and interorganizational learning. Strategic management journal 19, 461–477.

Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. Strategic Management Journal 27, 131–150. https://doi.org/10.1002/smj.507

Leachman, C., Pegels, C.C., Shin, S.K., 2005. Manufacturing performance: evaluation and determinants. Int Jrnl of Op & Prod Mnagemnt 25, 851–874. https://doi.org/10.1108/01443570510613938

Leeuw, T., Lokshin, B., Duysters, G., 2014. Returns to alliance portfolio diversity: The relative effects of partner diversity on firm's innovative performance and productivity. Journal of Business Research 67, 1839–1849. https://doi.org/10.1016/j.jbusres.2013.12.005

Leiponen, A., Helfat, C.E., 2010. Innovation objectives, knowledge sources, and the benefits of breadth. Strat. Mgmt. J. 31, 224–236. https://doi.org/10.1002/smj.807

Lin, E.S., Hsiao, Y.-C., Lin, H., 2013. Complementarities of R&D strategies on innovation performance: Evidence from Taiwanese manufacturing firms. Technological and Economic Development of Economy 19, S134–S156. https://doi.org/10.3846/20294913.2013.876684

Lokshin, B., Belderbos, R., Carree, M., 2008. The Productivity Effects of Internal and External R&D: Evidence from a Dynamic Panel Data Model*. Oxford Bulletin of Economics and Statistics 70, 399–413. https://doi.org/10.1111/j.1468-0084.2008.00503.x

López, A., 2011. The effect of microaggregation on regression results: an application to Spanish innovation data. University Library of Munich, Germany.

Love, J.H., Roper, S., 2009. Organizing the Innovation Process: Complementarities in Innovation Networking. Industry and Innovation 16, 273–290. https://doi.org/10.1080/13662710902923776

Love, J.H., Roper, S., 2001. Outsourcing in the innovation process: Locational and strategic determinants. Papers in Regional Science 80, 317–336. https://doi.org/10.1111/j.1435-5597.2001.tb01802.x

Luker, W., Lyons, D., 1997. Employment Shifts in High-Technology Industries, 1988-96. Monthly Labor Review 120, 12–25.

McIvor, R., 2009. How the transaction cost and resource-based theories of the firm inform outsourcing evaluation. Journal of Operations Management 27, 45–63. https://doi.org/10.1016/j.jom.2008.03.004

Mitsuhashi, H., Greve, H.R., 2009. A Matching Theory of Alliance Formation and Organizational Success: Complementarity and Compatibility. ACAD MANAGE J 52, 975–995. https://doi.org/10.5465/AMJ.2009.44634482

Mudambi, S.M., Tallman, S., 2010. Make, Buy or Ally? Theoretical Perspectives on Knowledge Process Outsourcing through Alliances. Journal of Management Studies 47, 1434–1456. https://doi.org/10.1111/j.1467-6486.2010.00944.x

Narula, R., 2001. Choosing Between Internal and Non-internal R&D Activities: Some Technological and Economic Factors. Technology Analysis & Strategic Management 13, 365–387. https://doi.org/10.1080/09537320120088183

Neyens, I., Faems, D., Sels, L., 2010. The impact of continuous and discontinuous alliance strategies on startup innovation performance. International Journal of Technology Management 52, 392–410. https://doi.org/10.1504/IJTM.2010.035982

Nieto, M.J., Santamaría, L., 2007. The importance of diverse collaborative networks for the novelty of product innovation. Technovation 27, 367–377. https://doi.org/10.1016/j.technovation.2006.10.001

OECD, 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd ed. Paris: Organisation for Economic Co-operation and Development.

Oerlemans, L.A.G., Knoben, J., Pretorius, M.W., 2013. Alliance portfolio diversity, radical and incremental innovation: The moderating role of technology management. Technovation 33, 234–246. https://doi.org/10.1016/j.technovation.2013.02.004

Oxley, J.E., 1997. Appropriability Hazards and Governance in Strategic Alliances: A Transaction Cost Approach. JLEO 13, 387–409.

Piga, C., Vivarelli, M., 2003. Sample selection in estimating the determinants of cooperative R&D. Applied Economics Letters 10, 243–246. https://doi.org/10.1080/1350485022000044156

Piga, C.A., Vivarelli, M., 2004. Internal and External R&D: A Sample Selection Approach*. Oxford Bulletin of Economics and Statistics 66, 457–482. https://doi.org/10.1111/j.1468-0084.2004.00089.x

Poppo, L., Zenger, T., 2002. Do formal contracts and relational governance function as substitutes or complements? Strat. Mgmt. J. 23, 707–725. https://doi.org/10.1002/smj.249

Rothaermel, F.T., Deeds, D.L., 2006. Alliance type, alliance experience and alliance management capability in high-technology ventures. Journal of Business Venturing, Entrepreneurship and Strategic Alliances 21, 429–460. https://doi.org/10.1016/j.jbusvent.2005.02.006

Rothaermel, F.T., Hitt, M.A., Jobe, L.A., 2006. Balancing vertical integration and strategic outsourcing: effects on product portfolio, product success, and firm performance. Strat. Mgmt. J. 27, 1033–1056. https://doi.org/10.1002/smj.559

Rundquist, J., Halila, F., 2010. Outsourcing of NPD activities: a best practice approach. European Journal of Innovation Management 13, 5–23. https://doi.org/http://0-dx.doi.org.cisne.sim.ucm.es/10.1108/14601061011013203

Sampson, R.C., 2005. Experience effects and collaborative returns in R&D alliances. Strat. Mgmt. J. 26, 1009–1031. https://doi.org/10.1002/smj.483

Sandulli, F.D., Fernandez-Menendez, J., Rodriguez-Duarte, A., Lopez-Sanchez, J.I., 2012. Testing the Schumpeterian hypotheses on an open innovation framework. Management Decision 50, 1222–1232. https://doi.org/10.1108/00251741211246978

Schilke, O., Goerzen, A., 2010. Alliance Management Capability: An Investigation of the Construct and Its Measurement. Journal of Management 36, 1192–1219. https://doi.org/10.1177/0149206310362102

Schmiedeberg, C., 2008. Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. Research Policy 37, 1492–1503. https://doi.org/10.1016/j.respol.2008.07.008

Sen, A., MacPherson, A., 2009. Outsourcing, externa collaboration, and innovation among US firms in the biopharmaceutical industry. Industrial Geographer 6, 20–36.

Spithoven, A., Clarysse, B., Knockaert, M., 2011. Building absorptive capacity to organise inbound open innovation in traditional industries. Technovation 31, 10–21. https://doi.org/10.1016/j.technovation.2010.10.003

Spithoven, A., Teirlinck, P., 2015. Internal capabilities, network resources and appropriation mechanisms as determinants of R&D outsourcing. Research Policy 44, 711–725. https://doi.org/10.1016/j.respol.2014.10.013

Stanko, M.A., Olleros, X., 2013. Industry growth and the knowledge spillover regime: Does outsourcing harm innovativeness but help profit? Journal of Business Research, Strategic Thinking in MarketingStrategic Management in Latin AmericaCorporate Social Responsibility and IrresponsibilityManaging Global Innovation and Knowledge 66, 2007–2016. https://doi.org/10.1016/j.jbusres.2013.02.026

Stefano, G.D., Peteraf, M., Verona, G., 2010. Dynamic capabilities deconstructed : a bibliographic investigation into the origins, development, and future directions of the research domain. Ind Corp Change dtq027. https://doi.org/10.1093/icc/dtq027

Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strategic Management Journal 18, 509–533.

Teirlinck, P., Dumont, M., Spithoven, A., 2010. Corporate decision-making in R&D outsourcing and the impact on internal R&D employment intensity. Ind Corp Change 19, 1741–1768. https://doi.org/10.1093/icc/dtq038

Teirlinck, P., Spithoven, A., 2013. Research collaboration and R&D outsourcing: Different R&D personnel requirements in SMEs. Technovation 33, 142–153. https://doi.org/10.1016/j.technovation.2012.11.005

Teirlinck, P., Spithoven, A., 2011. Formal R&d Management and Research Collaboration and R&D outsourcing in SMEs. Presented at the R&D Management and Research Collaboration and R&D outsourcing in SMEs, Aberdeen Business School, Aberdreen, pp. 820–826.

Teirlinck, P., Spithoven, A., 2008. The Spatial Organization of Innovation: Open Innovation, External Knowledge Relations and Urban Structure. Regional Studies 42, 689–704. https://doi.org/10.1080/00343400701543694

Tobin, J., 1958. Estimation of relationships for limited dependent variables. Econometrica 26, 24–36. https://doi.org/10.2307/1907382

Trombini, G., Comacchio, A., 2012. Cooperative Markets for Ideas: When does Technology Licensing Combine with R&D Partnerships? (Working Paper No. 8). Department of Management, Università Ca' Foscari Venezia.

Tsai, K.-H., 2009. Collaborative networks and product innovation performance: Toward a contingency perspective. Research Policy 38, 765–778. https://doi.org/10.1016/j.respol.2008.12.012

Tsai, K.-H., Hsieh, M.-H., 2009. How different types of partners influence innovative product sales: Does technological capacity matter? Journal of Business Research 62, 1321–1328. https://doi.org/10.1016/j.jbusres.2009.01.003

Tsai, K.-H., Hsieh, M.-H., Hultink, E.J., 2011. External technology acquisition and product innovativeness: The moderating roles of R&D investment and configurational context. Journal of Engineering and Technology Management 28, 184–200. https://doi.org/10.1016/j.jengtecman.2011.03.005

Tsai, K.-H., Wang, J.-C., 2009. External technology sourcing and innovation performance in LMT sectors: An analysis based on the Taiwanese Technological Innovation Survey. Research Policy, Special Issue: Innovation in Low-and Meduim-Technology Industries 38, 518–526. https://doi.org/10.1016/j.respol.2008.10.007

Tsai, K.-H., Wang, J.-C., 2008. External technology acquisition and firm performance: A longitudinal study. Journal of Business Venturing 23, 91–112. https://doi.org/10.1016/j.jbusvent.2005.07.002

Un, C.A., Cuervo-Cazurra, A., Asakawa, K., 2010. R&D Collaborations and Product Innovation. Journal of Product Innovation Management 27, 673–689. https://doi.org/10.1111/j.1540-5885.2010.00744.x

Vanhaverbeke, W., Cloodt, M., 2014. Theories of the Firm and Open Innovation, in: In Henry Chesbrough, Wim Vanhaverbeke and Joel West, Eds., New Frontiers in Open Innovation. Oxford University Press, Oxford, pp. 256–278.

Vega Jurado, J., Manjarrés Henríquez, L., Gutiérrez Gracia, A., 2010. Cooperation with scientific agents and firm's innovative performance. Presented at the 13th Conference of the International Schumpeter Society: Innovation, Organisation, Sustainability and Crises, Aalborg (Denmark).

Veugelers, R., 1997. Internal R & D expenditures and external technology sourcing. Research Policy 26, 303–315. https://doi.org/10.1016/S0048-7333(97)00019-X

Veugelers, R., Cassiman, B., 1999. Make and buy in innovation strategies: evidence from Belgian manufacturing firms. Research Policy 28, 63–80. https://doi.org/10.1016/S0048-7333(98)00106-1

Wang, Y., Li-Ying, J., 2014. When does inward technology licensing facilitate firms' NPD performance? A contingency perspective. Technovation 34, 44–53. https://doi.org/10.1016/j.technovation.2013.09.002

Wang, Y., Roijakkers, N., Vanhaverbeke, W., 2013. Learning-by-Licensing: How Chinese Firms Benefit From Licensing-In Technologies. IEEE Transactions on Engineering Management 60, 46–58. https://doi.org/10.1109/TEM.2012.2205578

Weigelt, C., 2009. The impact of outsourcing new technologies on integrative capabilities and performance. Strat. Mgmt. J. 30, 595–616. https://doi.org/10.1002/smj.760

Williamson, O.E., 1991. Comparative Economic Organization: The Analysis of Discrete Structural Alternatives. Administrative Science Quarterly 36, 269. https://doi.org/10.2307/2393356

Zobel, A.-K., 2013. Open Innovation: A dynamic Capabilities Perspective. Maastricht University, Maastricht.

Chapter 3: Open innovation and the comparison between startups and incumbent firms in Spain

3.1 Introduction

Amadeus, the Spanish leader in technology solutions for the global travel and tourism industry, has opened its code library to third-party developers, and has built strong partnerships with academic labs and leading IT players in order to spur innovation. Like Amadeus, other large companies, such as IBM, Intel, Philips, Unilever, and Procter & Gamble, have abandoned the traditional close innovation models and instead adopted an open innovation model (Chesbrough, 2012). Startups are following in their footsteps and engaging with larger firms in open innovation activities. For example, startups connect with Amadeus in three ways: first, startups bring to life their ideas by using Amadeus' interfaces; second, startups connect their value propositions to Amadeus' technology and experience; third, startups receive investment or engage in partnerships with Amadeus (emiliejessula, 2016). As such, startups are an important driver of innovation and economic growth, as they introduce innovations that changes the competitive rivalry in an industry, and thereby threaten the competitive advantage of incumbent firms (Adelino et al., 2014; Boyer and Blazy, 2013; Eftekhari and Bogers, 2015; Schumpeter, 1934). However, most research on open innovation focuses on large and incumbent firms, with a minor emphasis on startups.

Startups and incumbent firms both play important roles in generating innovations and economic growth, but they contribute to the innovation ecosystem and economic development in different ways. There are notable differences between startups and incumbent firms in terms of resource endowments, external cooperation and innovative capabilities for reaching high innovation performance. In order to understand the innovation ecosystem, it is important to understand how both types of firm can contribute

to the economic prospects from their specific positions, and then benefit from these prospects. The aim of this study is therefore to compare the open innovation strategies between startups and incumbent firms. Based on an investigation of the extent to which both types of firms use external cooperation to generate new innovations over a ten year period, I can extract how the firms learn, how they are similar or different in their approaches to open innovation, and accordingly how they adapt their innovation strategies.

Using a longitudinal sample of startups and incumbent Spanish firms from the Spanish Technological Innovation Panel (PITEC), collected by the Spanish National Statistics Institute (INE), and taking the year 2004 as the focus year, I compare startups and incumbent firms on three main issues, 1) firms' degree of open innovation measured by the extent to which they engage in external cooperation during innovation activities, 2) radical innovation performance, and 3) incremental innovation performance. In this way, I contribute to the limited research that has studied the open innovation phenomenon in the context of startups, and directly compare the innovation activities of startups with those of incumbent firms to show the case of an innovation ecosystem in one particular country, namely Spain. I conclude the study by presenting how this study provides relevant implications for practitioners.

3.2 Engaging with external sources

Startups' innovation strategy is different from the innovation strategy of incumbent firms. Starting from Schumpeter's legacy, a large body of literature in small business economics has addressed the relationship between innovation and firm size, underpinning the different resources and capabilities that define the relative advantages of small firms and

large firms in innovation (e.g. Vossen, 1998). Nowdays, successful firms employ open innovation models, but the differences between firms still remain. In particular, startups do not have a portfolio of innovation projects, their OI practices must be framed into their general innovation strategy and business model, their OI activities are managed by the entrepreneur, and cooperating activities depends on the bond ties of the entrepreneur (Vanhaverbeke, 2017).

Open innovation usually implies cooperating with different external agents, such as customers, suppliers, competitors, universities or research centres (Wallin and von Krogh, 2010). The motivation to cooperate with external partners differs between startups and incumbent firms, mainly due to differences in resource endowments and legitimacy to develop and commercialize innovations. And the benefits of cooperating with external sources might also be different between startups and incumbent firms. Startups might achieve greater benefits from cooperating with other agents than larger firms because they are less bureaucratic, more willing to take risks, and more agile in reacting to changing environments (Vanhaverbeke, 2017).

Regarding startups, they are handicapped by their smallness and newness (Stinchcombe, 1965). Because of their small size, startups usually do not have the human and financial resources to bring a new technology or product to the market (Neyens et al., 2010). External sources are therefore considered essential in the startups' innovation process, since startups can acquire the resources they lack (Hite and Hesterly, 2001) or get access to complementary assets (Colombo et al., 2006). Because of their newness, startups lack reputation and legitimacy, as both reputation and legitimacy are built up over time (Neyens et al., 2010). External partners enhance the strategic position and legitimacy of a startup (Eisenhardt and Schoonhoven, 1996), since they act as endorsements by building public confidence about the value of the startup and its products (Stuart, 2000). An

example of how a startup has cooperated with an external partner to overcome its inadequacies is the case of Social&Beyond, a Spanish startup that developed a marketing application that transforms retailers' free Wi-Fi systems into a social media marketing pool. Social&Beyond lacked the track record to sell to big retailers. To compensate for this, they cooperated with Telefonica, who included the social media tool into their new broadband deals. This meant access to customers and therefore also revenue stream for Social&Beyond (Nesta et al., 2015).

In regard of incumbent firms, collaborating with external partners is also important for them, but it is a strategic decision, and a central question they ask themselves is whether to collaborate or hire internal resources. The incumbent firms' motivation to cooperate with external partners is to get a sustainable competitive advantage rather than to overcome a lack of resource endowment. By accessing partners' knowledge base, they can increase their opportunities for knowledge recombination, and thereby also find new ways of exploiting their own resources or speeding up the process (Teece, 2007). For example, Acciona, a leading Spanish corporation in the development and management of infrastructure, renewable energy, water and services, has collaborated with Ennomotive, an open platform for innovation in engineering, with the goal to use Ennomotive's open innovation platform to receive proposals about battery monitoring from experts around the world (Acciona, 2015). For incumbent firms, an increase in cooperation activities can also be due to an increase in the diversity of the different types of partners (Bogers, 2011), as different partners help meet different goals and objectives. The Spanish electric company Endesa, for instance, is aware of the current innovation ecosystem, and it has launched a platform called Opinno, which gathers experts from throughout the world (Opinno, 2016). Endesa thereby accesses valuable information from partners from distant countries, extending their reach to partners.

3.3 Types of innovation: Radical and Incremental

Compared to incumbent firms, startups are often characterized by their innovative capabilities, potentially outperforming incumbents. However, the literature is not clear about whether in reality startups are able to exploit these innovative capabilities and achieve a better innovation performance than incumbent firms.

On the one hand, the lack of financial resources of startups (Stinchcombe, 1965) hinders the innovation process, since they do not have enough financial resources to cover high R&D expenses. As a consequence, startups turn to external investors to raise money for innovation, but this process can be difficult due to the high uncertainty of the startup's innovation processes and information asymmetries between the startup and its investors (Katila and Shane, 2005). Moreover, the limited market knowledge of startups puts them in a disadvantageous position in comparison to incumbent firms. This is highly relevant, for example, when startups engage in markets based on standardized products since, in contrast to incumbent firms, startups have not developed innovation routines yet, nor have they an extended knowledge base on the industry (Katila and Shane, 2005). In contrast, incumbent firms have created routines and knowhow to use their existing knowledge and resources for innovation.

On the other hand, startups have demonstrated that they are highly innovative precisely because they do not have formal and rigid routines that might block more unstructured innovation processes. Startups have therefore been described as being more flexible than incumbent firms (Hyytinen et al., 2015; Katila and Shane, 2005). In contrast to incumbent firms, startups do not suffer from structural inertia (Criscuolo et al., 2012), which limits the ability of firms to introduce innovations because it restricts firms from making

adjustments changing the way they do things (Criscuolo et al. 2012; Katila and Shane 2005).

Studies on the innovation performance of the firm emphasize that it is important to explore the differences in the innovation process with regards to different degrees of novelty, which range from radical to incremental innovation (Laursen and Salter, 2006). Radical innovation refers to a firm's ability to develop products that are new to the market, whereas incremental innovation is understood as the ability to develop products that are new to the firm (OECD, 2005). Building on this distinction, startups are said to be better suited to develop radical innovations than incumbent firms since they are viewed as a source of "creative destruction" (Schumpeter, 1934). Their flexibility and absence of formal routines allow them to introduce revolutionary products to the market; products which squeeze the products of incumbent firms out of the market. As a consequence, numerous startups are recognized for their innovative capabilities; for example, the Spanish startup Emotion Research Lab impressed in the Open Innovation Business Contest with presenting a radical innovation; a device that through facial recognition could determine consumers' emotions to improve sales of products and services (Everis, 2017). Startups are entrepreneurially oriented and open to disruptive technologies and opportunities (Hyytinen et al., 2015), pursuing for radical innovations since radical innovation requires significant changes to the organizational routines and processes of a firm (Velu, 2015), which is more affordable in startups than in incumbent firms. As the firm becomes larger, it loses the ability to enter emerging markets (Christensen and Overdorf, 2000).

Research has analysed some of the antecedents that drive to an increase on radical innovation performance. Between these drivers, the composition of the network has been outlined as an important leverage. Startups will have different resources needs as they

move from the start-up stage to growth (Hite and Hesterly, 2001), and radical innovations, in particular, will require from different knowledge and perspectives. Accordingly, Elfring and Hulsink (2003) argued that startups pursuing radical innovations require a wider range of ties, mixing strong and weak ties, and this type of firms are better skilled on the exploration of diversity (Almeida and Kogut, 1997). Hence, the higher nature of startups to cooperate with a diversity of knowledge sources, as discussed in the previous section, will lead startups to pursue radical innovations. Another driver for radical innovations is the firms' willingness to cannibalize their own investment (Chandy and Tellis, 1998). Since startups do not have a record of previous investment and few incumbent firms are willing to cannibalize it, startups will tend to introduce more radical innovations than incumbent firms.

In regard to incremental innovation, its degree of novelty is lower, as incremental innovation does not require the same levels of innovative capabilities and disruptive innovation outcomes as radical innovation activities (Elfring and Hulsink, 2003). Incremental innovation can be seen as something that is relatively easy for incumbent firms to implement and which reinforces its dominance, as it requires few modifications tot he firm's current routines and processes (Velu, 2015). One key element in incremental innovation is capturing the rents of those innovations (Elfring and Hulsink, 2003). Since incumbent firms are usually in possession of the complementary assets (Teece, 1986), it is likely that they will get a better incremental innovation performance. Nevertheless, incremental innovations could put aside previous products of the firm, and thus the firm will lose income from its overall product portfolio. Since startups' innovative efforts do not cannibalize existing products (Arrow, 1962), as could happen for incumbent firms, startups may be encouraged to introduce incremental innovations as well.

3.4 Empirical data: The differences between startups and incumbent firms

To investigate whether there are differences between startups and incumbent firms in terms of cooperation breadth and innovation performance, I used a representative panel sample of Spanish firms from the Spanish Technological Innovation Panel (PITEC) database, collected by the Spanish National Statistics Institute (INE). The database has a wide sector coverage including both manufacturing and service sectors, and it is representative of the population of Spanish firms. The present article uses data from 2004 to 2013[3]. I split the sample into two groups; startups[4] and incumbents[5]. In total, there were 343 startups in 2004, and 4540 incumbent firms[6]. Table 3.1 describes the variables that I used for the analyses and Table 3.2 the descriptive statistics. Note that all variables show a higher average for startups, being much higher the average of radical innovation performance in startups. Below I examine the evolution each of the three variables, comparing startups with incumbent firms.

Table 3.1. Variable description

Variable	Description	Value	References
Cooperation Breadth	Addition of seven sources of R&D cooperation: suppliers, customers (public and private), competitors, consultants, universities, public research centers and technological centers.	0-7	Laursen & Salter (2014)
Radical Innovation Performance	Proportion relative to turnover of new or strongly improved products that the company introduced to the market and that were new to the market.	0-100	Laursen & Salter (2006)
Incremental Innovation Performance	Proportion relative to turnover of new or strongly improved products that the company introduced to the market and that were new to the firm.	0-100	Laursen & Salter (2006)

[3] PITEC was created in 2003, but the questionnaire suffered important modifications in 2004, so we used the year 2004 rather than 2003. In this way, we could also ensure that we observed data before and after the financial crisis in 2008 to elucidate whether external factors influenced the results.

[4] Start-ups are defined as firms that answered yes to the question about the firm was newly established during the last three years.

[5] Firms that in 2004 had been in business for more than 10 years.

[6] The average size over the 10-year period is 39 employees for startups, and 421 employees for incumbent firms. 54% of the startups are high-tech firms, while 18% of incumbent firms operate in high-tech sectors. In our robustness checks we tested industry differences.

Table 3.2. Descriptive statistics

Incumbent firms	Obs	Mean	Std. Dev.	Min	Max
Coop. Breadth	42119	0.911	1.625	0	7
Radical Inn. Perform.	42119	9.803	22.213	0	100
Incremental Inn. Perform.	42119	14.736	27.622	0	100
Startups					
Coop. Breadth	2349	1.464	1.914	0	7
Radical Inn. Perform.	2349	20.375	32.693	0	100
Incremental Inn. Perform.	2349	22.990	34.929	0	100

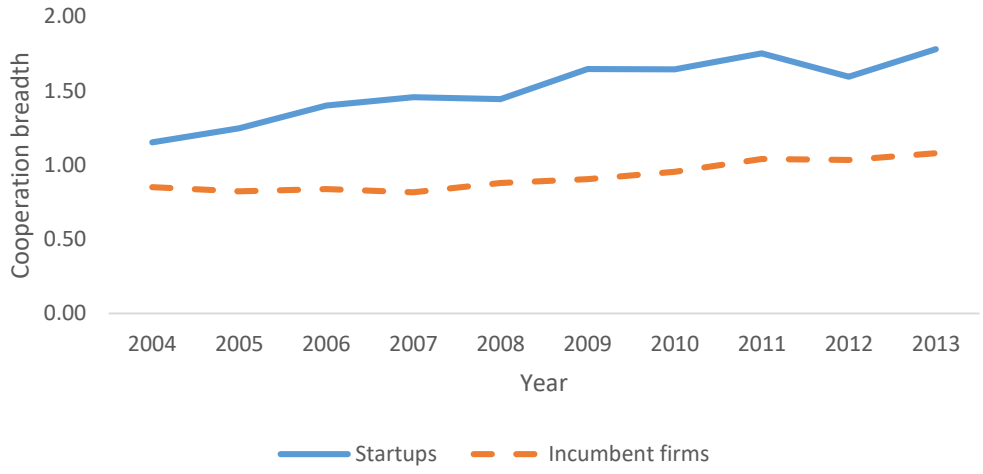
3.4.1 Cooperation breadth

Firstly, I propose that due to the lack of resources in startups, they collaborate with more partners than incumbent firms. In Figure 3.1, I compare the evolution of cooperation breadth for startups and incumbent firms. The average of cooperation breadth is higher for startups than for incumbent firms. Specifically, the average of cooperation breadth was 1.15 sources for startups, while it was 0.85 sources for incumbent firms in 2004. In 2013, the average of cooperation breadth for startups had grown by 54.5%, while the growth for incumbent firms was 26.8%. These figures show a general increase in firms' cooperation patterns, but stronger for startups. To compare whether the differences in cooperation breadth between the two groups are statistically significant, I conducted a t-test, and as expected, I found that the average cooperation breadth of startups was higher than that of incumbent firms at a 1 per cent significance level[7]. In other words, data suggests that startups are significantly more engaged in cooperation activities than incumbent firms. Startups cooperate with external agents to overcome their smallness and newness, seeking to enhance their innovation performance. Startups often lack different

[7] Year-by-year t-tests also show a 1% of significance level in all years.

types of resources, which makes cooperation with different partners a necessity, so the cooperation breadth of these firms is higher than the cooperation breadth of incumbents.

Figure 3.1. Evolution of cooperation breadth



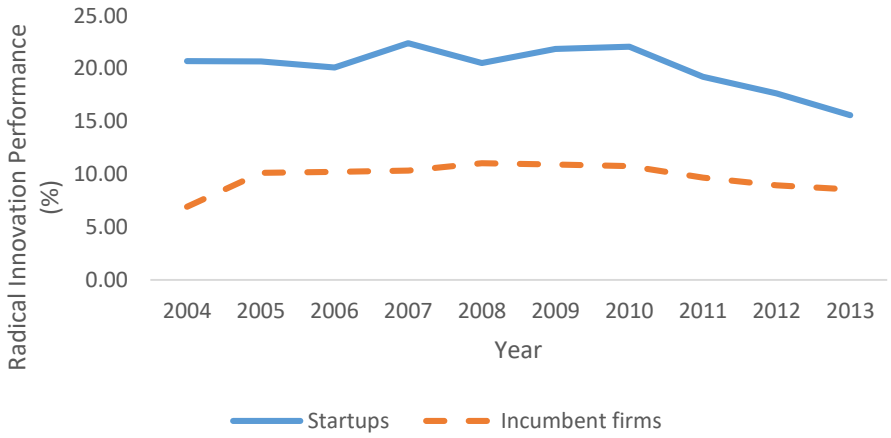
Source: Own elaborated from FECYT & INE (2016)

3.4.2 Radical innovation performance

Secondly, I investigated whether startups are more innovative and thereby have a higher innovation performance than incumbent firms. I did this by examining both radical and incremental innovation. Figure 3.2 shows the evolution of the radical innovation performance for startups and incumbent firms, and I observe that it is higher for startups than for incumbent firms over the ten-year period analysed. In 2004, the average of startups' radical innovation performance reached 20.69%, while it was 6.93% for incumbent firms. The figure also reveals that the radical innovation performance kept relatively steady for incumbent firms. On the contrary, the average of startups' radical innovation performance dropped 24.69% over the 10 years. This might be due to the fact

that startups lose their competitive advantages of flexibility and few formal routines after being in business for more than five years. To test the difference on radical innovation performance between startups and incumbent firms, I performed a t-test of mean comparison and found that, at a 1 per cent significance level, the startups' radical innovation performance is higher than that of incumbent firms[8]. Hence, startups overturn incumbent firms since they are able to introduce revolutionary products into the market and improve their innovation performance.

Figure 3.2. Evolution of radical innovation performance



Source: Own elaborated from FECYT & INE (2016)

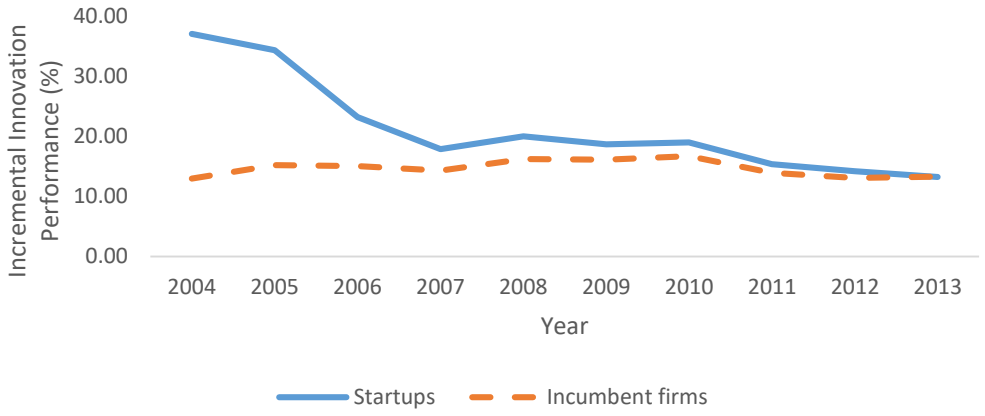
3.4.3 Incremental innovation performance

With regard to incremental innovation performance, there are arguments in favor of both a higher incremental innovation performance for incumbent firms and a higher

[8] Year-by-year t-test also show a 1% of significance level in all years.

performance for startups. In Figure 3.3, I present the evolution of incremental innovation performance for startups and incumbent firms. This Figure shows interesting results, since there is a sharp drop in the level of incremental innovation for startups; it decreased by 64.33% over the ten-year time period examined. In 2004, I observe a high difference in the average incremental innovation performance between startups (3.98%) and incumbent firms (12.96%), but this difference decreases over time, up to the point of disappearing. In 2013, the average incremental innovation performance was slightly higher for incumbent firms (13.26%) than for startups (13.19%). Again, I conducted a t-test to compare the differences between startups and incumbent firms with regard to their incremental innovation performance. Considering the ten-year period, I found a significant difference at a 1% of significance level: on average incremental innovation performance is higher for startups than incumbent firms. Nevertheless, since the graphs show that the tendency is much greater during the early years than later, I conducted a year-by-year t-test to estimate when the differences are no longer present. I found that the difference on the average incremental innovation performance between startups and incumbent firms disappears approx. 5 years after a startup was established (year 2009 in data). There are several possible reasons for this. It might be explained by the fact that, by that time, startups already have products in the market, so they no longer enjoy the benefit of newness, but they cannibalize their own products. In other words, as startups become established, their incremental innovations are reduced to a level equivalent to that of incumbent firms. Furthermore, given the nature of the startups, i.e. them being risk seeking (as compared to incumbents that are more risk adverse), I would expect them to focus their energy on introducing radical innovations to the market, as shown above (in the previous section on radical innovations), leaving little or no resources to pursue incremental innovation, and therefore the steep drop.

Figure 3.3. Evolution of incremental innovation performance



Source: Own elaborated from FECYT & INE (2016)

3.5 Conclusion

The aim of this study was to compare the open innovation strategy between startups and incumbent firms. Drawing on panel data on Spanish firms from PITEC, the results conclude that startups and incumbent firms differ in terms of cooperation breadth, radical innovation performance and incremental innovation performance. These results support previous research, which claims that startups have innovative capabilities and that they are better suited to develop radical innovation (e.g. Christensen & Overdorf, 2000; Hyytinen et al., 2015). In particular, this study is in line with Criscuolo et al. (2012) who, using data from the UK innovation survey, found that startups have a higher proportion of sales from innovative products than incumbent firms, and that startups also have a higher likelihood of generating product innovations than incumbent firms. I extend this analysis by distinguishing on the basis of the degree of innovation and analyzing it from an open innovation perspective, as well as adding a longitudinal view. In other words, I differentiate between radical and incremental innovation and I incorporate the variable

cooperation breadth into the analysis. The longitudinal perspective allows us to study the evolution of the open innovation strategy for startups and incumbent firms. At the same time this perspective sheds light on startups' maturity process and their evolution to becoming incumbent firms[9].

This study has relevant implications for practitioners and policy makers. First, in recent decades, models of innovation suggest that managers should cooperate with external partners to enhance innovation outcomes, to increase market share and to survive in the current competitive market. Cooperation activities by large incumbent firms are often in the public eye, for example, Microsoft cooperated with IBM, Apple and UNIX to deal with the uncertainty they were facing over the future of microcomputer operating systems (Grant and Baden-Fuller, 2004). However, the results show that incumbent firms are less open than startups. I recommend that managers from incumbent firms increase their breadth of cooperation, since they could benefit from more diverse knowledge in their innovation activities and enhance their innovation performance.

Second, startups find in their partners the resources and legitimacy that they lack. Hence, having an open innovation strategy is especially relevant for them. Managers of new firms who have not implemented an open innovation model should consider the benefits of opening their innovation processes and engaging with external partners to improve innovation performance.

Third, startups and incumbent firms bring variety to the innovation ecosystem. Startups' flexibility and their absence of formal routines boost their innovative capabilities, thereby

[9] As a robustness check, we split the sample between high-tech and low-tech firms and reran the same analyses as presented in the main results. All the main results were confirmed, although the year-by-year t-tests for incremental innovation performance revealed that, for low-tech firms, the significant differences between startups and incumbent firms disappear in 2007; while for high-tech firms they do so in 2011.

leaving room for the creation of radical innovations. Managers at startups are therefore operating in a very different setting than that of managers in incumbent firms. While startups' managers have more freedom because they are not restricted by internal routines and procedures, managers of incumbent firms are operating in organizations with set structures and routines, and employees expecting certain approaches to innovation. As a consequence, each type of firm plays a different role in the innovation ecosystem.

Fourth, I found that startups have better radical innovation performance than incumbent firms. In this setting, managers struggle with established corporate values and "the way of doing things", limiting their abilities to introduce radical innovations. The results therefore go hand in hand with Christensen & Overdorf (2000) research, in which they suggest that the best way to address radical innovations is through the creation of new organizational spaces to develop these innovative activities. They propose three mechanisms for this: 1) create new organizational structures within the company, 2) spin out an independent organization that carries out the new processes, and 3) acquire a new organization whose processes and values fit with the new processes and integrate that firm into the organization. I add to their mechanisms, and suggest that incumbent firms should engage with startups to increase their radical innovation performance.

Fifth, the study analysed the evolution of the open innovation strategy for a period of ten years. This allowed us to observe how firms' reliance on open innovation processes changes over a period of time. The rather low levels of open innovation shown could be due to difficulties in implementing open innovation. Many firms experience a wealth of managerial challenges in effectively implementing open innovation strategies (e.g. dealing with employee attitudes affected by the "Not Invented Here" syndrome). It could take time before managers develop their capacities to successfully implement an open innovation strategy. For example, Italcementi, the leading Italian cement manufacturer,

evolved from being a closed innovator to become an open innovator, but it faced a significant challenge and clearly required a remarkable change in the organization and management systems (Chiaroni et al., 2011). I warn managers that the positive outcomes of open innovation processes might not be easily achieved, as deeply rooted routines need to be challenged. I recommend that managers be patient, and ensure that the right incentive structures are in place to unfold open innovation activities properly.

Finally, the longitudinal study also reveals the evolution of startups' innovation strategies. I evidenced how the startups' incremental innovation performance sharply decreases after some years. Startups' managers should be aware that the advantageous position of high radical and incremental innovation capacities does not go on forever. There is a time when the startup becomes an incumbent firm, with a portfolio of products and a set of values and routines. If the startup's strategy is to remain with a startup culture and exploit the benefits of high innovation performance, managerial focus on not routinizing firm structures must be maintained, despite the temptation to "fall into old routines".

From a policy perspective, the study also provides relevant implications. In an era of open innovation, policy makers should design targeted policies that increase knowledge sharing between firms. These policies should take into account the different roles of startups and incumbent firms for the national economy and innovation system. Large and high-intensive R&D firms are currently those that benefit most from policies that provide incentives for cooperation (Barge-Gil, 2010), but policies should also focus on startups, because they are also implementing open innovation models, and as I show, to an even higher extent than incumbent firms. Policies should therefore support startups, since they are the motor of the economy for many countries, such as Spain.

Finally, this study suffers some limitations. The startup sample represents 4% of the sample of PITEC firms. This figure is slightly lower than the proportion of startups in Spain, since the birth rate in 2004 was almost 10% (INE, 2016) of the total number of firms. The sample could suffer from some survivorship bias, since PITEC only provides information about firms that were in business. Nevertheless, I do not expect the results to be biased, since PITEC follows a representative method to select the sample of firms, and since I compared the initial conditions for some control variables (internal R&D, firm size and market scope) between survivors and non-survivors and I did not find any significant difference. This study was tested using a sample of Spanish firms, but I expect that the results are generalizable across countries. Despite these limitations, this study brings important conclusions about the differences between startups and incumbent firms on developing innovations and the study suggests how managers can cope with open innovation strategies.

References

Acciona, 2015. Open innovation to solve social challenges [WWW Document]. URL https://www.acciona.com/pressroom/news/2015/october/open-innovation-solve-social-challenges/ (accessed 4.28.17).

Adelino, M., Ma, S., Robinson, D.T., 2014. Firm Age, Investment Opportunities, and Job Creation (Working Paper No. 19845). National Bureau of Economic Research.

Almeida, P., Kogut, B., 1997. The Exploration of Technological Diversity and Geographic Localization in Innovation: Start-Up Firms in the Semiconductor Industry. Small Business Economics 9, 21–31. https://doi.org/10.1023/A:1007995512597

Arrow, K.J., 1962. Economic Welfare and the Allocation of Resources for Invention (NBER Chapters). National Bureau of Economic Research, Inc.

Barge-Gil, A., 2010. Open, Semi-Open and Closed Innovators: Towards an Explanation of Degree of Openness. Ind. Innov. 17, 577–607. doi:10.1080/13662716.2010.530839

Bogers, M., 2011. The open innovation paradox: knowledge sharing and protection in R&D collaborations. Eur. J. Innov. Manag. 14, 93–117. doi:10.1108/14601061111104715

Boyer, T., Blazy, R., 2013. Born to be alive? The survival of innovative and non-innovative French micro-start-ups. Small Bus. Econ. 42, 669–683. doi:10.1007/s11187-013-9522-8

Chandy, R.K., Tellis, G.J., 1998. Organizing for Radical Product Innovation: The Overlooked Role of Willingness to Cannibalize. Journal of Marketing Research 35, 474–487. https://doi.org/10.2307/3152166

Chesbrough, H., 2012. Open Innovation: Where We've Been and Where We're Going. Res.-Technol. Manag. 55, 20–27. doi:10.5437/08956308X5504085

Chiaroni, D., Chiesa, V., Frattini, F., 2011. The Open Innovation Journey: How firms dynamically implement the emerging innovation management paradigm. Technovation, Open Innovation - ISPIM Selected Papers 31, 34–43. doi:10.1016/j.technovation.2009.08.007

Christensen, C.M., Overdorf, M., 2000. Meeting the Challenge of Disruptive Change. Harv. Bus. Rev. 78, 66–76.

Colombo, M.G., Grilli, L., Piva, E., 2006. In search of complementary assets: The determinants of alliance formation of high-tech start-ups. Res. Policy, Special issue commemorating the 20th Anniversary of David Teece's article, "Profiting from Innovation", in Research Policy 35, 1166–1199. doi:10.1016/j.respol.2006.09.002

Criscuolo, P., Nicolaou, N., Salter, A., 2012. The elixir (or burden) of youth? Exploring differences in innovation between start-ups and established firms. Res. Policy 41, 319–333. doi:10.1016/j.respol.2011.12.001

Eftekhari, N., Bogers, M., 2015. Open for Entrepreneurship: How Open Innovation Can Foster New Venture Creation. Creat. Innov. Manag. 24, 574–584. doi:10.1111/caim.12136

Eisenhardt, K.M., Schoonhoven, C.B., 1996. Resource-Based View of Strategic Alliance Formation: Strategic and Social Effects in Entrepreneurial Firms. Organ. Sci. 7, 136–150.

Elfring, T., Hulsink, W., 2003. Networks in Entrepreneurship: The Case of High-technology Firms. Small Bus. Econ. 21, 409–422. doi:10.1023/A:1026180418357

emiliejessula, 2016. Amadeus's Open Innovation Strategy and Collaboration with Startups. Innov. Prime.

Everis, 2017. Two Spanish companies will compete in the NTT DATA start-up final in Tokyo [WWW Document]. Everis U. K. URL https://www.everis.com/united-kingdom/en/news/newsroom/two-spanish-companies-will-compete-ntt-data-start-final-tokyo (accessed 4.28.17).

FECYT, INE, 2016. Panel de Innovación Tecnológica (PITEC).

Grant, R.M., Baden-Fuller, C., 2004. A Knowledge Accessing Theory of Strategic Alliances. J. Manag. Stud. 41, 61–84. doi:10.1111/j.1467-6486.2004.00421.x

Hite, J.M., Hesterly, W.S., 2001. The evolution of firm networks: from emergence to early growth of the firm. Strateg. Manag. J. 22, 275–286. doi:10.1002/smj.156

Hyytinen, A., Pajarinen, M., Rouvinen, P., 2015. Does innovativeness reduce startup survival rates? J. Bus. Ventur. doi:10.1016/j.jbusvent.2014.10.001

INE, 2016. Instituto Nacional de Estadística. (National Statistics Institute) [WWW Document]. URL http://www.ine.es/jaxi/menu.do?type=pcaxis&path=%2Ft37%2Fp204&file=inebase&L=0 (accessed 1.18.17).

Katila, R., Shane, S., 2005. When Does Lack of Resources Make New Firms Innovative? Acad. Manage. J. 48, 814–829. doi:10.5465/AMJ.2005.18803924

Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. Strateg. Manag. J. 27, 131–150. doi:10.1002/smj.507

Laursen, K., Salter, A.J., 2014. The paradox of openness: Appropriability, external search and collaboration. Res. Policy, Open Innovation: New Insights and Evidence 43, 867–878. doi:10.1016/j.respol.2013.10.004

Nesta, Founders Intelligence, Startup Europe Partnership, 2015. Winning together: a guide to successful corporate-startup collaborations. Nesta, United Kingdom.

Neyens, I., Faems, D., Sels, L., 2010. The impact of continuous and discontinuous alliance strategies on startup innovation performance. Int. J. Technol. Manag. 52, 392–410. doi:10.1504/IJTM.2010.035982

OECD, 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd ed. Paris: Organisation for Economic Co-operation and Development.

Opinno, 2016. Endesa Energy Challenges incubates the future of energy [WWW Document]. Opinno - We Deliv. Impact Innov. URL http://www.opinno.com/en/content/endesa-energy-challenges-incubates-future-energy?language=es (accessed 4.29.17).

Schumpeter, J.A., 1934. The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle. Transaction Publishers.

Stinchcombe, A.L., 1965. Organizations and social structure. Handb. Organ. 44, 142–193.

Stuart, T.E., 2000. Interorganizational alliances and the performance of firms: a study of growth and innovation rates in a high-technology industry. Strateg. Manag. J. 21, 791–811. doi:10.1002/1097-0266(200008)21:8<791::AID-SMJ121>3.0.CO;2-K

Teece, D.J., 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strateg. Manag. J. 28, 1319–1350. doi:10.1002/smj.640

Teece, D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Res. Policy 15, 285–305. doi:10.1016/0048-7333(86)90027-2

Vanhaverbeke, W., 2017. Managing Open Innovation in SMEs. Camdridge University Press.

Velu, C., 2015. Business model innovation and third-party alliance on the survival of new firms. Technovation 35, 1–11. https://doi.org/10.1016/j.technovation.2014.09.007

Vossen, R.W., 1998. Relative Strengths and Weaknesses of Small Firms in Innovation. International Small Business Journal 16, 88–94. https://doi.org/10.1177/0266242698163005

Wallin, M.W., von Krogh, G., 2010. Organizing for Open Innovation:: Focus on the Integration of Knowledge. Organ. Dyn., Designing Organizations for the 21st-Century Global Economy Special Issue 39, 145–154. doi:10.1016/j.orgdyn.2010.01.010

Chapter 4: Do startups benefit more from opening to external sources? An analysis of the role of startups for radical innovation performance

4.1 Introduction

From a Schumpeterian point of view, startups are a key driver in the production of innovation and economic change. As evidenced in the previous chapter, startups have a higher rate for innovation performance, in particular, for radical innovation performance as the differences in incremental innovation performance disappear after some years a new firm is established. Startups also have a higher cooperation breadth, but the relationship between cooperation breadth and innovation performance was not tested in the previous chapter.

For developing innovations and new knowledge combinations is essential to acquire external scientific, technological and entrepreneurial knowledge (Spender et al., 2017). Evolutionary economics focusses on the role of new knowledge creation that explains the creation and survival of new firms (Audretsch, 1995). One of the main cornerstones of entrepreneurial research is the study of organizational learning processes as a key driver for startups' success. Organizational learning produces new organizational routines in startups (i.e. Sapienza et al. 2006). Organizations may learn from direct experience or from the experience of others (Levitt and March, 1988). Since compared to other organizations startups are characterized by newness, the potential to retrieve lessons from their own history would be limited. For this reason, this research will focus on organizational learning that results in the development of new products from the acquisition and absorption of external technological knowledge (Almeida et al., 2003). This study explores this second learning context by studying how startups may benefit to a greater extent from defining specific knowledge source strategies for the radical innovation performance.

Startups face two huge problems: smallness and newness (Stinchcombe, 1965), so they lack human, financial and complementary assets to complete their innovation processes. External sources become an essential tool for startups to overcome their liabilities, in a way that startups could benefit more from openness than other firms. Existing research has focused on the role of openness for large and established companies (Gassmann et al., 2010), with scant papers focused on small and medium firms (SMEs) (Brunswicker and Vanhaverbeke, 2015) and startups (Alberti and Pizzurno, 2017; Criscuolo et al., 2012; Segers, 2015; Spender et al., 2017; Usman and Vanhaverbeke, 2017). Startups are different from SMEs and large firms because they are bounded by the liability of newness (Usman and Vanhaverbeke, 2017), so more research that analyses the particularities of startups is needed. For example, Criscuolo et al. (2012) evidenced that start-ups differ considerably from established firms in their innovative activities. Differentiating between services and manufacturing firms, they found that in services, startups have a higher likelihood of generating product innovations than established firms, while, in manufacturing, they did not find significant differences. They also found that startups have a higher proportion of sales from innovative products than established firms and that these advantages were greatest in industries with strong appropriability regimes.

The differences in extracting the benefits from external sources could therefore be dependent on some contingencies, such as the industrial sector in which the firm operates. The industry is the most obvious external characteristic that might affect the effectiveness of open innovation (Huizingh, 2010). Theoretically, technology intensive sector generates more opportunities and boost the use of external sources and open innovation strategies (Schroll and Mild, 2011; Tunzelmann and Acha, 2006). However, some scholars argue that when other factors are taken into account, for example, firm size, it is not clear openness to be more important for intensive technology sectors (Tether, 2002;

Chesbrough and Crowther, 2006). To contribute to this research gap, I analyse whether the role of startups on benefiting from external sources is increased in knowledge-intensive industries.

I test the model on a panel dataset from the Spanish Technological Innovation Panel database (PITEC), collected by the Spanish National Statistics Institute (INE). The results show that cooperation breadth draws an inverted-U shape with the innovation performance, and these effects are steepening in the case of startups. The liabilities of smallness and newness make that startups can benefit to a greater extent of external breadth. In particular, startups in high-tech sectors are those that can benefit the most from cooperation breadth because they highly depend on external resources.

This paper contributes to literature in several ways. First, it advances in the integration of open innovation with the entrepreneurship theory. Scholars have underlined the important role of external actors for the innovation process of new firms and have remarked the need for future studies to focus on startups (Bogers et al., 2016; Brunswicker and Van De Vrande, 2014; Eftekhari and Bogers, 2015). This study examines the fact of being a startup for the relationship between cooperation breadth and radical innovation performance. To my knowledge no previous studies have analysed whether startups benefit to a greater extent from inbound open innovation strategies. The smallness and newness liabilities that startups suffer, rather than being a limitation, they are an incentive for openness. It poses the nature of breadth as a mechanism to integrate heterogeneous external knowledge and to provide complementary assets. Second, I contribute to understand the contingencies on open innovation strategies. I deepen in the relationship between knowledge-intensive industries and openness, evidencing that the steepening effect of cooperation breadth in high-tech sectors is kept when startups are considered.

Third, this study further contributes to empirical literature because it uses panel data, considering a ten year period.

The remainder of this paper is structured as follows. In the next section I review the theoretical background and I develop the hypothesis. The third section describes methodology and in the fourth section I present the statistical method and the results of the analyses. I then discuss the findings. Finally, I conclude with implications and directions for future research.

4.2 Conceptual background and hypothesis

The knowledge-based view literature has linked knowledge management to firms' innovation performance (Bengtsson et al., 2015). Open innovation literature highlights that internal knowledge must be combined with external knowledge to enhance firms' innovation performance (e.g. Berchicci, 2013; Chesbrough, 2006; Santamaría et al., 2009). Two key characteristics of external knowledge search are uncertainty and irreversibility (Nelson and Winter, 1982). Firms need to be accurate in defining specific routines to determine the direction of their cooperation activities. Since external cooperation implies highly uncertain outcomes, firms may mitigate the risk associated to external cooperation by diversifying knowledge sources. On this regard, among the different routines that explain successful inbound open innovation strategies, open innovation research has shown the relevance of an efficient degree of sources breadth. Laursen and Salter (2014) defined cooperation breadth as the number of different types of sources with which a firm cooperates, such as suppliers, customers, competitors, consultants, universities, research centres, etc. Each type of external source have a different knowledge base that combined with the own base of knowledge of the firm,

result in a different knowledge recombination (Teece, 1986). External sources also differ in the facility to access that knowledge (Un et al., 2010) and in the strength of this interaction (Brunswicker and Vanhaverbeke, 2015). Even if firms may benefit from cooperating with diverse external sources, transaction costs and the need for specific capabilities to obtain and exploit heterogeneous knowledge may constrain the returns to excessively diversified sources (Laursen and Salter, 2006). Empirical literature has evidenced that the effect of external breadth on the innovation performance might be positive (Chesbrough and Appleyard, 2007; Leiponen and Helfat, 2010; Zobel, 2013), inverted-U shaped (Laursen and Salter, 2006; Leeuw et al., 2014; Oerlemans et al., 2013), or even negative (Bengtsson et al., 2015).

Startups depend on those knowledge flows. There is a consensus among literature from different theoretic perspectives that openness to external sources (e.g. cooperation strategies) are critical to startups. The resource based view of the firm (RBV) suggests that startups overcome their liabilities of smallness and newness (Stinchcombe, 1965) by using their networks to acquire the resources that they lack (Bhalla and Terjesen 2013; Eisenhardt and Schoonhoven 1996; Gruber et al. 2010, 2013; Haeussler, Patzelt and Zahra 2012; Neyens et al. 2010; Pangarkar and Wu 2013). In his literature review paper, Hayter (2013) brings four theoretical frameworks –network approach, social capital perspective, relational view perspective, and knowledge spillover perspective- to evidence that networks and networks characteristics provide important resources to entrepreneurial performance. First, the network approach proposes that founders use their personal network of professional contacts to acquire information and resources that are of critical importance to and enhance firm performance (Larson and Starr, 1993). Second, with regard to the social capital perspective (e.g. Gulati, Nohria, and Zaheer, 2000; Hoang and Antoncic, 2003; Walker, Kogut, and Shan, 1997), it highlights the value of specific

relationship ties and characteristics of the network overall, underlining the role of the network density and trust on partners to transmit knowledge between partners and enhance firm exchanges and entrepreneurial performance (Coleman, 1988). Third, the relational view perspective argues that external relationships are a source of 'relational rents' and competitive advantage in terms of specific assets, knowledge-sharing routines, complementary resources or capabilities, and effective governance (Dyer and Singh, 1998). Fourth, the knowledge spillover perspective emphasizes the role of external relationships in knowledge dissemination and economic growth (Cockburn and Henderson, 1998), and promotes firms clustering to tap knowledge spills (Audretsch and Lehmann, 2005). Authors on this stream of literature (e.g. Acs, Audretsch, and Lehmann, 2013; Audretsch and Lehmann, 2005) consider that knowledge created endogenously results in knowledge spillovers which becomes a source for opportunity creation and exploitation by entrepreneurs. While these studies remark the relevance of external knowledge, little is known on the specific internal routines that startups deploy to search, capture, absorb and exploit external knowledge, which determine the potential benefits of open innovation for startups.

4.2.1 Startups and cooperation breadth

Startups can use the degree of cooperation breadth as a strategy to impact on innovation performance. External knowledge flows could be managed to meet the innovation outcomes of startups. The knowledge-based view points out two dimensions of knowledge management: exploration and exploitation (March, 1991). Exploration is identified with knowledge generation (Spender, 1992) and it refers to the idea that alliances are a vehicle for transferring and absorbing partner's knowledge as well as

learning from the partner (Grant and Baden-Fuller, 2004). Upon the above argument, startups could benefit more from knowledge exploration when engage in a diversity of cooperation activities because they need to access to more knowledge and learn from their partners.

First, the diversity of external relationships provides diverse knowledge insights, which foster the identification of more business opportunities. Exploring strategies involve the scout or search of knowledge in the external environment, where firms would be able to create new knowledge and find business opportunities (March, 1991) that would eventually lead to increase the innovation performance. Scholars have stated that search strategies exert an impact on the innovation activities of firms (Katila and Ahuja, 2002; Laursen and Salter, 2006; Spithoven et al., 2013). Since startups existence depends on their ability to source novel information (Yu et al., 2011), cooperation breadth would bring them the necessary insights to discover business opportunities. The purpose of technology scouting into a diversity of sources is not to gather large sets of detailed information, but creating insights or awareness of technological opportunities and threats regarding patterns of change in external environment (Parida et al., 2012) to gain a competitive advantage at an early stage and to provide the technological capabilities needed to face these challenges (Rohrbeck, 2010). In this sense, Alvarez and Barney (2001) stressed the importance for startups to be a continual source of innovation by developing an inventive capability that large firms cannot develop or imitate.

Second, exploration activities can be understood as a process of search, variation, experimentation and discovery (March, 1991) that is used by startups. At the earliest stages, startups are usually engaged with proximate partners (Butler and Hansen, 1991; Hite and Hesterly, 2001; Lechner and Dowling, 2003) because it is easier for them to reach acquaintances. However, to keep up with their innovation performance and find

more diverse knowledge, they need to make a distant search that provides a different knowledge base with potential for recombinations of that new and unfamiliar knowledge with the existing knowledge (Nelson and Winter, 1982). On this basis, Wadhwa and Kotha (2006) linked the exploration activities to distant search to explain firms' innovation processes, arguing that firms establish equity relationships with startups to explore for new opportunities. In the same way, startups use these relationships to identify opportunities with value creation potential. Hence, cooperation breadth involves a distant knowledge search that would let startups access different knowledge resources.

Regarding knowledge exploitation, it has been identified with knowledge application (Spender, 1992) and it refers to knowledge share and access to exploit the complementarities between partner's knowledge bases, but maintaining the own distinctive specialized knowledge bases (Grant and Baden-Fuller, 2004). Startups could benefit more from knowledge exploitation when engage in a diversity of cooperation activities because they offer commercial channels, perform as a sign of quality, bring complementary assets, and share the risks.

First, I have previously discussed that startups use external relationships to overcome their liabilities of smallness and newness (Colombo et al., 2006; Eisenhardt and Schoonhoven, 1996). One of those limitations is the lack of market access or commercial linkages since startups are not visible and lack external legitimacy (Stinchcombe, 1965). External cooperation partners become a source for complementary assets (Teece, 1986) since they would provide the commercial assets that startups lack. Entrepreneurial literature has discussed that startups move from social networks to more strategic linkages, consists of professional and business partners (Butler and Hansen, 1991; Hite and Hesterly, 2001; Lechner and Dowling, 2003). In this sense, firms can intentionally use their cooperation breadth to meet different types of partners to open paths to markets.

In additions, a mechanism to get that market access is to engage with partners with commercial knowledge and reputation since external partners perform as a sign of quality and support for startups' legitimacy (Hoang and Antoncic, 2003; Lee et al., 2012; Martinez and Aldrich, 2011; Wang et al., 2012).

Second, grounding in the Resource Based View (RBV) and entrepreneurship literature, it has been argued that startups use external sources to overcome their financial and human needs (Bhalla and Terjesen, 2013; Eftekhari and Bogers, 2015; Haeussler et al., 2012; Pangarkar and Wu, 2013). The diversity of partners is positive for startups' success because they would have a broader knowledge access. As startups grow, their resources needs change. Startups reallocate their resources according to their current needs. Cooperation breadth could be a way to answer to the change in resources needs. Partners could fill their resources gaps and provide complementary assets in a timely manner (Etemad and Wright, 1999). Moreover, cooperation breadth provides insights of the market from different points of view, complementing the startups' understanding of the market condition to get a competitive advantage.

Third, researching, developing and commercializing new products might be a costly process, take a long time and be very risky for startups because of their smallness and newness liabilities (Stinchcombe, 1965). Cooperation diminishes the risks and costs of the innovation process because they are split between the partners (Cassiman and Veugelers, 2002). In the way that startups cooperate with diverse partners, they distribute their risks between several projects and share their costs with the collaboration partners, which decreases the risks of startups' mortality due to the failure of a project.

All in all, I consider that startups can benefit more from cooperation breadth because it helps them to overcome their liabilities of smallness and newness when explore and exploit external knowledge:

Hypothesis 3.1: *Startups will benefit to a greater extent from cooperation breadth for their innovation performance.*

4.2.2 High-tech startups and cooperation breadth

The effectiveness of cooperation breadth on innovation performance could be affected by the sector in which the startup operates. Startups, which are focused on bringing innovations to the market (Schumpeter, 1934), could benefit more from openness in high-tech sectors because technology intensive sector generate more opportunities and boost the use of external sources and open innovation strategies (Schroll and Mild, 2011; Tunzelmann and Acha, 2006).

On the one hand, in high-tech sectors, products are more complex and knowledge is more distributed, so firms need to allocate more resources for new product development. This necessity effect is more challenging in startups because they lack internal R&D resources (Eisenhardt and Schoonhoven, 1996; Neyens et al., 2010; Stinchcombe, 1965), so they will have a higher necessity to look for external agents with internal R&D capacities (Parida et al., 2012). On the other hand, in high-tech sectors firms are unlikely to encompass all the capacities needed to develop their innovations (Gassmann, 2006), while startups enjoy from an inventive capability (Alvarez and Barney, 2001; Neyens et al., 2010). As a result, startups in high-tech sectors will cooperate with larger firms to accomplish innovation projects since the complementary between firms generates

situations of value creation (Alvarez and Barney, 2001; Barge-Gil, 2010; Bayona et al., 2001; Colombo et al., 2006; Tether, 2002).

Technology intensive industries are featured by uncertainty that makes firms benefit from sharing risks with external partners. In the same way, these industries are characterized by technological turbulence or rapid technological development, making that awareness of the environment to be crucial (Barge-Gil, 2010) and that firms open the innovation processes. Given the uncertainty and turbulence, larger firms opt to lean on internal knowledge to keep themselves under their technological trajectory (Almirall and Casadesus-Masanell, 2010) and distinguish from their competitors (Toh and Kim, 2013). On the contrary, startups are described as being more flexible (Hyytinen et al., 2015; Katila and Shane, 2005) since they do not suffer from structural inertia (Criscuolo et al., 2012), which limits the ability of firms to introduce innovations. As a consequence, startups easily adapt to environmental changes because they are not restricted to a way of doing things, rather they can make adjustments in their organizations (Criscuolo et al., 2012; Katila and Shane, 2005). Startups therefore are more flexible and they offer a fast answer when they have to readapt their search processes of external knowledge sources, balancing out the uncertainty inconveniences, which contributes to startups to benefit more from open innovation strategies.

In addition, in high-tech sectors is most likely to surge emergent markets. Emergent industries are characterized by the entry of new firms. In such industries, most of the knowledge is tacit and, hence, its access requires technological cooperation initiatives (Dussauge et al., 2000). Startups in these industries will tend to cooperate with partners in a higher propensity (Eisenhardt and Schoonhoven, 1996). Since startups play a key role in this type of markets, and this industry requires to cooperate with external knowledge source, the positive benefits of cooperation breadth could be multiplied for

startups. The diversity of partners will bring more resources, will reduce the costs and risks by sharing with other firms, and will help to legitimate the new market (Eisenhardt and Schoonhoven, 1996), contributing to the innovation performance of startups.

Therefore, the lack of R&D resources, the inventive capability, the strength to adapt to environmental changes, and the emergence of new markets make startups to be prone to adopt open innovation strategies in high-tech sectors, and benefit more from cooperation breadth. Hence, I propose:

Hypothesis 3.2*: Startups operating in high-tech sectors will benefit to a greater extent from cooperation breadth for their innovation performance.*

4.3 Methodology

4.3.1 Sample

I test the model on a representative sample of Spanish firms from the Spanish Technological Innovation Panel database (PITEC), collected by the Spanish National Statistics Institute (INE), in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). The database has a wide sector coverage including both manufacturing and service sectors, being representative of the population of Spanish firms. The survey is based in the core Eurostat Community Innovation Survey (CIS), whose method and types of questions are described in Oslo Manual (OECD, 2005). CIS data has been used in numerous academic papers (e.g. Cassiman and Veugelers, 2002, 2006; Escribano et al., 2009; Gimenez-Fernandez and Sandulli, 2016; Grimpe and Kaiser, 2010; Laursen and Salter, 2006;

Spithoven et al., 2011), and also applied in the context of startups (Colombelli et al., 2016; Criscuolo et al., 2012).

PITEC data are collected on a yearly base from 2003, and in 2004 and 2005 there were two enlargements of the sample. In addition, in 2004 PITEC introduced some important changes in the questionnaire, affecting variables related to cooperation with external sources for technology innovation, which are central variables in this study. Due to these limitations, this study will use data from 2004 to 2013 to test the hypotheses. Since I analyse the open innovation phenomenon, I only focus on firms that intended to have an innovation activity, even failed. In total, the sample consists of 76,764 observations from 11,085 firms.

4.3.2 Measures

Dependent variables

In this paper I analyse the fact of being a startup on the relationship between cooperation breadth and innovation performance since I argue that startups could benefit more from openness in the innovation process. A well-established proxy for innovation performance is product innovation (Belderbos et al., 2004; Faems et al., 2005, 2010; Laursen and Salter, 2006; Nieto and Santamaría, 2007). In the startup context, there is also strong support in literature for using product innovation as a proxy for innovation performance (Criscuolo et al., 2012) since it has been evidenced the role of startups in introducing new products to the market (Almeida and Kogut, 1997). In the questionnaire firms are asked to assert what share of their sales can be ascribed to innovations new to the market. Hence, innovation performance is measured as proportion relative to turnover of new or strongly

improved products that the company introduced to the market and that were new to the market.

Independent variables

This study considers the effect of startups on the relationship between cooperation breadth and innovation performance. Cooperation breadth is defined as the number of different types of sources with which a firm cooperates (Laursen and Salter, 2014). In the survey, firms are asked if they cooperated with the following sources in the last three years: suppliers, customers (private and public sector), competitors or other firms from the same activity field, consultants or commercial laboratories, universities or other higher education institutes, public or private research centres and technological centres. Following the methodology of Laursen and Salter (2006, 2014), the variable cooperation breadth is constructed as the addition of those seven cooperation partners. Each of the seven cooperation partners is coded as a binary variable, 1 if the firm cooperated with that partner, and 0 being no use. Subsequently, the seven types of cooperation partners are added up so that each firm gets a 0 when no cooperation agreements with any type of partner were taken, and 7 when it cooperated with all the different types of partners. Empirical literature has found mixed results regarding the linearity effect of external breadth on the innovation performance, evidencing a positive effect (Chesbrough and Appleyard, 2007; Leiponen and Helfat, 2010; Zobel, 2013), inverted-U shaped (Laursen and Salter, 2006; Leeuw et al., 2014; Oerlemans et al., 2013), or even negative effect (Bengtsson et al., 2015). To test the linearity of cooperation breadth, I included its square term.

Startups are new enterprises in the first stage of their operations trying to solve a problem whose solution is not guaranteed (Michelino et al., 2017). According to Blank (2010), a startup is a company, partnership or temporary organization designed to search for a repeatable and scalable business model. There is not unanimous definition of a startup, but literature highlights as a feature the age of the firm or the fact of being developing the business. Alberti and Pizzurno (2017, p. 53) defined a start-up as "a few-year-old business which is not yet established in the industry and in the market and could more easily fail". The survey asks firms if the firm is new creation or it was during the two last years, and I use this question to build the startup variable (Laursen and Salter, 2006). Hence, startup is measured as a binary variable indicating whether the firm is of new creation. I create the interaction cooperation breadth and startup for the greater benefits on startups.

Literature has discussed that firms operating in knowledge-intensive sectors are more prone to open their boundaries (Schroll and Mild, 2011; Tunzelmann and Acha, 2006). I measure the intensive technology sectors through a dummy variable that indicates if the firm belongs to a high-tech sector (Luker and Lyons, 1997). I follow the Spanish National Statistics Institute classification to determine the firms that operate in a high-tech sector. In particular, this classification considers that are high-tech sectors: pharmaceutical industry, computing material, electronic components, telecommunications, aeronautic and space industries, research and development services, and computing services. Since it is not clear whether the tendency to be more open in intensive technology sectors remains when considering other factors (Tether, 2002; Chesbrough and Crowther, 2006), I test the effect of cooperation breadth in high-tech sectors when the firm is a startup. For that purpose, I create a dummy variable indicating whether the firm is both a startup and it operates in high-tech sectors. I then create an interaction variable between cooperation breadth and startups operating in high-tech sectors.

Control variables

In order to rule out possible alternative explanations to those formally hypothesized, the model includes the following control variables. First, as scholars consider internal R&D to be crucial for innovation (Lin, 2003; Schmiedeberg, 2008), and a proxy for absorptive capacity (Cohen and Levinthal, 1990), I include firm's internal R&D efforts, measured as the proportion of its internal innovation expenses. Second, firms need to protect their innovations and deploy suitable appropriation strategies against imitation, as well as avoid intentionally or unintentionally allowing partners to collect all the benefits (Pisano 2006; Teece 1986). Literature has recognized the importance of having an appropriation strategy (Alkaersig et al., 2015; Gans and Stern, 2003). Hence, I include a variable to control for the startups' formal appropriation strategy. This variable is built following Laursen and Salter (2014) methodology, where the addition of the different appropriation mechanisms that a firm uses generates the firm's 'appropriability strategy'. The variable is therefore measured by the addition of the use of the four appropriation mechanisms -patents, trademarks, copyright, and design rights-. These items are binary variables, being 1 if the firm registered or applied it during the last three years, and 0 if it did not; and it gets the value of 4 when all the mechanisms were used by the firm, and 0 if it did not use any of them. Third, I also control for firm size as it has been argued to be relevant for firms' innovative behaviour (Berchicci, 2013; Cassiman and Veugelers, 2002). This variable is measured by the logarithm of the total number of employees. Fourth, I include a dummy variable to control if the firm belongs to a group because firms belonging to a corporate group could bring knowledge from the large corporation and being more innovative (Criscuolo et al. 2012). Fifth, I include as a control variable the scope of the market where the firm sells its products since it would increases the firm's market share. It is measured by the addition of the involvement in different markets: local, national,

European, and other international markets (Laursen and Salter, 2014). Finally, I have created dummy variables to control the possible bias of the observation year (Un et al. 2010; Wang, Roijakkers, and Vanhaverbeke 2013). Controlling time-varying effects is necessary in a rapid changing environment such as technology and innovation, and to check if the economic crisis impact on results. A short description of the variables used to test the model and their references are included in Table 4.1.

Table 4.1. Variable description

Variable	Description	References
Innovation Performance	Proportion relative to turnover of new or strongly improved products that the company introduced to the market and that were new to the market.	Belderbos et al. (2004); Faems et al. (2005, 2010); Nieto and Santamaría (2007)
Cooperation Breadth	Addition of seven cooperation partners: suppliers, customers (private and public sector), competitors or other firms from the same activity field, consultants or commercial laboratories, universities or other higher education institutes, public or private research centres and technological centres.	Laursen and Salter (2006, 2014)
Startup	Dummy variable to indicate whether the firm is new creation	Laursen and Salter (2006)
High-tech	Dummy variable to indicate whether the firm belongs to a high-tech sector.	Luker and Lyons (1997)
Internal R&D	Proportion of firm's internal innovation expenses.	Lin et al. (2013); Schmiedeberg (2008)
Formal Approp. Strategy	Addition of the use of the four appropriation mechanisms: patents, trademarks, copyright, and design rights.	Laursen and Salter (2014)
Size	Natural logarithm of the total number of employees.	Audretsch et al. (2000); Berchicci (2013); Cassiman and Veugelers (2002)
Group	Dummy variable to indicate if the firm belongs to a firm group.	Criscuolo et al. (2012)
Scope	Addition of the involvement in different markets: local, national, European, and other international markets.	Laursen and Salter (2014)
Year	A set of dummy variables for the observation year.	Un et al. (2010); Wang et al. (2013)

4.4 Results

Table 4.2 reports the basic statistics of the variables used in the analysis. The percentage of sales of new products remains relatively stable over time, being higher in 2008-2010. It suggests that Spanish firms launched new products during the financial crisis to face it or as result of a previous innovation process that takes a couple of years to emerge. Indeed, the internal R&D expenses slightly decreased in 2008-2010. On the contrary, the use of external sources has increased over time. In the data, the sample of startups is higher during the first years analysed. It is due to the fact that PITEC is a panel survey, that is, it consists of repeated observations on the same cross section of economic agents over time. As a consequence the big sample of startups is introduced when the panel was created or with the two main enlargements (2004, 2005), but the minor enlargements over time introduce few startups in the database. From the sample of startups, 57% of them are firms operating in high-tech sectors.

Table 4.3 shows the correlation coefficients of the variables (except year dummies) and it reveals some interesting points. For example, startups relate positively to innovation performance, while the coefficient for larger firms is negative. Moreover, startups are also positively related to cooperation breadth. It suggests that the liabilities of smallness and newness make these firms to open their barriers, but it is not a limitation for innovation, rather a boost. High-tech firms are also positively related to the innovation performance and to cooperation breadth. None of the correlations are sufficiently strong to suggest multicollinearity problems. Before calculating the interaction terms, the variables were mean-centered to avoid multicolinearity issues (Van de Vrande, 2013). In addition, I conducted a variance inflation factor (VIF) test. All the VIFs are lower than 10, and the average VIF is 2.06, indicating few problems of multicollinearity.

Table 4.2. Descriptive statistics

Year	Obs.	Inn. Perform.	Coop. Breadth	Startup	High-tech	Internal R&D	Formal Appr. Strat.	Size	Group	Scope
2004	7274	9.02	0.85	0.05	0.29	66.06	0.63	283.19	0.37	2.87
		(21.50)	(1.49)	(0.21)	(0.45)	(40.76)	(0.95)	(1220.55)	(0.48)	(1.05)
2005	9657	11.45	0.77	0.04	0.28	59.31	0.54	247.43	0.34	2.98
		(24.33)	(1.42)	(0.19)	(0.45)	(39.78)	(0.86)	(1100.58)	(0.48)	(1.12)
2006	9426	11.41	0.79	0.01	0.28	54.69	0.49	259.15	0.36	2.91
		(24.32)	(1.47)	(0.12)	(0.45)	(42.54)	(0.83)	(1186.94)	(0.48)	(1.07)
2007	8870	11.75	0.80	0.00	0.29	52.13	0.46	283.73	0.39	2.94
		(24.73)	(1.51)	(0.05)	(0.45)	(42.16)	(0.81)	(1372.70)	(0.49)	(1.06)
2008	8238	12.49	0.87	0.00	0.29	51.18	0.44	305.05	0.40	2.96
		(25.11)	(1.57)	(0.01)	(0.45)	(42.63)	(0.78)	(1530.17)	(0.49)	(1.04)
2009	7905	12.48	0.90	0.00	0.18	48.23	0.42	309.79	0.41	2.98
		(25.16)	(1.61)	(0.01)	(0.39)	(42.84)	(0.77)	(1591.57)	(0.49)	(1.04)
2010	7570	12.19	0.95	0.00	0.18	46.57	0.41	326.86	0.42	3.03
		(24.72)	(1.68)	(0.03)	(0.39)	(43.02)	(0.76)	(1598.32)	(0.49)	(1.04)
2011	6249	10.96	1.03	0.00	0.19	51.73	0.42	345.74	0.45	3.09
		(23.76)	(1.76)	(0.03)	(0.39)	(43.08)	(0.77)	(1654.55)	(0.50)	(1.03)
2012	5934	9.72	1.02	0.00	0.19	54.78	0.38	358.94	0.47	3.15
		(22.40)	(1.70)	(0.04)	(0.39)	(43.12)	(0.74)	(1769.52)	(0.50)	(1.01)
2013	5461	9.22	1.05	0.00	0.19	55.90	0.38	372.68	0.49	3.20
		(21.63)	(1.73)	(0.04)	(0.39)	(43.06)	(0.74)	(1834.45)	(0.50)	(1.01)

Note: Standards errors in brackets.

Table 4.3. Correlation coefficients of major variables used in the model

	Inn. Perform.	Coop. Breadth	Startup	High-tech	Internal R&D	Formal Appr. Strat.	Size	Group
Coop. Breadth	0.118							
p-value	*0.000*							
Startup	0.060	0.016						
p-value	*0.000*	*0.000*						
High-tech	0.123	0.120	0.076					
p-value	*0.000*	*0.000*	*0.000*					
Internal R&D	0.228	0.165	0.066	0.172				
p-value	*0.000*	*0.000*	*0.000*	*0.000*				
Formal Appr. Strat.	0.176	0.187	0.056	0.065	0.233			
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*			
Size	-0.011	0.087	-0.014	-0.014	-0.045	0.028		
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		
Group	-0.018	0.119	-0.023	-0.037	0.001	0.031	0.163	
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.847*	*0.000*	*0.000*	
Scope	0.092	0.077	-0.055	-0.097	0.258	0.199	-0.025	0.125
p-value	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

Note: This table omits the correlation coefficients of year dummies.

This study uses longitudinal data from 2004 to 2013, so time-series effects can be considered. The nature of the variable related to the technology intensity sector in which the firm operates is almost unvarying because firms do not commonly shift between not

related sectors, so keeping on high-tech sectors or low-tech, but not moving from high-tech to low-tech sectors. Hence, a fixed effect model would not be accurate. I consider whether random effects or pool data are more accurate. The Breusch-Pagan Lagrange Multiplier (LM) test to control for random effects indicates that random effects are relevant in the model (χ^2=27233.83, p<0.01). Hence, I will use random effects regressions.

To determine the statistical model, I first check if the assumption of normality of residuals in the model is satisfied. Since I find that residuals are not normally distributed, but it could exist a left censoring, I employ a censored Tobit model (Laursen and Salter, 2006). This model was proposed by James Tobin (1958) to estimate relationships between variables when there is either left- or right- censoring or both left-censored and right-censored in the dependent variable. Moreover, to address the lack of normality of residuals, we assume a lognormal distribution for the residuals of the Tobit model (Laursen and Salter, 2006). Hence, I introduce a latent variable, lnnewmer, as a logarithmic transformation of an observed measure of innovation performance, lnnewmer = ln(1+newmer)[10]. Our latent models would be as follows:

$$(\#1)\quad y^*_i = \textit{Inn. Performance} = \beta_0 + \beta_1 \textit{Coop. Breadth} + \beta_2 \textit{Coop. Breadth\^2} + \beta_3 \textit{Startup} + \beta_4 \textit{Coop. Breadth*Startup} + \beta_5 \textit{Coop. Breadth\^2*Startup} + \beta_6 \textit{InternalR\&D} + \beta_7 \textit{Formal App. Strat.} + \beta_8 \textit{Size(log)} + \beta_9 \textit{Group} + \beta_{10} \textit{Scope} + \beta_{11} \textit{High-tech} + \beta_{12} \textit{YearDummies} + \varepsilon,\ \varepsilon \sim N(0, \sigma^2)$$

[10] Note: The lognormal transformation does not change the signs, nor the significance for the key variables' parameters in the subsequent estimations.

$$(\#2)\quad y^*_i = Inn.\ Performance = \beta_0 + \beta_1 Coop.\ Breadth + \beta_2 Coop.\ Breadth\text{^}2 + \beta_3 High\text{-}techStartups + \beta_4 Coop.\ Breadth{*}High\text{-}techStartups + \beta_5 Coop.\ Breadth2{*}High\text{-}techStartups + \beta_6 InternalR\&D + \beta_7 Formal\ App.\ Strat. + \beta_8 Size(log) + \beta_9 Group + \beta_{10} Scope + \beta_{11} High\text{-}tech + \beta_{12} YearDummies + \varepsilon\ \varepsilon \sim N(0, \sigma^2)$$

The results of the random effects Tobit regressions can be found in Table 4.4. First, I estimate Model I, which contains the control variables (for reasons of space I do not include results from year dummy variables in the table); then Model II, which contains the independent and control variables of Hypothesis 3.1. In Model III I include the interaction term between cooperation breadth and startup. Model IV includes the independent and control variables variables of Hypothesis 3.2; and Model V also includes the interaction between cooperation breadth and startup in high-tech sectors.

I hypothesised that startups will benefit to a greater extent from cooperation breadth for innovation performance. Cooperation breadth draws a curvilinear relationship since I can observe in Model II that the parameter for cooperation breadth is significant and positive (β=0.387, $p<0.01$), while the parameter for its squared term is significant, but negative (β=-0.031, $p<0.01$). Since I am testing the effect of being a startup over a variable that draws an inverted-U shape, the hypothesis would be confirmed whether there is a steepening of the curve. To test it, β_5 has to be significant and negative (Haans et al., 2016). In Model III, the coefficient for the interaction between cooperation breadth square and startups is significant and negative (β=-0.083, $p<0.01$), confirming the Hypothesis 3.1. In other words, startups benefit more from cooperation breadth for innovation performance. Figure 4.1 shows how the curve is steeped when the firm is a startup. It can

also be observed that the curve for startups is higher than that for non-startups. The graphic therefore provides support for Hypothesis 3.1.

In Hypothesis 3.2, I raised the question whether startups in high-tech sectors benefit more from cooperation breadth. Again, I am testing the effect of a variable –high-tech startups - over a variable that draws an inverted-U shape –cooperation breadth-, so the hypothesis is confirmed when there is a steepening of the curve, which happens if β_5 is significant and negative (Haans et al., 2016). In Model V the coefficient for the interaction between cooperation breadth square and startups in high-tech sectors is significant and negative (β=-0.088, $p<0.01$), meaning that startups in high-tech sectors benefit more from cooperation breadth than the rest of firms. Hence, I find support for the Hypothesis 3.2. Figure 4.2 graphically explains this effect. The curve for cooperation breadth is steepening in the case of high-tech startups. Note that for low levels of cooperation breadth, high-tech startups perform a lower innovation performance since they need external resources in their innovation processes.

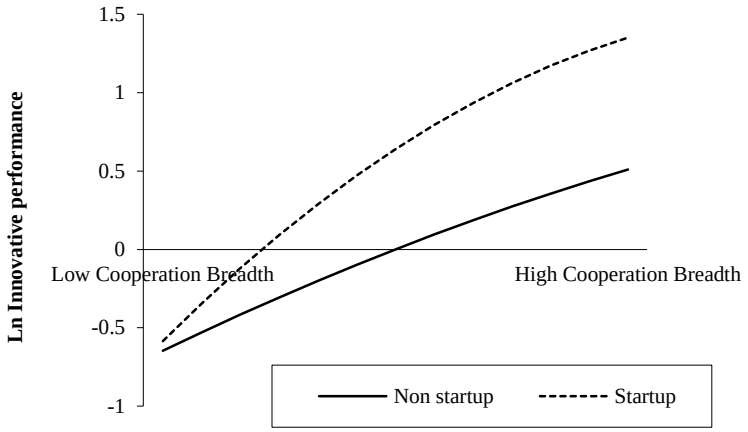
From the control variables, I found evidence in all models of the positive impact of internal R&D expenses for innovation performance. I also found that the formal appropriation strategy is positively related to the innovation performance, so the use of intellectual propriety rights enhances innovation performance. Firms with a greater market scope enjoy a higher innovation performance; and also firms operating in high-tech sectors. Finally, the models suggest that smaller firms have a higher innovation performance for products new to the market than larger firms.

Table 4.4. Tobit regression with random effects.

	Model I	**Model II**	**Model III**	**Model IV**	**Model V**
Internal R&D	0.008***	0.007***	0.007***	0.007***	0.007***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Formal Appr. Strat.	0.479***	0.427***	0.426***	0.428***	0.428***
	[0.017]	[0.017]	[0.017]	[0.017]	[0.017]
Size	-0.070***	-0.103***	-0.102***	-0.106***	-0.106***
	[0.017]	[0.017]	[0.017]	[0.017]	[0.017]
Group	0.151***	0.111**	0.111**	0.113**	0.113**
	[0.046]	[0.045]	[0.045]	[0.045]	[0.045]
Scope	0.279***	0.270***	0.270***	0.267***	0.267***
	[0.019]	[0.019]	[0.019]	[0.019]	[0.019]
High-tech	0.585***	0.519***	0.518***	0.517***	0.517***
	[0.048]	[0.047]	[0.047]	[0.048]	[0.048]
Year Dummies	Yes	Yes	Yes	Yes	Yes
Coop. Breadth		0.387***	0.385***	0.387***	0.386***
		[0.017]	[0.017]	[0.017]	[0.017]
Coop. Breadth^2		-0.031***	-0.030***	-0.031***	-0.031***
		[0.004]	[0.004]	[0.004]	[0.004]
Startup		0.480***	0.639***		
		[0.109]	[0.124]		
Coop. Breadth*startup			0.260**		
			[0.113]		
Coop. Breadth^2*Startup			-0.083***		
			[0.029]		
High-tech Startup				0.254*	0.389**
				[0.141]	[0.162]
Coop. Breadth*High-tech startup					0.313**
					[0.150]
Coop. Breadth^2*High-tech Startup					-0.088**
					[0.040]
Constant	-3.034***	-2.657***	-2.659***	-2.623***	-2.624***
	[0.097]	[0.097]	[0.097]	[0.097]	[0.097]
sigma_u	2.674***	2.598***	2.598***	2.599***	2.599***
Constant	[0.031]	[0.030]	[0.030]	[0.030]	[0.030]
sigma_e	2.282***	2.269***	2.268***	2.269***	2.269***
Constant	[0.011]	[0.011]	[0.011]	[0.011]	[0.011]
Log Likelihood	-9.17E+04	-9.12E+04	-9.12E+04	-9.12E+04	-9.12E+04
No. of Obs	76764	76764	76764	76764	76764
Left censored obs.	47867	47867	47867	47867	47867
Wald-Chi2	2229.43***	3151.254***	3159.732***	3135.568***	3140.677***

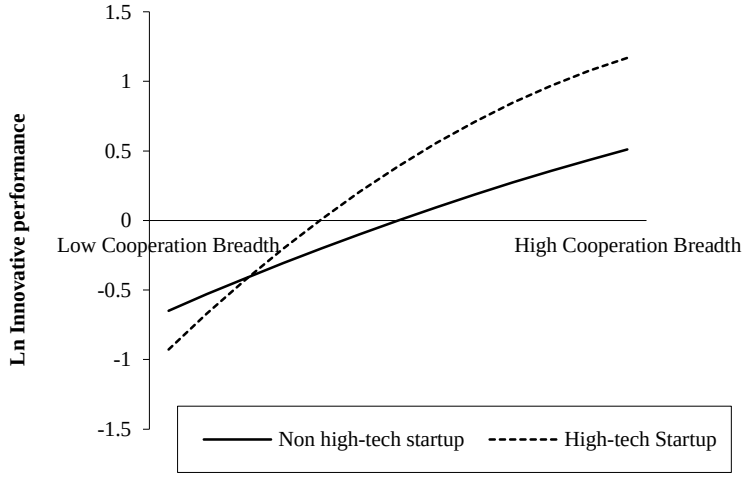
Note: Standard errors in brackets. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Figure 4.1. Effect of being a startup on the relationship between cooperation breadth and innovation performance



Note: Graphic readjusted to the scale.

Figure 4.2. Effect of being a high-tech startup on the relationship between cooperation breadth and innovation performance



Note: Graphic readjusted to the scale.

I ran several further robustness checks (not included by the sake of brevity). First, I confirmed that the Tobit random effect models are robust to alternative estimations. I ran a pooled Tobit regression and I found evidence for both hypotheses if the dependent variable is not transformed into a lognormal variable. The control variables remained

significant, except for the variable group, which had only weak significance in Table 4.4. I also ran random effect OLS regressions, and they revealed same results than presented, but the group variable also turned insignificant (it presents the same sign that in Table 4.4). Finally, I run cross-sectional OLS regressions, and the estimations support the results found in Table 4.4, except, again, for the group variable.

Second, drawing on the entrepreneurship research I have argued the liability of newness and smallness characterizing startups' innovation processes. According to that body of literature, there might be other variables, such as, the difficulties on finding funds, the high costs of the innovation processes, the lack of knowledge about markets and technologies, the degree of turbulence of the market, and the characteristics of firms' human resources that could influence the innovation performance (Veugelers and Schneider, 2017). To link the entrepreneurship theory with the open innovation paradigm, I have added a series of control variables to check the robustness of our findings to those circumstances. In particular, I have introduced the following control variables: the degree of importance of lacking fundings, the degree of importance of lacking external financing, the degree of importance of high innovation costs, the degree of importance of lacking qualified employees, the degree of importance of lacking technological information, the degree of importance of lacking market knowledge, and the degree of importance of uncertain demand for innovative products and service. All these variables are measured in a Likert scale, being 0 if the factor is not important for the firm, and 3 if it is highly important. I have also added a dummy variable to measure if the firm had any training expense or not. Our hypotheses remain significant with the introduction of these variables, and I found that the degree of importance of lacking external financing, the degree of importance of high innovation costs, the degree of importance of lacking qualified employees, the degree of importance of uncertain demand for innovative

products and service, and having training expense are significant, so they influence the innovation performance of the firm.

Third, to check whether startups in all types of knowledge intensity sectors benefit to a greater extent from cooperation breadth, or this effect is only depicted by high-tech startups, I split the sample between high-tech firms and low- and medium-tech firms, and I found that the positive effect of being a startup keeps in both groups. Additionally, I ran a random effects Tobit regression where I included both high-tech and low- and medium-tech startups and their interaction with cooperation breadth. I found that the coefficient for both the interaction term between cooperation breadth square and high-tech startups, and between cooperation breadth square and low- and medium-tech startups is significant and negative, indicating that all startups benefit to a greater extent from cooperation breadth, and therefore supporting the Hypothesis 3.1. However, that coefficient was higher in absolute terms for high-tech startups. To test whether high-tech startups benefit from cooperation breadth to a greater extension than low- and medium-tech startups, I conducted a Wald test. Since it is significant (χ^2=8.96, $p<0.05$), I can conclude that the benefits that get startups when they cooperate are higher in high-tech sectors, confirming the Hypothesis 3.2.

Finally, I measured cooperation breadth as the ratio of the number of partners' types with to a firm cooperates and the maximum possible number of types of cooperation partners, and then squaring the result to show that an increase at a higher level is seen as larger than an increase at lower levels (Leeuw et al. 2014; Oerlemans et al. 2013). I re-estimated all the models, and the new estimates showed similar results than those found in Table 4 (except for the coefficient of high-tech Startup that turned insignificant), so the hypotheses remain consistent.

4.5 Discussion

The aim of this study was to analyse the effect of startups and high-tech startups on the relationship between cooperation breadth and innovation performance. Startups face the liabilities of newness and novelty, and they have not built a resource portfolio yet when they are created (Sirmon et al., 2007), so external sources acquire a crucial role for startups success, being even more important for this type of firms. This result is in line with previous literature on strategic alliances, which evidenced that startups are more likely to cooperate than incumbent firms (Shan et al., 1994). Startups therefore follow a collaborative entrepreneurial strategy (Burgelman and Hitt, 2007), which allow them to overcome their limitations while they explore and exploit business opportunities. The liabilities of smallness and newness are not a limitation for these firms, rather they are a major boost for openness and innovation. In this way, this study extend previous literature since I analyse how startups can benefit from cooperation breadth to a greater extension. Laursen and Salter (2006) analysed the effect of cooperation breadth and depth in firm's innovation performance, and they included startups as control variable, but it was not significant. In a previous study, I analysed the interaction between cooperation and R&D outsourcing breadth, controlling by startups, and it resulted to be significant. In this study I deepen in the understanding of openness in startups and their motivation to use external sources. Startups benefit more from knowledge exploration when engage in a diversity of cooperation activities because they need to access to more knowledge and learn from their partners; and they also benefit more from knowledge exploitation when engage in a diversity of cooperation activities because partners offer commercial channels, perform as a sign of quality, bring complementary assets, and share the risks of the innovation processes.

Secondly, I argued that the lack of R&D resources, the inventive capability, the strength to adapt to environmental changes, and the emergence of new markets would make startups to be prone to adopt open innovation strategies in high-tech sectors, and benefit more from cooperation breadth, and I found support for that hypothesis. Although both high-tech and low- and medium-tech firms benefit from cooperation breadth for their innovation performance, those benefits are higher for startups operating in high-tech sectors. The fact of high-tech startups benefit more from cooperation breadth means that these firms can effectively explore and exploit business opportunities from a diversity of external partners. It is in line with previous research, which identified commercial complementary assets as a driver of the formation of exploitative alliance in high-tech startups (Colombo et al., 2006). Some scholars argued that when other factors, such as firm size, are taken into account, it is not clear openness to be more important in intensive technology sectors (Tether, 2002; Chesbrough and Crowther, 2006). I analysed the fact of being a startup as a contingency, and I found that high-tech startups benefit from cooperation breadth to a greater extent. Hence, this study complements that literature since the smallness factor might cancel the effect of knowledge-intense sectors, but the newness factor does not.

Regarding the control variables, firms that expend a bigger proportion on internal R&D will enjoy a higher innovation performance. Having a good own knowledge-base is helpful to absorb external knowledge (Cohen and Levinthal, 1990). Moreover, firms need to develop mechanisms to capture the value of their innovations (Pisano, 2006; Teece, 1986). The results show that intellectual propriety rights play a key role for capturing the rents from innovation. Smaller firms are more likely to introduce products that are new to the market. It could be due to their flexibility and lower bureaucratic processes (Parida

et al., 2012). Finally, firms with a higher market scope enjoy a better innovation performance.

4.6 Conclusion

In conclusion, this study examines how startups and, in particular, high-tech startups may benefit to a greater extent from cooperation breadth on the innovation performance. Startups are forced to open up their boundaries to overcome the liabilities of newness and smallness, and it far from being a limitation, it is an opportunity for triggering knowledge exploration and knowledge exploitation. Cooperation breadth brings more diverse knowledge inputs to identify opportunities and enhances innovation performance, and provide access to market to exploit opportunities, which enhance the innovation performance.

The contributions of this paper are situated at both theoretical and managerial levels. From a theoretical perspective, I contribute to the open innovation literature since it advances in the integration of open innovation with the entrepreneurship literature. Open innovation scholars have underlined the important role of external actors for the startups' innovation processes and have remarked the need for future studies to focus on startups (Bogers et al., 2016; Brunswicker and Van De Vrande, 2014; Eftekhari and Bogers, 2015). To my best knowledge, no previous studies have analysed whether startups benefit to a greater extent from inbound open innovation strategies. The startups' smallness and newness liabilities, rather than being a limitation, they are an incentive for openness. While previous innovation studies have explained some benefits and disadvantages of breadth, they have not considered its nature. The fact that I find a higher contribution for startups poses that breadth can be used in a different way and it is a tool for innovation.

The liabilities of startups make openness to be a necessity to get financial and human resources, and it is a source for startups' knowledge exploration and exploitation.

On the one hand, breadth brings diverse knowledge and startups are more dynamic than incumbent firms to integrate heterogeneous knowledge. It leads to the conclusion that the flexibility and dynamism are more important to use external knowledge than having an extensive knowledge base as proposed by the absorptive capacity theory (Cohen and Levinthal, 1990). This dynamism of startups to integrate external knowledge is in line with the extension of absorptive capacity developed by the knowledge spillover theory of entrepreneurship, which introduced the concept of entrepreneurial absorptive capacity (Qian and Acs, 2013). The entrepreneurial absorptive capacity is defined as the ability of entrepreneurs to understand new knowledge, recognise its value, and commercialize it (Qian and Acs, 2013), so it not based on the extension of a knowledge base, but in the capacity to utilize external knowledge.

On the other hand, the fact that startups benefit more from cooperation breadth than other firms means that breadth is a mechanism to access to complementary assets. In this way, this study advances on the explanation of how startups use external partners to gain more knowledge exploitation opportunities. Burgelman and Hitt (2007) explained how individually or collaboratively, entrepreneurs can take action to exploit opportunities and create value; and Gans and Stern (2003) theoretically argued the 'markets for ideas' and how startups can commercialise their innovations and the implications for industrial dynamics. This study supports those studies and emphasizes the use of cooperation breadth as a strategy exploit business opportunities. Since incumbent firms already have a pool of complementary assets, the benefits of using cooperation breadth are bigger for startups. In addition, in the way that startups cooperate with a diversity of external

sources, they are exposed to more knowledge spillovers. The spillover theory of entrepreneurship discusses that knowledge stock has a positive effect on the level of entrepreneurship (Acs et al., 2013) and that startups take advantage of knowledge spillovers from the stock of knowledge (Acs and Audretsch, 1988), but its effect depends on how efficiently incumbent firms exploit knowledge flows (Acs et al., 2013). I complement the knowledge spillover theory since I explain how startups use cooperation breadth for exploiting business opportunities.

This study further contributes to understand the contingencies on open innovation strategies and deepens in the relationship between knowledge-intensive industries and openness in startups. I found that startups in high-tech sectors are the one that benefit the most from cooperation breadth. I contribute to literature through exploring the newness as a contingency factor of the effect of openness in high-tech sectors. While previous literature has argued that the effect of the technology intensity sector tend to disappear when smallness factor is taken into consideration, I explain that the technology intensity sector effect does not disappear when newness factor is taken into consideration. Finally, I contribute to empirical literature since I test the hypotheses on a panel dataset, while most of literature has performed cross-sectional studies.

From a managerial perspective, this study highlights the importance of openness for startups. I found that while cooperation breadth is important for firms, their positive effects are increased if the firm is a startup. Open innovation is a key strategy for startups to outperform their competitors and enhance the innovation performance, especially if the startup operates in knowledge-intensive sectors. From a policy perspective, I argue that policy makers should support cooperative programs, making a special emphasis on the

relationships between startups and incumbent firms. It would improve the innovation outcomes of a country.

This study has several limitations that can lead to follow-on studies. First, this study has used a panel database to test the hypotheses. The nature of a panel data implies that I have repeated observations on the same cross section of economic agents over time. As a consequence the big sample of startups is introduced when the panel was created or with the two main enlargements (2004, 2005). The startup phenomenon is therefore observed during the first years of the panel, with few observations at the end. Second, I have used random effect Tobit regressions because I observed that the variable innovation performance was left-censored. Other specifications that regard the nature of the data could also be used, for example, an interquartile regression could be applied, so it considers the distribution of the residuals. Third, it would be desirable to use other sampling frames than Spanish firms to extend the validity of the findings. The positive effects that get startups when cooperating with a diversity of partners could be higher in first-runners and technologically-advanced countries, but it could disappear in those based on the imitation of technologies. Fourth, this study has analysed the role of startups as a contingent factor, but other factors, such as the appropriation strategy, could reinforce the differences to openness between high- and low-tech sectors. Lastly, this study also leaves some interesting issues for future research. The research has focused on the impact of startups on cooperation breadth, but its effect could be dependent on the type of alliance (horizontal, vertical). Future research could analysis whether startups benefit more from cooperate, for example, with universities. Moreover, startups' benefit could be dependent on the geography of the cooperation. An internationalization perspective would help to understand the knowledge networks spread of a firm and its evolution.

References

Acs, Z.J., Audretsch, D.B., 1988. Innovation in Large and Small Firms: An Empirical Analysis. Am. Econ. Rev. 78, 678–690.

Acs, Z.J., Audretsch, D.B., Lehmann, E.E., 2013. The knowledge spillover theory of entrepreneurship. Small Bus. Econ. 41, 757–774. doi:10.1007/s11187-013-9505-9

Alberti, F.G., Pizzurno, E., 2017. Oops, I did it again! Knowledge leaks in open innovation networks with start-ups. Eur. J. Innov. Manag. 20, 50–79. doi:10.1108/EJIM-11-2015-0116

Alkaersig, L., Beukal, K., Reichstein, T., Beukel, K., 2015. Intellectual Property Rights Management: Rookies, Dealers and Strategists. Springer.

Almeida, P., Dokko, G., Rosenkopf, L., 2003. Startup size and the mechanisms of external learning: increasing opportunity and decreasing ability? Res. Policy, Special Issue on Technology Entrepreneurship and Contact Information for corresponding authors 32, 301–315. doi:10.1016/S0048-7333(02)00101-4

Almeida, P., Kogut, B., 1997. The Exploration of Technological Diversity and Geographic Localization in Innovation: Start-Up Firms in the Semiconductor Industry. Small Bus. Econ. 9, 21–31. doi:10.1023/A:1007995512597

Almirall, E., Casadesus-Masanell, R., 2010. Open Versus Closed Innovation: A Model of Discovery and Divergence. Acad. Manage. Rev. 35, 27–47.

Alvarez, S.A., Barney, J.B., 2001. How Entrepreneurial Firms Can Benefit from Alliances with Large Partners. Acad. Manag. Exec. 1993-2005 15, 139–148.

Audretsch, D.B., 1995. Innovation, growth and survival. Int. J. Ind. Organ., The Post-Entry Performance of Firms 13, 441–457. doi:10.1016/0167-7187(95)00499-8

Audretsch, D.B., Houweling, P., Thurik, A.R., 2000. Firm Survival in the Netherlands. Rev. Ind. Organ. 16, 1–11. doi:10.1023/A:1007824501527

Audretsch, D.B., Lehmann, E.E., 2005. Does the Knowledge Spillover Theory of Entrepreneurship hold for regions? Res. Policy, Regionalization of Innovation Policy 34, 1191–1202. doi:10.1016/j.respol.2005.03.012

Barge-Gil, A., 2010. Open, Semi-Open and Closed Innovators: Towards an Explanation of Degree of Openness. Ind. Innov. 17, 577–607. doi:10.1080/13662716.2010.530839

Bayona, C., García-Marco, T., Huerta, E., 2001. Firms' motivations for cooperative R&D: an empirical analysis of Spanish firms. Res. Policy 30, 1289–1307. doi:10.1016/S0048-7333(00)00151-7

Belderbos, R., Carree, M., Lokshin, B., 2004. Cooperative R&D and firm performance. Res. Policy 33, 1477–1492. doi:10.1016/j.respol.2004.07.003

Bengtsson, L., Lakemond, N., Lazzarotti, V., Manzini, R., Pellegrini, L., Tell, F., 2015. Open to a Select Few? Matching Partners and Knowledge Content for Open Innovation Performance. Creat. Innov. Manag. 24, 72–86. doi:10.1111/caim.12098

Berchicci, L., 2013. Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance. Res. Policy 42, 117–127. doi:10.1016/j.respol.2012.04.017

Bhalla, A., Terjesen, S., 2013. Cannot make do without you: Outsourcing by knowledge-intensive new firms in supplier networks. Ind. Mark. Manag., Managing Key Supplier Relationships 42, 166–179. doi:10.1016/j.indmarman.2012.12.005

Blank, S., 2010. What's A Startup? First Principles. Steve Blank.

Bogers, M., Zobel, A.-K., Afuah, A., Almirall, E., Brunswicker, S., Dahlander, L., Frederiksen, L., Gawer, A., Gruber, M., Haefliger, S., Hagedoorn, J., Hilgers, D., Laursen, K., Magnusson, M.G., Majchrzak, A., McCarthy, I.P., Moeslein, K.M., Nambisan, S., Piller, F.T., Radziwon, A., Rossi-Lamastra, C., Sims, J., Wal, A.L.J.T., 2016. The open innovation research landscape: established perspectives and emerging themes across different levels of analysis. Ind. Innov. 0, 1–33. doi:10.1080/13662716.2016.1240068

Brunswicker, S., Van De Vrande, V., 2014. Exploring Open Innovation in Small and Medium-Sized Enterprises, in: New Frontiers in Open Innovation. Oxford University Press, Oxford.

Brunswicker, S., Vanhaverbeke, W., 2015. Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators. J. Small Bus. Manag. 53, 1241–1263. doi:10.1111/jsbm.12120

Burgelman, R.A., Hitt, M.A., 2007. Entrepreneurial actions, innovation, and appropriability. Strateg. Entrep. J. 1, 349–352. doi:10.1002/sej.28

Butler, J.E., Hansen, G.S., 1991. Network evolution, entrepreneurial success, and regional development. Entrep. Reg. Dev. 3, 1–16. doi:10.1080/08985629100000001

Cassiman, B., Veugelers, R., 2006. In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition. Manag. Sci. 52, 68–82. doi:10.1287/mnsc.1050.0470

Cassiman, B., Veugelers, R., 2002. Complementarity in the Innovation Strategy: Internal R&D, External Technology Acquisition and Cooperation (SSRN Scholarly Paper No. ID 308601). Social Science Research Network, Rochester, NY.

Chesbrough, H., 2006. Open Innovation: A new paradigm for understanding industrial innovation, in: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), Open Innovation: Researching a New Paradigm. Oxford University Press, Oxford.

Chesbrough, H., Appleyard, M., 2007. Open Innovation and Strategy. Bus. Adm. Fac. Publ. Present.

Cockburn, I.M., Henderson, R.M., 1998. Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery. J. Ind. Econ. 46, 157–182. doi:10.1111/1467-6451.00067

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: A new perspective on learning and innovation. Adm. Sci. Q. 35, 128–152. doi:10.2307/2393553

Coleman, J.S., 1988. Social Capital in the Creation of Human Capital. Am. J. Sociol. 94, S95–S120. doi:10.1086/228943

Colombelli, A., Krafft, J., Vivarelli, M., 2016. To be born is not enough: the key role of innovative start-ups. Small Bus. Econ. 1–15. doi:10.1007/s11187-016-9716-y

Colombo, M.G., Grilli, L., Piva, E., 2006. In search of complementary assets: The determinants of alliance formation of high-tech start-ups. Res. Policy, Special issue commemorating the 20th Anniversary of David Teece's article, "Profiting from Innovation", in Research Policy 35, 1166–1199. doi:10.1016/j.respol.2006.09.002

Criscuolo, P., Nicolaou, N., Salter, A., 2012. The elixir (or burden) of youth? Exploring differences in innovation between start-ups and established firms. Res. Policy 41, 319–333. doi:10.1016/j.respol.2011.12.001

Dussauge, P., Garrette, B., Mitchell, W., 2000. Learning from Competing Partners: Outcomes and Durations of Scale and Link Alliances in Europe, North America and Asia. Strateg. Manag. J. 21, 99–126.

Dyer, J.H., Singh, H., 1998. The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage. Acad. Manage. Rev. 23, 660–679. doi:10.5465/AMR.1998.1255632

Eftekhari, N., Bogers, M., 2015. Open for Entrepreneurship: How Open Innovation Can Foster New Venture Creation. Creat. Innov. Manag. 24, 574–584. doi:10.1111/caim.12136

Eisenhardt, K.M., Schoonhoven, C.B., 1996. Resource-Based View of Strategic Alliance Formation: Strategic and Social Effects in Entrepreneurial Firms. Organ. Sci. 7, 136–150.

Escribano, A., Fosfuri, A., Tribó, J.A., 2009. Managing external knowledge flows: The moderating role of absorptive capacity. Res. Policy 38, 96–105. doi:10.1016/j.respol.2008.10.022

Etemad, H., Wright, R.W., 1999. Internationalization of SMEs: Management responses to a changing environment. J. Int. Mark. Chic. 7, 4–10.

Faems, D., De Visser, M., Andries, P., Van Looy, B., 2010. Technology Alliance Portfolios and Financial Performance: Value-Enhancing and Cost-Increasing Effects of Open Innovation*. J. Prod. Innov. Manag. 27, 785–796. doi:10.1111/j.1540-5885.2010.00752.x

Faems, D., Van Looy, B., Debackere, K., 2005. Interorganizational Collaboration and Innovation: Toward a Portfolio Approach*. J. Prod. Innov. Manag. 22, 238–250. doi:10.1111/j.0737-6782.2005.00120.x

Gans, J.S., Stern, S., 2003. The product market and the market for “ideas”: commercialization strategies for technology entrepreneurs. Res. Policy, Special Issue on Technology Entrepreneurship and Contact Information for corresponding authors 32, 333–350. doi:10.1016/S0048-7333(02)00103-8

Gassmann, O., 2006. Opening up the innovation process: towards an agenda. RD Manag. 36, 223–228. doi:10.1111/j.1467-9310.2006.00437.x

Gassmann, O., Enkel, E., Chesbrough, H., 2010. The future of open innovation. RD Manag. 40, 213–221. doi:10.1111/j.1467-9310.2010.00605.x

Gimenez-Fernandez, E.M., Sandulli, F.D., 2016. Modes of inbound knowledge flows: are cooperation and outsourcing really complementary? Ind. Innov. 0, 1–22. doi:10.1080/13662716.2016.1266928

Grant, R.M., Baden-Fuller, C., 2004. A Knowledge Accessing Theory of Strategic Alliances. J. Manag. Stud. 41, 61–84. doi:10.1111/j.1467-6486.2004.00421.x

Grimpe, C., Kaiser, U., 2010. Balancing Internal and External Knowledge Acquisition: The Gains and Pains from R&D Outsourcing. J. Manag. Stud. 47, 1483–1509. doi:10.1111/j.1467-6486.2010.00946.x

Gruber, M., Heinemann, F., Brettel, M., Hungeling, S., 2010. Configurations of resources and capabilities and their performance implications: an exploratory study on technology ventures. Strateg. Manag. J. 31, 1337–1356. doi:10.1002/smj.865

Gruber, M., MacMillan, I.C., Thompson, J.D., 2013. Escaping the Prior Knowledge Corridor: What Shapes the Number and Variety of Market Opportunities Identified Before Market Entry of Technology Start-ups? Organ. Sci. 24, 280–300. doi:10.1287/orsc.1110.0721

Gulati, R., Nohria, N., Zaheer, A., 2000. Strategic networks. Strateg. Manag. J. 21, 203–215. doi:10.1002/(SICI)1097-0266(200003)21:3<203::AID-SMJ102>3.0.CO;2-K

Haans, R.F.J., Pieters, C., He, Z.-L., 2016. Thinking about U: Theorizing and testing U- and inverted U-shaped relationships in strategy research. Strateg. Manag. J. 37, 1177–1195. doi:10.1002/smj.2399

Haeussler, C., Patzelt, H., Zahra, S.A., 2012. Strategic alliances and product development in high technology new firms: The moderating effect of technological capabilities. J. Bus. Ventur. 27, 217–233. doi:10.1016/j.jbusvent.2010.10.002

Hayter, C.S., 2013. Conceptualizing knowledge-based entrepreneurship networks: perspectives from the literature. Small Bus. Econ. 41, 899–911. doi:10.1007/s11187-013-9512-x

Hite, J.M., Hesterly, W.S., 2001. The evolution of firm networks: from emergence to early growth of the firm. Strateg. Manag. J. 22, 275–286. doi:10.1002/smj.156

Hoang, H., Antoncic, B., 2003. Network-based research in entrepreneurship: A critical review. J. Bus. Ventur. 18, 165–187. doi:10.1016/S0883-9026(02)00081-2

Huizingh, E.K.R.E., 2010. Open innovation: State of the art and future perspectives. Technovation 31, 2–9. doi:10.1016/j.technovation.2010.10.002

Hyytinen, A., Pajarinen, M., Rouvinen, P., 2015. Does innovativeness reduce startup survival rates? J. Bus. Ventur. doi:10.1016/j.jbusvent.2014.10.001

Katila, R., Ahuja, G., 2002. Something Old, Something New: A Longitudinal Study of Search Behavior and New Product Introduction. Acad. Manage. J. 45, 1183–1194. doi:10.2307/3069433

Katila, R., Shane, S., 2005. When Does Lack of Resources Make New Firms Innovative? Acad. Manage. J. 48, 814–829. doi:10.5465/AMJ.2005.18803924

Larson, A., Starr, J.A., 1993. A network model of organization formation. Entrep. Theory Pract. 17, 5–16.

Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. Strateg. Manag. J. 27, 131–150. doi:10.1002/smj.507

Laursen, K., Salter, A.J., 2014. The paradox of openness: Appropriability, external search and collaboration. Res. Policy, Open Innovation: New Insights and Evidence 43, 867–878. doi:10.1016/j.respol.2013.10.004

Lechner, C., Dowling, M., 2003. Firm networks: external relationships as sources for the growth and competitiveness of entrepreneurial firms. Entrep. Reg. Dev. 15, 1–26. doi:10.1080/08985620210159220

Lee, H., Kelley, D., Lee, J., Lee, S., 2012. SME Survival: The Impact of Internationalization, Technology Resources, and Alliances. J. Small Bus. Manag. 50, 1–19. doi:10.1111/j.1540-627X.2011.00341.x

Leeuw, T., Lokshin, B., Duysters, G., 2014. Returns to alliance portfolio diversity: The relative effects of partner diversity on firm's innovative performance and productivity. J. Bus. Res. 67, 1839–1849. doi:10.1016/j.jbusres.2013.12.005

Leiponen, A., Helfat, C.E., 2010. Innovation objectives, knowledge sources, and the benefits of breadth. Strateg. Manag. J. 31, 224–236. doi:10.1002/smj.807

Levitt, B., March, J.G., 1988. Organizational Learning. Annu. Rev. Sociol. 14, 319–338. doi:10.1146/annurev.so.14.080188.001535

Lin, B.-W., 2003. Technology transfer as technological learning: a source of competitive advantage for firms with limited R&D resources. RD Manag. 33, 327–341. doi:10.1111/1467-9310.00301

Lin, E.S., Hsiao, Y.-C., Lin, H., 2013. Complementarities of R&D strategies on innovation performance: Evidence from Taiwanese manufacturing firms. Technol. Econ. Dev. Econ. 19, S134–S156. doi:10.3846/20294913.2013.876684

Luker, W., Lyons, D., 1997. Employment Shifts in High-Technology Industries, 1988-96. Mon. Labor Rev. 120, 12–25.

March, J.G., 1991. Exploration and Exploitation in Organizational Learning. Organ. Sci. 2, 71–87. doi:10.1287/orsc.2.1.71

Martinez, M.A., Aldrich, H.E., 2011. Networking strategies for entrepreneurs: balancing cohesion and diversity. Int. J. Entrep. Behav. Res. 17, 7–38. doi:10.1108/13552551111107499

Michelino, F., Cammarano, A., Lamberti, E., Caputo, M., 2017. Open innovation for start-ups: A patent-based analysis of bio-pharmaceutical firms at the knowledge domain level. Eur. J. Innov. Manag. 20, 112–134. doi:10.1108/EJIM-10-2015-0103

Nelson, R.R., Winter, S.G., 1982. The Schumpeterian Tradeoff Revisited. Am. Econ. Rev. 72, 114–132.

Neyens, I., Faems, D., Sels, L., 2010. The impact of continuous and discontinuous alliance strategies on startup innovation performance. Int. J. Technol. Manag. 52, 392–410. doi:10.1504/IJTM.2010.035982

Nieto, M.J., Santamaría, L., 2007. The importance of diverse collaborative networks for the novelty of product innovation. Technovation 27, 367–377. doi:10.1016/j.technovation.2006.10.001

OECD, 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd ed. Paris: Organisation for Economic Co-operation and Development.

Oerlemans, L.A.G., Knoben, J., Pretorius, M.W., 2013. Alliance portfolio diversity, radical and incremental innovation: The moderating role of technology management. Technovation 33, 234–246. doi:10.1016/j.technovation.2013.02.004

Pangarkar, N., Wu, J., 2013. Alliance formation, partner diversity, and performance of Singapore startups. Asia Pac. J. Manag. 30, 791–807. doi:10.1007/s10490-012-9305-9

Parida, V., Westerberg, M., Frishammar, J., 2012. Inbound Open Innovation Activities in High-Tech SMEs: The Impact on Innovation Performance. J. Small Bus. Manag. 50, 283–309. doi:10.1111/j.1540-627X.2012.00354.x

Pisano, G., 2006. Profiting from innovation and the intellectual property revolution. Res. Policy, Special issue commemorating the 20th Anniversary of David Teece's article, "Profiting from Innovation", in Research Policy 35, 1122–1130. doi:10.1016/j.respol.2006.09.008

Qian, H., Acs, Z.J., 2013. An absorptive capacity theory of knowledge spillover entrepreneurship. Small Bus. Econ. 40, 185–197. doi:10.1007/s11187-011-9368-x

Rohrbeck, R., 2010. Harnessing a network of experts for competitive advantage: technology scouting in the ICT industry. RD Manag. 40, 169–180. doi:10.1111/j.1467-9310.2010.00601.x

Santamaría, L., Nieto, M.J., Barge-Gil, A., 2009. Beyond formal R&D: Taking advantage of other sources of innovation in low- and medium-technology industries. Res. Policy 38, 507–517. doi:10.1016/j.respol.2008.10.004

Sapienza, H.J., Autio, E., George, G., Zahra, S.A., 2006. A Capabilities Perspective on the Effects of Early Internationalization on Firm Survival and Growth. Acad. Manage. Rev. 31, 914–933. doi:10.5465/AMR.2006.22527465

Schmiedeberg, C., 2008. Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. Res. Policy 37, 1492–1503. doi:10.1016/j.respol.2008.07.008

Schroll, A., Mild, A., 2011. Open innovation modes and the role of internal R&D. Eur. J. Innov. Manag. 14, 475–495. doi:http://0-dx.doi.org.cisne.sim.ucm.es/10.1108/14601061111174925

Schumpeter, J.A., 1934. The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle. Transaction Publishers.

Segers, J.-P., 2015. The interplay between new technology based firms, strategic alliances and open innovation, within a regional systems of innovation context. The case of the biotechnology cluster in Belgium. J. Glob. Entrep. Res. 5, 1–17. doi:10.1186/s40497-015-0034-7

Shan, W., Walker, G., Kogut, B., 1994. Interfirm cooperation and startup innovation in the biotechnology industry. Strateg. Manag. J. 15, 387–394. doi:10.1002/smj.4250150505

Sirmon, D.G., Hitt, M.A., Ireland, R.D., 2007. Managing Firm Resources in Dynamic Environments to Create Value: Looking Inside the Black Box. Acad. Manage. Rev. 32, 273–292. doi:10.5465/AMR.2007.23466005

Spender, J.-C., 1992. Limits to learning from the west: How western management advice may prove limited in Eastern Europe. Int. Exec. 34, 389–413. doi:10.1002/tie.5060340503

Spender, J.-C., Corvello, V., Grimaldi, M., Rippa, P., 2017. Startups and open innovation: a review of the literature. Eur. J. Innov. Manag. 20, 4–30. doi:10.1108/EJIM-12-2015-0131

Spithoven, A., Clarysse, B., Knockaert, M., 2011. Building absorptive capacity to organise inbound open innovation in traditional industries. Technovation 31, 10–21. doi:10.1016/j.technovation.2010.10.003

Spithoven, A., Vanhaverbeke, W., Roijakkers, N., 2013. Open innovation practices in SMEs and large enterprises. Small Bus. Econ. 41, 537–562. doi:10.1007/s11187-012-9453-9

Stinchcombe, A.L., 1965. Organizations and social structure. Handb. Organ. 44, 142–193.

Teece, D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Res. Policy 15, 285–305. doi:10.1016/0048-7333(86)90027-2

Tether, B.S., 2002. Who co-operates for innovation, and why: An empirical analysis. Res. Policy 31, 947–967. doi:10.1016/S0048-7333(01)00172-X

Tobin, J., 1958. Estimation of relationships for limited dependent variables. Econometrica 26, 24–36. doi:10.2307/1907382

Toh, P.K., Kim, T., 2013. Why Put All Your Eggs in One Basket? A Competition-Based View of How Technological Uncertainty Affects a Firm's Technological Specialization. Organ. Sci. 24, 1214–1236. doi:10.1287/orsc.1120.0782

Tunzelmann, N. von, Acha, V., 2006. Innovation In "Low-Tech" Industries. doi:10.1093/oxfordhb/9780199286805.003.0015

Un, C.A., Cuervo-Cazurra, A., Asakawa, K., 2010. R&D Collaborations and Product Innovation. J. Prod. Innov. Manag. 27, 673–689. doi:10.1111/j.1540-5885.2010.00744.x

Usman, M., Vanhaverbeke, W., 2017. How start-ups successfully organize and manage open innovation with large companies. Eur. J. Innov. Manag. 20, 171–186. doi:10.1108/EJIM-07-2016-0066

Van de Vrande, V., 2013. Balancing your technology-sourcing portfolio: How sourcing mode diversity enhances innovative performance. Strateg. Manag. J. 34, 610–621. doi:10.1002/smj.2031

Veugelers, R., Schneider, C., 2017. Which IP strategies do young highly innovative firms choose? Small Bus Econ 1–17. doi:10.1007/s11187-017-9898-y

Wadhwa, A., Kotha, S., 2006. Knowledge Creation Through External Venturing: Evidence from the Telecommunications Equipment Manufacturing Industry. Acad. Manage. J. 49, 819–835. doi:10.5465/AMJ.2006.22083132

Walker, G., Kogut, B., Shan, W., 1997. Social Capital, Structural Holes and the Formation of an Industry Network. Organ. Sci. 8, 109–125. doi:10.1287/orsc.8.2.109

Wang, H., Wuebker, R.J., Han, S., Ensley, M.D., 2012. Strategic alliances by venture capital backed firms: an empirical examination. Small Bus. Econ. 38, 179–196. doi:http://0-dx.doi.org.cisne.sim.ucm.es/10.1007/s11187-009-9247-x

Wang, Y., Roijakkers, N., Vanhaverbeke, W., 2013. Learning-by-Licensing: How Chinese Firms Benefit From Licensing-In Technologies. IEEE Trans. Eng. Manag. 60, 46–58. doi:10.1109/TEM.2012.2205578

Yu, J., Gilbert, B.A., Oviatt, B.M., 2011. Effects of alliances, time, and network cohesion on the initiation of foreign sales by new ventures. Strateg. Manag. J. 32, 424–446. doi:10.1002/smj.884

Zobel, A.-K., 2013. Open Innovation: A dynamic Capabilities Perspective. Maastricht University, Maastricht.

Chapter 5: The paradox of openness in startups

5.1 Introduction

Startups are often viewed as a source of innovation and economic growth (Gruber et al., 2008; Schumpeter, 1934; Shane and Venkataraman, 2000), yet they lack human and financial resources to develop and capture the value of their own innovations (Eisenhardt and Schoonhoven, 1996; Gruber et al., 2013, 2010; Ketchen et al., 2007; Neyens et al., 2010), as well as reputation and legitimacy, which is obtained through experience (Neyens et al. 2010). Two central issues are essential to overcome these constraining factors: cooperate with external sources and ensure appropriation mechanisms in place.

First, strategic alliance literature suggests that cooperation with external partners is important for startups and their innovation activities, for example to acquire resources (Hite and Hesterly, 2001), get access to complementary assets (Colombo et al., 2006; Marx and Hsu, 2015), enhance their strategic position and legitimacy (Eisenhardt and Schoonhoven, 1996), improve their market power (Eisenhardt and Schoonhoven, 1996), and provide functional activities that are peripheral to the core innovation (Gruber et al., 2010) but needed to commercialize innovation that otherwise startups could not manage (Ketchen et al. 2007). Second, attention towards value appropriation is core as well. A strategy that startups can use to capture the value from their innovations is the application of Intellectual Property Rights (IP rights). IPRs, such a patents, constitute a crucial set of assets and resources for startups for the innovation strategy (Vries et al., 2016). Some of the utilities of having IPRs rights are the protection of the innovation (Gans and Stern, 2003; Wang et al., 2015) and barrier to the diffusion of how that value is produced (Burgelman and Hitt, 2007), or the signal of quality towards external partners (Holgersson, 2013).

Entrepreneurship literature provides evidence on how these two factors interact with each other or they independently influence the firm performance (e.g. Dushnitsky and Shaver 2009; Gans and Stern 2003; Hsu and Ziedonis 2013; Katila, Rosenberger, and Eisenhardt 2008; Shan, Walker, and Kogut 1994). However, there are still unanswered questions regarding how startups' innovation performance is determined independently and jointly by their cooperation activities and their appropriation mechanisms. For example, Katila et al. (2008) focused on the tension that firms face between the need for resources from partners and the potentially damaging misappropriation of their own resources, determining the circumstances for tie formation. While they argued that one of those circumstances is having an effective defence mechanism, this study focuses on how startups can increase their innovation performance, arguing that having a formal appropriation strategy when they cooperate with external sources will increase the innovation performance. Gans and Stern (2003) analysed the trade-off between cooperation and competition, basing their arguments on two key aspects of the commercialization environment –IP regimen and existence of complementary assets-. I extend their research focusing on the advantages of open innovation strategies to increase the innovation performance. I argue that cooperating with external sources and having a formal appropriation strategy at the same time, enhance the innovation performance. I explain that innovative startups base their innovation strategy on the search of complementary assets, and I consider the appropriation strategy at the firm level rather than in the industry level, arguing that it helps to both, attracting new partners and assuring the value capture.

Hsu and Ziedonis (2013) explained the efficacy of patents as a strategic solution to information asymmetries. Basing the arguments of this study on the signalling function of IP mechanisms, I extend that paper by arguing that having a formal IP strategy is

complementary with cooperating, and conducting both strategies enhance the innovation performance. Dushnitsky and Shaver (2009) focused on the conditions –IP regimen and industry overlap- under which entrepreneurs choose to obtain resources from a CVC versus an IVC. It implies that the decision of whom to partner with isn't randomly chosen. Hence, I introduce the concept of 'cooperation breadth', understood as the number of different types of partners with whom the firm cooperate, into the entrepreneurship literature as a determinant of the startups' innovation strategy.

Recently, open innovation literature has also referred to the interplay between openness and the appropriation strategy of the firm, coining it as the "openness paradox" (Arora et al., 2016; Huang et al., 2014; Jensen and Webster, 2009; Laursen and Salter, 2014; Miozzo et al., 2016; Stefan and Bengtsson, 2017; Zobel et al., 2016). However, while the intricate of the relationship between openness and appropriability has largely been studied, there is scarce evidence about openness and appropriability in relation with firm performance (Stefan and Bengtsson, 2017). Although Stefan and Bengtsson (2017) try to answer to that research gap, they fail to test the interaction effects between appropriability mechanisms and openness. Moreover, these scholars have mainly focused on large and established firms, with the exception of Zobel et al. (2016) that analysed a sample startups in the solar industry, and they found that patenting increases new entrants' number of open innovation relationships.

To fill these research gaps, and clarify how openness in the value creating process and appropriation strategy as part of the value capturing process interrelate and influence the innovative performance startups, this study analyses the independently and jointly impact of cooperation breadth and the appropriation strategy on startups' innovation performance. While previous entrepreneurship literature has analysed the trade-off between cooperation and misappropriation, basing their arguments on the 'paradox of

disclosure', I go a step further and analyse their impact –independently and jointly- on the innovation performance. Hence, I do not analyse the casual effect between both strategies, rather I analyse their complementarity for the innovation performance. While some authors have considered the IP regimen as a circumstance to determine the cooperation strategy, I consider appropriation strategy and cooperation strategy as endogenous variables at the firm level that determine the innovation outcome of the firm. I also contribute to the entrepreneurship literature by linking it to the innovation strategy perspective, and introducing concepts, such as breadth of cooperation, on the entrepreneurship research.

I test the hypotheses on a representative sample of Spanish startups from the Spanish Technological Innovation Panel (PITEC), collected by the Spanish National Statistics Institute (INE). The results show that startups draw an inverted-U shape in the relationship between cooperation breadth and radical innovation performance, and a positive linear relationship between appropriation strategy and radical innovation performance. I also find a complementarity effect between cooperation and formal appropriation, meaning that both strategies form the innovation strategy of startups and that using both is better than the sum of performing either.

This study contributes to literature in several ways. First, it advances on the integration of open innovation with the entrepreneurship literature. Scholars have underlined the important role of external actors for the innovation process of new firms and have remarked the need for future studies to focus on startups. This study places in this emergent research line and analyses the processes of value creation and value capture in startups. Second, this study contributes to the entrepreneurship literature by sheding light on the importance of formal appropriation mechanisms for startups. Third, I deepen on the *paradox of openness* by examining its effect for startups. Recent literature explains

the trade-off between openness and appropriation, providing arguments and contingences on the relationship between them (Arora et al., 2016; Huang et al., 2014; Jensen and Webster, 2009; Laursen and Salter, 2014; Miozzo et al., 2016; Zobel et al., 2016). I contribute to this recent debate by evidencing a complementary effect between these two strategies for startups innovation performance.

The remainder of this study is structured as follows. In the next section I develop the hypotheses. In the third section I describe the methodology and in the fourth section I present the statistical methods and the results of the analyses. I then discuss the findings. Finally, I conclude with implications and directions for future research.

5.2 Conceptual background and hypotheses

5.2.1 Cooperation breadth in startups

Cooperation is considered an open strategy for complex and tacit knowledge sharing (Teirlinck and Spithoven 2008, 2013), where the transformation of valuable knowledge is jointly made between two firms (Gimenez-Fernandez and Sandulli, 2016). Cooperation agreements can be compared to a collaborative membrane through which skills and capabilities flow between partners (Hamel, 1991). Of particular relevance to cooperation research is the idea of cooperation breadth or diversity of cooperation partners and ties in the innovation process. Laursen and Salter (2014) defined cooperation breadth as the number of different types of sources with which a firm cooperates, including suppliers, customers, universities, competitors, consultants or research centres. Some entrepreneurship scholars have also referred to the breadth of external sources, and they have outlined the importance of using different knowledge sources by startups' owners (Gruber et al. 2013; Pangarkar and Wu 2013). However, entrepreneurship theory has

traditionally studied not the concept of breadth, but the different types of ties –family vs business ties, weak vs strong ties- in which owners of startups are involved (Hite and Hesterly, 2001; Larson and Starr, 1993; Lechner and Dowling, 2003). For example, using a sample of biotech startups, Baum, Calabrese, and Silverman (2000) evidenced that startups involved in multiple types of ties were more innovative than those which only utilized one type of tie. They argued that this was because an 'efficient' alliance configuration provides access to more diverse information and capabilities with minimum costs of redundancy, conflict and complexity.

Research on established firms has studied the linearity of the relationship between openness and innovation performance (Bengtsson et al., 2015; Chesbrough and Appleyard, 2007; Laursen and Salter, 2006; Leeuw et al., 2014; Leiponen and Helfat, 2010; Oerlemans et al., 2013; Zobel, 2013). Extending this stream of literature, I integrate entrepreneurial literature to open innovation, and consider startups features to discuss the linearity of cooperation breadth on startups' innovation performance.

The potential benefits for startups of using different external partners for innovation are multiple. In this way, the different theoretical perspectives that have highlighted the centrality of cooperation strategies for startups (e.g. Colombo et al., 2006; Eisenhardt and Schoonhoven, 1996; Terjesen et al., 2011) are especially pertinent to my approach. Applying the lens of the Resource-Based View (RBV) it is argued that startups can overcome their smallness and newness liabilities (Stinchcombe, 1965) and gain access to the human and economic resources that they lack through cooperation (Eisenhardt and Schoonhoven, 1996; Gruber et al., 2010, 2013; Moghaddam et al., 2016; Neyens et al., 2010). In addition, cooperation strategies allow startups to develop complementary assets (Teece, 1986), which are particularly relevant for the commercialization strategies of new products (Colombo et al., 2006). The diversity of cooperation partners will bring startups

a wide range of resources and complementary assets to enhance the innovation performance. While startups can find in one type of partner the resources needed for basic research, for example, cooperating with universities; the can cooperate with other type of partners, such as suppliers, to find commercial channels. Different cooperators provide not only provide access to distinct skills and knowledge, but also they help startups in their overall external sources portfolio in terms of risk and autonomy. For example, cooperating with an university pose lower threats to a startup than cooperating with a customer; or venture capital places strict controls on startups, so the cooperation partners portfolio is balanced (Pangarkar and Wu, 2013).

Entrepreneurship scholars have argued that partners can be a sign for legitimacy, and startups can leverage their partners reputation to help their performance (Elfring and Hulsink, 2003; Hoang and Antoncic, 2003; Moghaddam et al., 2016) since external partners acts as endorsements by building public confidence about the value of the startup and its products (Stuart, 2000). The more well-known is the startup in different scenarios and parts of the supply chain, the better for its outcome. Entrepreneurship scholars have also discussed that small entrepreneurial firms can boost their opportunity-seeking advantages and exploit their innovations through their partners' channels (Ketchen et al., 2007). In this sense, partners are used as a mechanism for knowledge exploration and knowledge exploitation. Each type of external source have a different knowledge base that combined with the own base of knowledge of the firm, result in a different knowledge recombination (Teece, 1986). Since startups' role is to be a continuous source of innovation by developing an inventive capability that large firms cannot develop or imitate (Alvarez and Barney, 2001), they will enhance their innovation outcome by cooperating with a diversity of partners.

From an organizational learning perspective, it has been argued that organizational learning produces new organizational routines in startups (i.e. Sapienza et al., 2006). Cooperation brings tacit knowledge to the firm, so startups can learn from their partner and become more proficient at managing external relationships (Pangarkar and Wu, 2013). Startups learn from the experience of others (Levitt and March, 1988), and the potential to retrieve different lessons from their partners might increase according to the types of partners. Startups could benefit from cooperating with different external sources since they are flexible and they do not suffer from structural inertia (Criscuolo et al., 2012; Hannan and Freeman, 1984). Structural inertia limits the ability of firms to introduce innovations because it restricts firms' adjustments and avoids the change in firms' way of doing things (Criscuolo et al., 2012; Katila and Shane, 2005). Consequently, startups do not have internal bureaucratic processes nor do they have formal routines developed yet, therefore it reduces the costs associated with changes. In addition, startups might not be afraid of knowledge from outside, not suffering the Not Invented Here (NIH) syndrome (Katz and Allen, 1982) since they have fuzzy borders as they have just been established (Hsieh et al., 2016).

However, having a high degree of cooperation breadth is not always positive for startups. As same as literature has evidenced a decreasing or negative effect of external breadth on established firms' innovation performance (Bengtsson et al., 2015; Laursen and Salter, 2006; Leeuw et al., 2014; Oerlemans et al., 2013), startups also suffer from negative consequences of over-breadth. In particular, the negative effects from a high level of cooperation breadth could come from their lack of experience and lack of market knowledge. First, their lack of experience (Gans and Stern, 2003) could lead to an opportunity identification myopia. Startups could turn down good market opportunities because of not putting the necessary attention on a project or not knowing how to allocate

their scarce resources between all their cooperative projects. It means that startups would not be pursuing the right innovation project, rather developing a diversity of risky project. Moreover, their lack of experience increases the costs of poor implementation, splitting their attention into several partners. Second, the lack of market knowledge creates a situation of asymmetries with their partners (Alvarez and Barney, 2001; Rothaermel and Deeds, 2004). Since trust is built through knowledge-based relationship or deterrence from reputation (Gulati, 1998) and startups lack them, the cooperative agreements are not symmetric. It places startups in vulnerable positions since they over-trust on their partners. The high level of external relationships prevents startups from developing bond ties with their partners. It increases the risks of opportunistic behaviour of their partners (Hamel 1991; Moghaddam et al. 2016; Williamson 1991).

Additionally, technological learning is influenced by a startup's ability to absorb and transform external knowledge into new products. The liability of newness entails that startups do not have an extended own knowledge base, which is a requirement to be able to absorb external knowledge (Cohen and Levinthal, 1990). Former literature has proposed a U-inverted relationship between the diversity of knowledge sources and technological learning in startups due to increasing transaction costs from geographical diversity when knowledge is sourced abroad (Hitt et al., 1997; Zahra et al., 2000) or from the need to deal with knowledge sources which produce heterogeneous knowledge in terms of applicability to the specific context of the new venture (Un and Asakawa, 2015) either of novelty (Belderbos et al., 2004). The lack of internal organizational learning increases the likelihood of poor partner selection and negative returns as the number of alliances increases (Moghaddam et al. 2016). Startups will not therefore be able to learn and absorb the knowledge from a high diversity of partners, which harm the innovation outcome.

All in all, the positive effects of breadth enhances the radical innovation performance, but after a certain point the costs start to dominate the linearly increasing benefits of cooperation breadth. Subtracting these costs from the benefits gives rise to an inverted-U shape relationship between the independent variable and the performance outcome (Haans et al., 2016). Therefore, I propose that:

Hypothesis 4.1: *Cooperation breadth draws an inverted-U shape with startup's radical innovation performance.*

5.2.2 Appropriation strategy in startups

In order to capture rents from innovations, firms need to protect their intellectual assets and deploy suitable appropriation strategies against imitation, as well as avoid intentionally or unintentionally allowing partners to collect all the benefits derived from their innovations (Pisano, 2006; Teece, 1986). There are different mechanisms to capture the rents from startups' intellectual assets: formal and informal methods (Gans and Stern, 2003). Formal methods consist of Intellectual Property Rights (IPRs), these are in comparison to informal methods (e.g. secrecy) easy defensible in legal suits (Hall et al. 2014). Research on the role of the efficiency of the different appropriation mechanisms for startups or small firms is not clear (see e.g. Arundel (2001), who provides arguments for small firms' preference for patents, as well as arguments for the preference for secrecy). Though formal and informal mechanisms can be jointly used (Holgersson, 2013) and usages is highly correlated (Alcacer et al., 2017). Research has tended to focus more on informal appropriation mechanisms for startups, and when focused on formal ones, it has mainly been analyzed the use of patents. To fill this research gap, I am going to analyse the joint on formal appropriation strategy of startups.

There are four main IPR mechanisms utilized as formal methods that together consist of the IPR strategy of a firm: patents, trademark, copyrights and design rights, and they each cover elements of a product. Patents are related to the technology of a product, design rights to the shape and aesthetic features of the product, trademarks are linked to the brand and copyright to for example written text, pictures, music, and film (Alkaersig et al., 2015). Literature on appropriation has explored these different appropriation mechanisms, underlying their different effectiveness (Grandstrand, 1999; Levin et al., 1987; Vries et al., 2016). For example, Vries et al. (2016) outlined that startups can use patents as protection, blocking, reputation, exchange and incentives motives, whereas trademarks are only filed for protection, reputation and exchange, but not for blocking and incentives motives. Though there are some differences between the mechanisms, it does not mean that they have to be used in an isolated way, but different mechanisms can be used at the same time by the startup. In other words, firms use various appropriation strategies in a complementary way. The addition of the different appropriation mechanisms that a firm uses generates the 'appropriability strategy' of the firm (Cohen et al., 2000; Laursen and Salter, 2014).

Literature has outlined a number of ways in which firms benefit from having a formal appropriation strategy. There is thereby a number of generic strategies that firms engage in for appropriating returns from innovation, namely proprietary, defensive, and leveraging strategies (Somaya 2012). First, IP is used as an isolating mechanism to ensure that what a firm wants to be kept away from others is also possible (Lippman and Rumelt 2003) and the value that entrepreneurs can appropriate from their innovation activities (Foss and Foss 2008). Accordingly, inventors, e.g. startups that have invented a new technology, design, film etc. can uphold the business advantage that has been created by their innovative activities (see e.g. Hall and Ziedonis 2001; Mazzoleni and Nelson 1998;

Somaya, Teece, and Wakeman 2011). Criscuelo et. al (2012) argued that the development of appropriation mechanisms to capture the rents from innovations is critical for startups since incumbent firms are usually in control of the complementary assets.

Second, IPRs provide a legal protection against rivals and prevent imitation, giving the company ownership rights, but they are less effective as vehicles for knowledge exchange (Henttonen, Hurmelinna-Laukkanen, and Ritala 2016). As a result, applying for IP gives a position where a firm holding the right to an invention might need access to other IP to enable the commercialization of the invention. A startup can therefore use defensive IP as a bargain with established firms to establish access to markets, e.g. through cross-licensing or through establishing collaborations with other IP owners that have access to complementary assets than the startup lacks.

Third, IPRs are themselves a quality stamp. They are viewed as a codification of a technology that is novel and inventive. Firms can therefore use IP to signal quality of their technology (Gick 2008). This signaling function reduces the informational imperfections and it is especially relevant for startups, which are not well-known in the market yet because of their newness. For example, Hsu and Ziedonis (2013) found that patents confer advantages in strategic factor markets above and beyond their added protection in final markets for goods and services. Additionally, for startups facing liability of newness the signaling quality can be necessary to attract collaboration partners, investors or access to media. Such partners might possess complementary assets, needed for the commercialization of the innovation (Holgersson 2013).

In sum, having high levels of appropriability, understood as the addition of the different formal appropriation mechanisms that the startups uses -breadth of formal mechanisms- will ensure that they play on the different situations and strategies of the startups, and it will allow to enhance their innovation performance. Nevertheless, some authors have

referred to an "over-appropriability problem" (Laursen and Salter 2014), but this is when associated with the possibilities for external collaboration. Patents, in particular, present high legal transaction costs11, whereas other types of IP are cheaper and less complex (design rights and trademarks costs approximately one tenth of that of a patent, and copyrights does most often not incur any registration fees) (Alcacer et al., 2017), and are easy accessible for startups. Since I am considering the whole startups' formal appropriation strategy for the innovation performance, I do not expect that "over-appropriability problem" and I argue a linear relationship between the formal appropriation strategy and the innovation performance. Therefore, the higher the formal appropriation strategy of startups, understood as the addition of the different formal appropriation mechanisms that the startups uses, the more the startup would be able to capture the rents from their innovations, having positive implications for a startups' radical innovation performance.

Hypothesis 4.2: *The formal appropriation strategy is positively related to startup's radical innovation performance.*

5.2.3 The complementarity between cooperation and appropriation in startups

Scholars have considered knowledge management strategies as central elements of the firm's competitive advantage (Dyer and Singh, 1998; Teece and Pisano, 1994). As I have described in the previous sections, startups are dependent on being open towards externals, but at the same time they create formal mechanisms to protect themselves to enable licensing and cooperation, as well as ensuring that they can capture value from their innovations. Cooperation relationships can lead to involuntary outgoing spillovers

[11] A patent family costs approx. 60-600.000USD (Alcacer et al., 2017).

that need to be controlled by the firm (Cassiman and Veugelers, 2002), and this is done by the use of appropriation mechanisms (Burgelman and Hitt, 2007). The interplay between value creation and value appropriation has received some attention in literature, discussing if the value created in collaboration with external partners favours or impedes knowledge appropriation. For example, Lavie (2007) advanced the study of value creation and value appropriation by taking into consideration the resources and competitive positions of collaborative partners, so network resources contribute to value creation regarding the complementarity of those resources, but the relative bargaining power of the partners constrains the firm's appropriation capacity. Jensen and Webster (2009) analysed the interaction between the collaboration with external actors -knowledge creation- and different appropriation mechanisms –knowledge appropriation. Using a sample of Australian firms, they found that engaging in collaboration with external actors improves knowledge creation, but it undermines the use of patents as a knowledge appropriation mechanism since openness requires a certain degree of trust, but appropriation mechanisms generates suspicion and foster conflict, so they suggest appropriation to be counterproductive. Katila et al. (2008) argued that entrepreneurs take the risk of collaboration when they need resources that established firms uniquely provide, and when they have effective defensive mechanisms to protect their own resources. And Gans and Stern (2003) analysed the trade-off between cooperation and competition, basing their arguments on two key aspects of the commercialization environment –IPR regime and existence of complementary assets-.

Recent studies have explored the trade-off between openness and appropriation (Arora et al., 2016; Huang et al., 2014; Laursen and Salter, 2014; Miozzo et al., 2016; Zobel et al., 2016), coining this phenomenon as the *paradox of openness* (Laursen and Salter, 2014). Laursen and Salter (2014) explained that the creation of innovations requires some

openness to get new knowledge, but the commercialization of the innovation requires certain protection to let firms capture the returns from their innovations. Using data from a UK innovation survey, they concluded that there is a concave relationship between firm's breadth of cooperation and the strength of the firm's appropriability strategy, so the appropriability strategy allows more openness to a certain point where higher levels of it are associated with decreasing levels of openness.

Huang et al. (2014), using a sample of Australian firms also found that the relationship between openness and the scope of appropriability regimes exhibit an inverse-U shape. In their study, they categorized the appropriation regimes into formal and informal mechanisms. They argued that the degree of openness would be positively related to formal mechanisms since formal protection instruments could be used with the purposes of knowledge sharing and knowledge brokering, rather than knowledge protection. They explained that the necessary disclosure of knowledge of these formal mechanisms could be understood as a voluntary knowledge spillover to partners. On the contrary, informal mechanisms do not have any disclosure element, so they deliberately limit the knowledge flows between firms. However, they did not find evidence for any of their hypotheses. In a similar way, Miozzo et al. (2016) found a positive association between the importance of innovation collaboration and the importance of formal appropriability mechanisms for a sample of publicly-traded UK and US knowledge-intensive business services firms. Arora et al. (2016) also analysed the paradox of openness, but they only focused on patents as the appropriation mechanism. Using data from the Community Innovation Survey in UK, they proposed that the relationship between openness and appropriation is contingent to whether firms are leaders or followers. They argued that leaders are more likely to benefit from a formal appropriation strategy when they are open because they are more vulnerable to unintended knowledge spillovers, whereas followers have less to

gain from patenting when engaging in collaborative relationships. However, these studies do not consider the complementary effect between openness and appropriation for the innovation performance in the context of startups. Only Zobel et al. (2016) referred to a sample of new entrants in the solar industry and they analysed how the patents stock influences their subsequent openness, considering the contingency of the technology intensity of the relationship.

In this study I propose several reasons for why startups can benefit from having at the same time an open innovation process and a formal appropriation strategy for their radical innovation performance. First, startups are featured as a source of *creative destruction* (Schumpeter, 1934), but they need from the knowledge and resources from external actors (Colombo et al., 2006; Eftekhari and Bogers, 2015). Startups are first-runners in the introduction of new products in the market, and their innovation processes can shape their survival chances (Criscuolo et al., 2012). On this basis, startups are highly vulnerable to unintended knowledge spillovers, so the relationship between openness and appropriability is strong (Arora et al., 2016). Subsequently, for startups to capture the value from their innovations in open innovation process, it is advisable for startups to protect their innovations from knowledge spillovers and to enable collaboration. Hence, a complementary effect when they use both strategies.

Second, having formal appropriation mechanisms diminishes the risk of opportunistic behaviour of partners (Laursen and Salter, 2014; Teece, 2000). The fact of having IP rights enforceable in legal suits performs as a barrier to partners' opportunistic behaviour. It is crucial for startups since they are over-dependent of their partners and it increases the risk of opportunistic behaviour (Granovetter, 1985; Villena et al., 2011). Thus, there would be a complementary effect between openness and appropriation since formal appropriation mechanisms reduces the likelihood of opportunistic behaviours of

cooperative partners, and cooperation is needed for startups due to their limited resources, complementary assets and knowledge base.

Third, formal appropriation mechanisms are not only a mean to protect the inventions, but they can also be used for other purposes. Indeed, some entrepreneurial scholars have emphasized that despite the use of formal mechanisms by innovators, they are sometimes a poor strategy to protect innovations (Holgersson, 2013). IP performs as a signal of quality or innovation capabilities (Miozzo et al., 2016) that can help startups to attract more partners and connect with partners with complementary assets (Colombo et al. 2006; Teece 1986; Wang et al. 2015). On this basis, Colombo et al. (2006) derive an empirical model, considering the patent propensity and argue that the combination of specialized complementary assets is a key driver of the formation of exploitative alliances, and found that as long as startups become larger and possess specialized commercial assets, their need for commercial alliances decreases. This highlights the importance of the formal appropriation mechanisms for startups since patents are a driver for alliances formation, but the importance of this mechanism decreases as the startup develops. In the same sense, Wang et al. (2015) also connected commercial or exploitation alliances to the startups' patent strategy and found that firms with exploitation alliances should maintain a depth and breadth patent portfolio, so patents will affect the impact of these alliances to increase innovation performance. Therefore, it also exemplifies the complementary effect between openness and the formal appropriation strategy.

Figure 5.1 summarizes the idea of a complementary effect between openness and appropriation in a matrix. It categorizes startups according to the degree of openness in open vs closed, and regarding the fact of having or not having a formal appropriation strategy. Firms that are open and have a formal appropriation strategy will experience a

complementary effect for the innovation performance (#4 in Figure 5.1). Startups with an open innovation strategy, but without IP rights are focused on value creation (#3 in Figure 5.1); while startups with a closed innovation strategy and with IP rights are focused on value appropriation (#2 in Figure 5.1). Startups with a closed innovation strategy and without any IP rights (#1 in Figure 5.1) will be outperformed by the rest of categories.

Figure 5.1. Matrix openness and appropriation strategy

		Appropriation strategy	
		No IPR	IPR
Openness strategy	Closed	(1) Losers	(2) Value appropriation
	Open	(3) Value creation	(4) Complementary effect

Source: Own elaborated.

To sum up, I propose that alignment between the open innovation strategy and the formal appropriation strategy is crucial for startups, so using both strategies will generate a complementary effect for the radical innovation performance, meaning that the sum of having a formal appropriation strategy and an open innovation strategy is more than the sum of the two:

Hypothesis 4.3: *The openness innovation strategy and the formal appropriation strategy will have a complementary effect on startup's radical innovation performance.*

5.3 Methodology

5.3.1 Sample

I test the model on a representative sample of innovative Spanish startups from the database Spanish Technological Innovation Panel (PITEC), collected by the Spanish

National Statistics Institute (INE), in collaboration with the Spanish Science and Technology Foundation (FECYT) and the Foundation for Technological Innovation (COTEC). The survey is based in the core Eurostat Community Innovation Survey (CIS), whose method and types of questions are described in Oslo Manual (OECD, 2005). CIS data has previously been used in the context of startups (Criscuolo et al. 2012; Colombelli, Krafft, and Vivarelli 2016). Though in some countries, the Innovation Survey do not consider firms with less than 10 employees, PITEC data do not suffer from this limitation since PITEC includes all size firms, allowing the study of the startup phenomenon. The database has a wide sector coverage including both manufacturing and service sectors, being representative of the population of Spanish firms.

Although PITEC covers an eleven-year period from 2003 to 2013, the present article uses data from 2004 to 2013 because the questionnaire suffered important modifications regarding to external sourcing questions from 2003 to 2004. In the survey firms are asked if they are startups –if the firm is new creation or it was during the two last years-, so I use this question to identify the sample. Accordingly, the focal year is 2004, so I select the sample of startup firms by picking the firms that positively answered to that question in 2004 (startups represents 4.72% of the full living sample). I do not include firms that had more than 1000 employees in 2004. Though arbitrary, the 1000 cut-off warrantee that I take out outliers from the sample. From that sample, information of those firms is gathered along a ten-year period to test the model. Nevertheless, I have used pooled data instead of panel data because maximum likelihood estimations –used for the OLS regressions- might introduce biases (López, 2011), and observations produce change due to mergers, disclosure, etc., that could mislead (Baum and Silverman 2004; Teirlinck, Dumont, and Spithoven 2010). The initial sample consists of 344 startup firms and due

to some missing data and firms that leave the panel (attrition), I account with 2349 observations.

5.3.2 Measures

Dependent variable

Though there are different forms through which firm innovation performance can be assessed, I use product innovation as a proxy to indicate the innovative performance. It includes both technologically new products -'goods and services that differ significantly in their characteristics or intended uses from products previously produced by the firm' (OECD, 2005, p. 48)-, and technologically improved products, -'occur through changes in materials, components and other characteristics that enhance performance' (OECD, 2005, p. 48)-. In particular, I focus on radical innovations –product innovations that were new to the market- since there is strong support in literature for the role of startups in introducing this type of innovation (Almeida and Kogut, 1997). In the questionnaire firms are asked to assert what share of their sales can be ascribed to innovations new to the market. Hence, I measure innovation performance as the proportion relative to turnover of new or highly improved products that the company introduced to the market and that were new to the market.

Independent variables

This study analyses the impact of cooperation breadth and the appropriation strategy on the innovation performance of startups, as well as the complementary effect between openness and the appropriation strategy. First, cooperation breadth refers to agreements

with a diversity of external sources, such as suppliers, customers, competitors, consultants, universities and research centres. Literature has evidenced how different types of external sources impact the innovation performance of startups (Baum et al. 2000; Neyens et al. 2010). Following the methodology of Laursen and Salter (2006, 2014), the variable cooperation breadth is constructed as the addition of seven cooperation partners: suppliers, customers (private and public sector), competitors or other firms from the same activity field, consultants or commercial laboratories, universities or other higher education institutes, public or private research centres, and technological centers. The seven types of cooperation partners are added up so that each startup gets a 0 when no cooperation agreements with any type of partner were taken in the last three years, and the startup gets the value of 7 when it cooperated with all the different types of partners in the last three years. To test the shape of the relationship between cooperation breadth and innovation performance, I include the square term of cooperation breadth.

Second, in this study I only focus on the formal appropriation strategy of startups. Literature on entrepreneurship has recognized its relevance to capture the rents from their innovation activities (Gans and Stern 2003; Wang et al. 2015). The formal appropriation strategy variable consists of the four major intellectual property assets: patents, trademarks, copyright, and design rights. In the survey firms are asked whether they applied or registered any patent, design right, trademark or copyright. I adapt Laursen and Salter (2014)'s measure of appropriation strategy and I build formal appropriation strategy variable by adding the use of the four appropriation mechanisms, so it gets the value of 4 when all the mechanisms were used by the startup, and 0 if it did not use any of them.

Ennen and Richter (2010) explained that complementary exits when the total economic value added by combining two or more factors in a production system exceed the value

that would be generated by applying these production factors in isolation. Also, complementarity effects might not be revealed when researchers check individual interaction effects (Ennen and Richter, 2010). Indeed, I checked for the interation effects between coopeating and having IPRs –not included for the sake of breverty-, and the complementarity between them was not revealed with individual interaction effects. A more appropriate way to test complementarity is therefore be to use a system approach as described in Ennen and Richter (2010) and Milgrom and Roberts (1995). Hence, to test the complementarity between openness and appropriation I create dummy variables referred to openness and having or not IP rights. The matrix consists of four categories: 1) startups with a closed innovation strategy, and without IP rights, 2) startups with a closed innovation strategy, but with IP rights, 3) startups with an open innovation strategy, but without IP rights, and 4) startups with an open innovation strategy and with IP rights. The former category is used as the benchmark.

Control variables

In order to rule out possible alternative explanations to those formally hypothesized, the model includes the following control variables. First, scholars consider internal R&D to be crucial for innovation (Lin et al., 2013; Schmiedeberg, 2008), I include firm's internal R&D efforts measured as the proportion of its internal innovation expenses. Second, following prior literature I control for firm size, it is measured using the logarithm of the total number of employees. Third, I include a dummy variable to control if the firm belongs to a group because firms belonging to a corporate group could bring knowledge from the large corporation influencing their innovation performance (Criscuolo et al. 2012). Fourth, another variable that could influence startups' innovation performance is the scope of the market where the firm sells its products. I control for this, by controlling

for the startups' involvement in different markets: local, national, European, and other international markets (Laursen and Salter, 2014). Fifth, I introduce dummy variables to control for context characteristics. Startups operating in high-tech sectors could have a better innovation performance, so I include a dummy variable to indicate whether the firm operates in a high-tech industry (Luker and Lyons, 1997). I follow the Spanish National Statistics Institute classification to determine the firms that operate in a high-tech sector, which includes firms in the pharmaceutical industry, computing material, electronic components, telecommunications, aeronautic and space industries, research and development services, and computing services. Finally, I also apply dummy variables to control the possible bias of the observation year. The year 2004 is used as benchmark.

5.4 Statistical method and results

Table 5.1 reports the annual descriptive statistics (mean and standard deviation) of the variables used in the analysis. The data reveals interesting points. The startups' radical innovation performance varies over years, not drawing a linear pattern. It remains quite stable during the first three years (around 20%), it then gets the maximum value in 2007 (22.39%), and it drops since 2011, being notably lower in 2013 (15.58%). Along the ten-year period, the cooperation breadth variable increases (from 1.15 to 1.78). However, the formal appropriation strategy variable sharply decreases through the years (from an average of 0.83 to 0.38). This could indicate that the startups have already found trusty and long-term partners, so they do not need to legally protect their intellectual assets. It could also be due to the drop of the innovation performance. Finally, I can observe the movements over the years for the openness-appropriation matrix. While in 2004, 30 per cent of the startups had an open innovation strategy and at least one type of IP right, in 2013, this category decreases to 19 per cent. This drop is due to the decrease in the startups

with a formal appropriation mechanism, not to the firms' cooperation strategy, where I can see more startups that cooperate with external partners (from 45% in 2004 to 54% in 2013).

Table 5.1. Descriptive statistics

Year	Obs.	Innov. Perfor.	Coop. Breadth	Formal App Strat	Open& IPR	Open& NoIPR	Closed&IPR	Closed& NoIPR	Internal R&D	Size	Group	Scope	High-tech
2004	343	20.69	1.15	0.83	0.30	0.15	0.21	0.34	68.55	35.18	0.24	2.07	0.58
		(34.84)	(1.66)	(1.00)	(0.46)	(0.36)	(0.41)	(0.47)	(37.90)	(86.33)	(0.43)	(0.91)	(0.49)
2005	295	20.66	1.25	0.82	0.31	0.20	0.21	0.27	61.98	34.30	0.27	2.35	0.56
		(32.05)	(1.67)	(0.96)	(0.46)	(0.40)	(0.41)	(0.45)	(38.94)	(80.20)	(0.45)	(1.12)	(0.50)
2006	284	20.08	1.40	0.74	0.31	0.21	0.19	0.29	64.91	32.83	0.28	2.32	0.59
		(33.59)	(1.84)	(0.88)	(0.46)	(0.41)	(0.39)	(0.45)	(37.27)	(73.70)	(0.45)	(1.00)	(0.49)
2007	267	22.39	1.46	0.61	0.25	0.25	0.16	0.33	58.50	33.67	0.27	2.42	0.63
		(34.98)	(1.93)	(0.85)	(0.43)	(0.44)	(0.37)	(0.47)	(38.44)	(76.72)	(0.44)	(1.06)	(0.48)
2008	244	20.51	1.44	0.54	0.22	0.29	0.14	0.35	62.13	40.67	0.30	2.53	0.62
		(32.39)	(1.93)	(0.85)	(0.42)	(0.45)	(0.35)	(0.48)	(39.29)	(101.30)	(0.46)	(1.04)	(0.49)
2009	224	21.85	1.65	0.54	0.24	0.29	0.11	0.37	60.58	42.18	0.35	2.56	0.42
		(32.79)	(2.07)	(0.85)	(0.43)	(0.45)	(0.31)	(0.48)	(40.29)	(96.68)	(0.48)	(1.04)	(0.49)
2010	203	22.07	1.65	0.45	0.20	0.33	0.09	0.38	62.62	40.98	0.37	2.69	0.44
		(33.15)	(2.06)	(0.80)	(0.40)	(0.47)	(0.29)	(0.49)	(38.60)	(91.31)	(0.49)	(1.07)	(0.50)
2011	181	19.21	1.75	0.47	0.20	0.35	0.11	0.34	67.13	45.95	0.41	2.69	0.46
		(30.51)	(2.10)	(0.79)	(0.40)	(0.48)	(0.31)	(0.47)	(37.78)	(107.63)	(0.49)	(1.07)	(0.50)
2012	163	17.63	1.60	0.44	0.20	0.32	0.10	0.38	67.61	46.63	0.40	2.77	0.49
		(30.23)	(2.00)	(0.73)	(0.40)	(0.47)	(0.31)	(0.49)	(37.00)	(105.11)	(0.49)	(1.08)	(0.50)
2013	145	15.58	1.78	0.38	0.19	0.34	0.09	0.37	66.58	46.41	0.39	2.81	0.48
		(27.43)	(2.10)	(0.66)	(0.40)	(0.48)	(0.29)	(0.49)	(40.06)	(95.01)	(0.49)	(1.10)	(0.50)

Note: Standards errors in brackets.

Correlation coefficients of the variables used in the estimations are reported in Table 5.2. None of the correlations are sufficiently strong to suggest multicollinearity problems, except for the categories of the matrix which is expected. To avoid bias in the results, I ran separate regressions, one regression to test Hypothesis 4.1 and 4.2 (equation #1), and another regression to test Hypothesis 4.3 (equation #2). In addition, I conducted variance inflation factor (VIF) tests, considering the two different models, and all the VIFs were lower than 10, suggesting that multicollinearity is not a problem in the results.

Table 5.2. Correlation coefficients of major variables used in the model

	Innov. Perfor.	Coop. Breadth	Formal App Strat	Open& IPR	Open& NoIPR	Closed & IPR	Closed & NoIPR	Internal R&D	Size	Group	Scope
Coop.	0.150										
Breadth	*0.000*										
Formal	0.192	0.208									
App Strat.	*0.000*	*0.000*									
Open&IPR	0.190	0.508	0.612								
	0.000	*0.000*	*0.000*								
Open&	-0.003	0.349	-0.419	-0.344							
NoIPR	*0.879*	*0.000*	*0.000*	*0.000*							
Closed&IP R	0.004	-0.325	0.432	-0.247	-0.252						
	0.841	*0.000*	*0.000*	*0.000*	*0.000*						
Closed&	-0.175	-0.544	-0.503	-0.412	-0.421	-0.302					
NoIP	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*					
Internal	0.122	0.214	0.120	0.137	0.110	0.021	-0.244				
R&D	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.306*	*0.000*				
Size	-0.066	0.023	-0.014	0.016	-0.020	-0.041	0.035	-0.021			
	0.001	*0.264*	*0.498*	*0.427*	*0.324*	*0.050*	*0.093*	*0.315*			
Group	-0.051	0.182	0.010	0.096	-0.021	-0.105	0.011	-0.001	0.324		
	0.014	*0.000*	*0.625*	*0.000*	*0.303*	*0.000*	*0.588*	*0.979*	*0.000*		
Scope	0.025	0.069	0.073	0.097	-0.034	0.010	-0.066	0.084	0.125	0.101	
	0.226	*0.001*	*0.000*	*0.000*	*0.104*	*0.630*	*0.001*	*0.000*	*0.000*	*0.000*	
High-tech	0.079	0.213	0.112	0.165	0.078	-0.013	-0.214	0.255	-0.070	-0.065	-0.146
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.517*	*0.000*	*0.000*	*0.001*	*0.002*	*0.000*

Note: p-value in italics.

(#1) $Inn.\ Performance = \beta_0 + \beta_1 Coop.\ Breadth + \beta_2 Coop.\ Breadth\text{^}2 + \beta_3 Formal\ App.\ Strat. + \beta_4 InternalR\&D + \beta_5 Size(log) + \beta_6 Group + \beta_7 Scope + \beta_8 High\text{-}Tech + \beta_9 Years + \varepsilon$

(#2) $Inn.\ Performance = \beta_0 + \beta_1 Open\&IPR + \beta_2 Open\&NoIPR + \beta_3 Closed\&IPR + \beta_4 InternalR\&D + \beta_5 Size(log) + \beta_6 Group + \beta_7 Scope + \beta_8 High\text{-}Tech + \beta_9 Years + \varepsilon$

I employed Ordinary Least Square (OLS) regressions to analyze the data. First, I estimated Model 1, which contains the control variables. Model 2 adds the direct effects of cooperation breadth (and its square term), whereas Model 3 adds formal appropriation strategy (I checked for a curvilinear relationship, but I took out the square term since it was not significant). Model 4 tests for Hypothesis 4.1 and 4.2, so it includes the direct effects of cooperation breadth (and its square term), and formal appropriation strategy. Model 5 includes the variables related to the openness-appropriation matrix to test Hypothesis 4.3. The results of the OLS regressions can be found in Table 5.3.

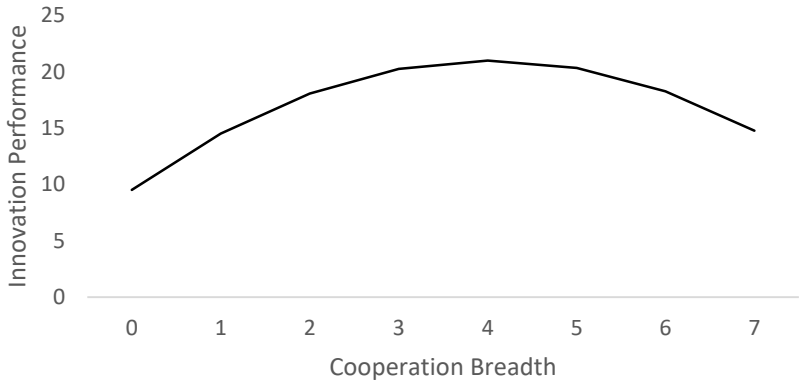
I hypothesized that cooperation breadth draws an inverted-U shape with the radical innovation performance (Hypothesis 4.1) since there are two countervailing forces that when subtracted gives rise to an inverted-U shape (Haans et al. 2016). The estimators of Model 4 support the hypothesis since the parameter for the cooperation breadth variable is significant and positive ($\beta = 5.702$, $p < 0.01$), and the parameter for cooperation breadth squared is significant as well and it is negative ($\beta = -0.707$, $p < 0.01$). The tipping point is placed at 4, which means that the innovation performance starts to decrease if cooperation breadth is higher than 4. In Figure 5.2, I observe this concave relationship. Cooperation breadth positively influence the radical innovation performance, but there is a point -4 different types of partners- where an increase in the number of partners becomes disadvantageous. I also hypothesized that the formal appropriation strategy is positively related to startup's radical innovation performance (Hypothesis 4.2). The results confirm the hypothesis and show that, *ceteris paribus*, for every added formal appropriability mechanism, radical innovation performance increases in 5.933 points ($\beta = 5.933$, $p < 0.01$).

Table 5.3. OLS regression with pooled data

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Internal R&D	0.095***	0.071***	0.082***	0.064***	0.070***
	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]
Size (Ln)	-1.822***	-1.873***	-1.797***	-1.789***	-1.725***
	[0. 577]	[0.574]	[0.569]	[0.568]	[0.567]
Group	-1.054	-2.346	-1.415	-2.328	-2.242
	[1.628]	[1.625]	[1.604]	[1.606]	[1.609]
Scope	1.529**	1.239*	0.877	0.689	0.68
	[0.677]	[0.670]	[0.670]	[0.666]	[0.671]
High tech	3.270**	0.911	2.167	0.357	0.748
	[1.420]	[1.437]	[1.405]	[1.422]	[1.423]
Year dummies	No	No	No	No	No
Coop. Breadth		6.178***		5.702***	
		[1.053]		[1.043]	
Coop. Breadth^2		-0.693***		-0.707***	
		[0.186]		[0.184]	
Formal App. Strat.			6.707***	5.933***	
			[0.776]	[0.784]	
Open&IPR					17.310***
					[1.828]
Open&NoIPR					6.056***
					[1.770]
Closed&IPR					6.709***
					[2.069]
Constant	13.671***	13.448***	10.987***	10.857***	11.167***
	[2. 680]	[2.667]	[2.656]	[2.657]	[2.690]
R-squared	0.028	0.052	0.058	0.075	0.064
Adj.R-squared	0.022	0.046	0.052	0.068	0.057
No of Obs	2349	2349	2349	2349	2349
F test	4.780***	8.014***	9.580***	11.091***	9.419***

Note: Standards errors in brackets.
* p < 0.10; ** p < 0.05; *** p < 0.01

Figure 5.2. Relationship between cooperation breadth and innovation performance



The estimation of Model 5 shows the coefficients for the different categories of the matrix openness-appropriation compared to the category of Closed&NoIPR. The parameters for both categories of startups with an open innovation strategy are positive and significant (Open&IPR: $\beta = 17.310$, $p < 0.01$; Open&NoIPR: $\beta = 6.056$, $p < 0.01$), and the category of closed startups with IPR is also positive and significant (Closed&IPR: $\beta = 6.709$, $p<0.01$). It means that the innovation performance of these startups that have either IPR or an OI strategy, or both of them, is higher than for startups without an OI strategy and an IPR strategy, being these latter firms tagged as 'losers' related to the rest of the firms. I proposed that there is a complementary effect between openness and appropriation for the startup's radical innovation performance (Hypothesis 4.3). The results support the hypothesis since the coefficient for Open&IPR is positive and higher than the coefficients for the rest of categories.

To test that the difference between the coefficients is significant, I additionally ran Wald tests, following the methodology proposed by Milgrom and Roberts (1995), and these tests support the hypothesis since they are significant ($H_{0:}$ Open&IPR = Open&NoIPR, $F(2, 2331) = 45.34$, $p < 0.01$; $H_{0:}$ Open&IPR = Closed&IPR, $F(2, 2331) = 44.95$, $p < 0.01$; $H_{0:}$ Open&NoIPR = Closed&IPR, $F(2, 2331) = 8.07$, $p < 0.01$; $H_{0:}$ Open&IPR = Open&NoIPR + Closed&IPR, $F(1, 2331) = 2.71$, $p < 0.10$). It means that there is a complementary effect between being open and having IPRs since the innovation performance for the startups that use both strategies is higher than for those startups that only focus on value appropriation plus those startups that only focus on value creation. One of the main reasons for this complementary effect is that startups need to cooperate to bring in reosurces into their innovation processes, but they are highly vulnerable. Startups may be superior in knowledge generation in industries characterized by technological opportunities, but larger firms are superior in appropriating from those

innovations (Almeida and Kogut, 1997). Thus, if they only focus on value creation, they are in risk of opportunistic behaviour from their partners because cooperation would entail an openness of the startups' borders, and a flow of knowledge between the firms. On the contrary, if startups only focus on value appropriation, they do not get the resources needed to enhance their innovation processes.

From the control variables, I found internal R&D to be positive and significant in all models. Firm size revealed to be negative and significant in all models, meaning that small firms are more innovative than larger firms.

To test the robustness of the findings, I ran several additional regressions and sensitivity checks (not reported for the sake of brevity). First, in an attempt to control for unobserved heterogeneity (e.g. time-invariant unobserved factors of innovation performance) that are not be possible with a cross-section analysis (Leiponen and Helfat, 2010; Love et al., 2014) I estimated random and fixed effects panel models. I ran two different regressions, the first including cooperation breadth and the formal appropriation strategy variables, and the second including the categories for the matrix. The Breusch-Pagan Lagrange Multiplier (LM) tests indicated that random effects are relevant ($\chi2 = 113.19$, $p < 0.01$; $\chi2 = 91.64$, $p < 0.01$, respectively). Random effects models revealed qualitatively same results as our main estimations. However, when I ran the additional test of complementarity using Milgrom and Roberts (1995) approach as above, I did not observe a significant difference between using both strategies at the same time and the sum of each strategy (despite using both strategies is tested significantly better than using each strategy individually). I conducted F-tests to control for fixed effects, and they were also relevant for the model ($F(7, 1998) = 8.12$, $p < 0.01$; $F(7, 1998) = 6.15$, $p < 0.01$, respectively). I therefore did OLS regressions with fixed effects, the estimations supports Hypothesis 4.1 and 4.2, however, despite using both strategies (Open&IPR) shows higher

coefficients than either of the single strategies, the Milgrom and Roberts (1995) complementarity test fails again. Second, since the dependent variable –radical innovation performance- ranges from 0 to 100, I ran a panel Tobit regression. Again, the coefficients have the same sign as the main models and they are significant. However, the additional test for complementarity fails again to find significant differences between using both strategies at the same time and the sum of each strategy, though it is significant when comparing coefficients of using both strategies with using only one strategy.

Third, not all the firms included in the sample survived to the whole period of analysis. Attrition may generate a bias of survivorship that may distort the estimates (Colombo et al. 2006). Hence, I tried to control for its extent by introducing a dummy variable that measures whether the firm survived to the next year or not. Results remain significant, except for the additional test for complementarity, though I found that that the coefficient for using both strategies is stronger than those referred to using only one strategy. As an alternative way to control for attrition bias, I ran the model with the firms that only survive the full period of analysis. Again, results remain significant and the complementarity test reveals that using both strategies is tested significantly better than using each strategy individually, but there is not a significant difference between using both strategies at the same time and the sum of each strategy. I also compared the initial conditions for control variables between survivors and non-survivors and I did not find any significant difference.

To understand why the significance of the additional complementarity test is low, I conducted a sensitivity test (see Appendix). Though I controlled for some characteristics of startups, I think that they are heterogeneous and that in some scenarios, in which the complementarity between openness and IPRs are more valuable. In particular, I think that startups going into international markets will benefit more from applying both strategies

than startups that have a locally focused strategy since external sources would accelerate the foreign development of the startup and provide knowledge about the foreign market (Presutti et al., 2007) and at the same time, the international diffusion process of SME's (and startups)'s innovations underscores the need for property right protection (Acs and Preston, 1997). Hence, I created a binary variable to measure if the startup expanded to international market that would be 1 if the firm sells goods or services in other countries and 0 otherwise; and I split the sample according to this variable. I ran an OLS estimation with fixed effects to control for the heterogeneity between firms. According to the predictions I observed that the complementary effect is higher for startups operating internationally than what I observed for the full sample ($H_{0:}$ Open&IPR = Open&NoIPR, $F(2, 892) = 12.79$, $p < 0.01$; $H_{0:}$ Open&IPR = Closed&IPR, $F(2, 892) = 15.03$, $p < 0.01$; $H_{0:}$ Open&NoIPR = Closed&IPR, $F(2, 892) = 3.27$, $p < 0.05$; $H_{0:}$ Open&IPR = Open&NoIPR + Closed&IPR, $F(1, 892) = 2.97$, $p < 0.10$), and the hypotheses are therefore supported. I also observe, that for startups that aren't focusing on international markets only hypotheses 1 remains significant.

5.5 Discussion

The aim of this study was to analyse the impact of cooperation breadth and the appropriation strategy on the radical innovation performance of startups, as well as the complementary effect between openness and the appropriation strategy. Startups face the liabilities of smallness and newness (Stinchcombe, 1965), so cooperating with external partners and developing mechanisms to capture the returns from their innovations is essential for them. First, this study evidenced that cooperating with a diversity of partners impacts on the startups' radical innovation performance. I tested for the non-linear relationship between cooperation breadth and radical innovation performance and found

an inverted-U shape relationship, so cooperating with different types of partners is beneficial for startups' innovation performance, but there is a point where there are decreasing returns from cooperation (I find the tipping point to be 4 partners). Though the lack of experience and knowledge market provoke some decreasing returns of startups' innovation performance, the organizational structure of startups boosts the benefits of cooperation since they do not suffer from structural inertia nor from the NIH syndrome. This result is in line with other studies about entrepreneurship, which also argued an inverted-U shape between external sources and different measures of performance (Deeds and Hill 1996; Moghaddam et al. 2016; Pangarkar and Wu 2013). Literature has also evidenced the non-linear behaviour between the breadth of external sources and innovation performance in a general sample of firms (e. g. Gimenez-Fernandez and Sandulli; Laursen and Salter 2006; Leeuw et al. 2014; Oerlemans et al. 2013), but startups' motivation to engage with external partners is different, and the need for external resources and knowledge is bigger for startups due to their initial resources limitations. As a consequence, I can observe that the number of different external sources that startups use is bigger than the number of different types of external sources from a general sample of firms that other studies analyse (Gimenez-Fernandez and Sandulli, 2016; Laursen and Salter, 2014)[12]. Therefore, I find indications for the idea that startups have a bigger propensity to cooperate over time than incumbent firms (Shan et al., 1994).

Second, I found that the formal appropriation strategy draws a linear relationship with startups' radical innovation performance. Startups use patents, trademarks, copyright or design rights to protect their innovations, as well as to connect with partners with complementary assets, to capture rents from their innovations. Though I propose a linear

[12] Gimenez-Fernandez and Sandulli (2016) found that the average for cooperation breadth, considering 7 types of external partner was 0.89; while Laursen and Salter (2014), considering 6 different types of partners, found that the average across industries was 0.84.

relationship in the model, I checked for the non-linear relationship since Laursen and Salter (2014) found a concave relationship between the appropriation strategy and cooperation breadth. I initially introduced the squared term of formal appropriation strategy, but it was not significant and therefore not included. This could be explained because, contrary to Laursen and Salter (2014), I only considered formal appropriation mechanisms. Moreover, they measured the appropriation strategy variable as the addition of the degree of importance of different methods of protection, while I considered the formal instruments as binary variables. Another reason for the linear relationship is that this study analysed the effect of the appropriation strategy on the radical innovation performance, rather than on cooperation breadth. Also, I are testing the model for a startup context where the risks of opportunistic behaviour are high, and appropriation mechanisms help them capture the value from their innovations.

Third, the interplay between openness and appropriation has recently been attracting much scholarly attention (Arora et al. 2016; Huang et al. 2014; Jensen and Webster 2009; Laursen and Salter 2014; Miozzo et al. 2016), but not in the context of startups. One notable exception being Zobel et al. (2016), who study how the patents stock of new entrants in the industry influences their subsequent openness. Extending this stream of literature, I tested for the complementarity between openness and appropriation for startups' radical innovation performance. Startups can benefit on their innovation performance from having at the same time an open innovation process and a formal appropriation strategy because of the high vulnerability of startups when engaging with external partners. Moreover, formal appropriation mechanisms reduces the likelihood of opportunistic behaviours of cooperative partners, and they help startups to attract more partners and connect with partners with complementary assets, thus, resulting in a complementary effect when startups use both strategies. However, this complementary

effect might not be generalizable to all startups, suggesting the study of the heterogeneity between firms.

5.6 Conclusion

This study examined the impact of cooperation breadth, the formal appropriation strategy, and the complementarity between them on the startups' radical innovation performance for a period of ten years. Startups are forced to open up their boundaries to overcome the liabilities of newness and smallness; but they also need to develop appropriation mechanisms to capture the rents from their innovations. Hence, combing an open innovation strategy with a formal appropriation strategy enhances startups' radical innovation performance.

The contributions of this paper are situated at a theoretical, empirical, and managerial level. From a theoretical perspective, this study advances the integration of open innovation with the entrepreneurship literature. Most of open innovation literature has focused on large firms, and some scholars recently are researching on SMEs (Brunswicker and Vanhaverbeke, 2015), remarking the need for future studies to focus on startups (Bogers et al., 2016; Brunswicker and Van De Vrande, 2014; Eftekhari and Bogers, 2015; Laursen and Salter, 2014). This study focused on the role of cooperation breadth as a strategy to create value by cooperating with a diversity of knowledge partners. This idea extents the entrepreneurship literature, which considers that the source of entrepreneurship lies in the differences in information about opportunities (Shane, 2000); and the knowledge spillover perspective, which emphasizes the role of external relationships in knowledge dissemination and economic growth (Cockburn and Henderson, 1998), and considers that knowledge spillovers are a source for opportunity

creation and exploitation by entrepreneurs (Acs et al., 2013; Audretsch and Lehmann, 2005). In the way that startups use of cooperation breadth as a strategy for creating more value, they enhance their radical innovation performance.

Second, this study sheds light on the importance of formal appropriation mechanisms for startups. Research shows that larger firms are more active in using this value capturing instrument, but also small and micro firms do actively seek out such protection (Alkaersig et al., 2015). This relatively lower use of IPRs for startups has led to many scholars to focus on informal mechanisms of appropriation. However, the use of IPRs in startups might have a great potential for capturing the rents from their innovations. I contribute to a better understanding of how startups can capture the value from their innovations, and how the formal appropriation strategy is a mechanism to shift the resource trajectory of startups. On this regard, the entrepreneurship theory discusses that startups lacking successful prior experience in sourcing a prominent venture capital (VC) in the initial financing round and those without the backing of prominent VCs at the time of an IPO can use patents as a signalling quality mechanism (e.g. Baum and Silverman, 2004; Hsu and Ziedonis, 2013), so patents can change the dependence trajectory of startups. I extend this research stream by analysing not only patents, but the impact of formal appropriation strategy, which includes the combination of four mechanisms, on radical innovation performance. Accordingly, I consider several functions of the IPRs (e.g. protection, quality signalling, and access to complementary assets) that help startups to enhance their radical innovation performance. Hence, the formal appropriation strategy performs as a lever of radical innovation performance.

Third, I have deepened on the "paradox of openness" for startups. Recent open innovation literature explains the trade-off between openness and appropriation, providing arguments and contingences on the relationship between them. Usman and

Vanhaverbeke's (2017) cases study revealed that OI can and should go hand in hand with eminent value capturing strategies, as long as it remains a win-win for all the parties involved in the network. I contribute to this recent debate by evidencing a complementary effect between these two strategies for startups innovation performance. From the entrepreneurship theory, Katila et al. (2008) argued that the tie formation is a negotiation that depends on resources needs, defence mechanisms, and alternative partners, I extend that study by arguing the joint benefits of using external sources and IPRs for the radical innovation performance.

From an empirical and practitioner point of view, I explained the relationship between startup's cooperation breadth and radical innovation performance, an inverted U-shape relationship between them. I point out to managers that they should not surpass a certain level of breadth. As Rindova et al. (2012) outline, the development of external relationships is a strategic process that startups can manage proactively, so startups' managers should select the optimal cooperation breadth. Furthermore, while literature have focused on startups as vehicle for creating new innovations (e.g. Katila and Shane 2005; Schumpeter 1934), startups also should possess an appropriation strategy in order to capture such returns. I evidence that the formal appropriation strategy enhances startups' innovation performance. Third, I contribute to empirical literature on the interplay between openness and appropriation strategy by testing its complementarity. I evidenced that the whole of doing both is more than the sum of each of the strategies. When deciding about the innovation strategies, managers should integrate and align both strategies. The openness to external sources should be aligned with the way in which firms protect their innovations (Laursen and Salter, 2014).

Although this study reveals some interesting points, it has several limitations, which not only represent the boundaries of its insights but also provide opportunities for future

research. First, I examined the impact of the appropriation strategy only considering formal appropriation mechanisms. Informal instruments can also be used in a complementary way to enhance the startups' innovation performance. However, as the uses of informal and formal appropriation mechanisms have shown to be highly positively correlated (Alcacer et al., 2017), I do not expect that if including also the informal mechanisms the results would change. Moreover, the different appropriation strategies were measured as binary variables, while other studies have considered their degree of importance. Future studies could create a measure weighting by the degree of importance of the different mechanisms. In data, as already discussed, the average usages of using any of the four formal IP mechanisms is just below half of the population (on average 40% of startups considers any of the four formal IP mechanisms), utilizing an importance measure in which respondents rate each of the formal IP mechanisms would therefore only help explaining the difference in the firms utilizing IP, not the difference between the two types of firms, namely those using IP and not using IP. Similarly, the measure for cooperation breadth did not consider the importance of the different types of alliances. Future studies could create a measure that weights according to the importance of each type of alliance. Second, the sample could suffer from some survivorship bias since the focal year is 2004 and the panel only provides information about startups that were alive during data collection for that year. Given that I sample startups this is a limitation to any startup study. As I conducted robustness tests and these support the findings I am not concerned about this. Third, although the study used longitudinal data, the highly changing nature of startups makes it difficult to draw strong causal inferences. Fourth, despite the main model indicating a complementarity effect between openness and IPR for all startups, suggesting the results to be generalizable across startup characteristics, I investigated the complementarity splitting the sample into two distinct types of startups,

one category in which the startup had an international focus and one category where the startup focuses on local markets only. The complementarity effect only remain significant for firms engaging in international markets. There are two other startup characteristics which could be interesting for the future to investigate: the use of appropriation mechanisms is dependent on industry (Cohen et al., 2000) and country (Alcacer et al., 2017), and I could therefore expect that moderating effects of certain countries or industries are interesting research for the future. Finally, drawing from a longitudinal sample, this research showed that openness and appropriation is fluctuating over time, future research could analyse how the degree of openness changes over time and how startups develop and become established firms, as well as compare startups behaviour to that of already established firms.

References

Acs, Z.J., Audretsch, D.B., Lehmann, E.E., 2013. The knowledge spillover theory of entrepreneurship. Small Bus. Econ. 41, 757–774. doi:10.1007/s11187-013-9505-9

Acs, Z.J., Preston, L., 1997. Small and Medium-Sized Enterprises, Technology, and Globalization: Introduction to a special issue on Small and Medium-Sized Enterprises in the Global Economy. Small Bus. Econ. 9, 1–6. doi:10.1023/A:1007945327618

Alcácer, J., Beukel, K., Cassiman, B., 2017. Capturing Value from Intellectual Property (IP) in a Global Environment, in: Geography, Location, and Strategy, Advances in Strategic Management. Emerald Publishing Limited, pp. 163–228. doi:10.1108/S0742-332220170000036006

Alkaersig, L., Beukal, K., Reichstein, T., Beukel, K., 2015. Intellectual Property Rights Management: Rookies, Dealers and Strategists. Springer.

Almeida, P., Kogut, B., 1997. The Exploration of Technological Diversity and Geographic Localization in Innovation: Start-Up Firms in the Semiconductor Industry. Small Bus. Econ. 9, 21–31. doi:10.1023/A:1007995512597

Alvarez, S.A., Barney, J.B., 2001. How Entrepreneurial Firms Can Benefit from Alliances with Large Partners. Acad. Manag. Exec. 1993-2005 15, 139–148.

Arora, A., Athreye, S., Huang, C., 2016. The paradox of openness revisited: Collaborative innovation and patenting by UK innovators. Res. Policy 45, 1352–1361. doi:10.1016/j.respol.2016.03.019

Arundel, A., 2001. The relative effectiveness of patents and secrecy for appropriation. Res. Policy 30, 611–624. doi:10.1016/S0048-7333(00)00100-1

Audretsch, D.B., Lehmann, E.E., 2005. Does the Knowledge Spillover Theory of Entrepreneurship hold for regions? Res. Policy, Regionalization of Innovation Policy 34, 1191–1202. doi:10.1016/j.respol.2005.03.012

Baum, J. a. C., Calabrese, T., Silverman, B.S., 2000. Don't go it alone : Alliance network composition and startups' performance in canadian biotechnology. Strateg. Manag. J. 21, 267–294.

Baum, J.A.C., Silverman, B.S., 2004. Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. J. Bus. Ventur., Evolutionary approaches to entrepreneurship: Honoring Howard Aldrich 19, 411–436. doi:10.1016/S0883-9026(03)00038-7

Belderbos, R., Carree, M., Lokshin, B., 2004. Cooperative R&D and firm performance. Res. Policy 33, 1477–1492. doi:10.1016/j.respol.2004.07.003

Bengtsson, L., Lakemond, N., Lazzarotti, V., Manzini, R., Pellegrini, L., Tell, F., 2015. Open to a Select Few? Matching Partners and Knowledge Content for Open Innovation Performance. Creat. Innov. Manag. 24, 72–86. doi:10.1111/caim.12098

Bogers, M., Zobel, A.-K., Afuah, A., Almirall, E., Brunswicker, S., Dahlander, L., Frederiksen, L., Gawer, A., Gruber, M., Haefliger, S., Hagedoorn, J., Hilgers, D., Laursen, K., Magnusson, M.G., Majchrzak, A., McCarthy, I.P., Moeslein, K.M., Nambisan, S., Piller, F.T., Radziwon, A., Rossi-Lamastra, C., Sims, J., Wal, A.L.J.T., 2016. The open innovation research landscape: established

perspectives and emerging themes across different levels of analysis. Ind. Innov. 0, 1–33. doi:10.1080/13662716.2016.1240068

Brunswicker, S., Van De Vrande, V., 2014. Exploring Open Innovation in Small and Medium-Sized Enterprises, in: New Frontiers in Open Innovation. Oxford University Press, Oxford.

Brunswicker, S., Vanhaverbeke, W., 2015. Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators. J. Small Bus. Manag. 53, 1241–1263. doi:10.1111/jsbm.12120

Burgelman, R.A., Hitt, M.A., 2007. Entrepreneurial actions, innovation, and appropriability. Strateg. Entrep. J. 1, 349–352. doi:10.1002/sej.28

Cassiman, B., Veugelers, R., 2002. R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium. Am. Econ. Rev. 92, 1169–1184. doi:10.1257/00028280260344704

Chesbrough, H., Appleyard, M., 2007. Open Innovation and Strategy. Bus. Adm. Fac. Publ. Present.

Cockburn, I.M., Henderson, R.M., 1998. Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery. J. Ind. Econ. 46, 157–182. doi:10.1111/1467-6451.00067

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: A new perspective on learning and innovation. Adm. Sci. Q. 35, 128–152. doi:10.2307/2393553

Cohen, W.M., Nelson, R.R., Walsh, J.P., 2000. Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not) (Working Paper No. 7552). National Bureau of Economic Research.

Colombelli, A., Krafft, J., Vivarelli, M., 2016. To be born is not enough: the key role of innovative start-ups. Small Bus. Econ. 1–15. doi:10.1007/s11187-016-9716-y

Colombo, M.G., Grilli, L., Piva, E., 2006. In search of complementary assets: The determinants of alliance formation of high-tech start-ups. Res. Policy, Special issue commemorating the 20th Anniversary of David Teece's article, "Profiting from Innovation", in Research Policy 35, 1166–1199. doi:10.1016/j.respol.2006.09.002

Criscuolo, P., Nicolaou, N., Salter, A., 2012. The elixir (or burden) of youth? Exploring differences in innovation between start-ups and established firms. Res. Policy 41, 319–333. doi:10.1016/j.respol.2011.12.001

Deeds, D.L., Hill, C.W.L., 1996. Strategic alliances and the rate of new product development: An empirical study of entrepreneurial biotechnology firms. J. Bus. Ventur. 11, 41–55. doi:10.1016/0883-9026(95)00087-9

Dushnitsky, G., Shaver, J.M., 2009. Limitations to interorganizational knowledge acquisition: the paradox of corporate venture capital. Strateg. Manag. J. 30, 1045–1064. doi:10.1002/smj.781

Dyer, J.H., Singh, H., 1998. The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage. Acad. Manage. Rev. 23, 660–679. doi:10.5465/AMR.1998.1255632

Eftekhari, N., Bogers, M., 2015. Open for Entrepreneurship: How Open Innovation Can Foster New Venture Creation. Creat. Innov. Manag. 24, 574–584. doi:10.1111/caim.12136

Eisenhardt, K.M., Schoonhoven, C.B., 1996. Resource-Based View of Strategic Alliance Formation: Strategic and Social Effects in Entrepreneurial Firms. Organ. Sci. 7, 136–150.

Elfring, T., Hulsink, W., 2003. Networks in Entrepreneurship: The Case of High-technology Firms. Small Bus. Econ. 21, 409–422. doi:10.1023/A:1026180418357

Ennen, E., Richter, A., 2010. The Whole Is More Than the Sum of Its Parts— Or Is It? A Review of the Empirical Literature on Complementarities in Organizations. J. Manag. 36, 207–233. doi:10.1177/0149206309350083

Foss, K., Foss, N.J., 2008. Understanding opportunity discovery and sustainable advantage: the role of transaction costs and property rights. Strateg. Entrep. J. 2, 191–207. doi:10.1002/sej.49

Gans, J.S., Stern, S., 2003. The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. Res. Policy, Special Issue on Technology Entrepreneurship and Contact Information for corresponding authors 32, 333–350. doi:10.1016/S0048-7333(02)00103-8

Gick, W., 2008. Little Firms and Big Patents: A Model of Small-Firm Patent Signaling. J. Econ. Manag. Strategy 17, 913–935. doi:10.1111/j.1530-9134.2008.00200.x

Gimenez-Fernandez, E.M., Sandulli, F.D., 2016. Modes of inbound knowledge flows: are cooperation and outsourcing really complementary? Ind. Innov. 0, 1–22. doi:10.1080/13662716.2016.1266928

Grandstrand, O., 1999. Patents and Intellectual Property: a general framework. Econ. Manag. Intellect. Prop. Intellect. Capital. 55–106.

Granovetter, M., 1985. Economic Action and Social Structure: The Problem of Embeddedness. Am. J. Sociol. 91, 481–510. doi:10.1086/228311

Gruber, M., Heinemann, F., Brettel, M., Hungeling, S., 2010. Configurations of resources and capabilities and their performance implications: an exploratory study on technology ventures. Strateg. Manag. J. 31, 1337–1356. doi:10.1002/smj.865

Gruber, M., MacMillan, I.C., Thompson, J.D., 2013. Escaping the Prior Knowledge Corridor: What Shapes the Number and Variety of Market Opportunities Identified Before Market Entry of Technology Start-ups? Organ. Sci. 24, 280–300. doi:10.1287/orsc.1110.0721

Gruber, M., MacMillan, I.C., Thompson, J.D., 2008. Look Before You Leap: Market Opportunity Identification in Emerging Technology Firms. Manag. Sci. 54, 1652–1665. doi:10.1287/mnsc.1080.0877

Gulati, R., 1998. Alliances and networks. Strateg. Manag. J. 19, 293–317. doi:10.1002/(SICI)1097-0266(199804)19:4<293::AID-SMJ982>3.0.CO;2-M

Haans, R.F.J., Pieters, C., He, Z.-L., 2016. Thinking about U: Theorizing and testing U- and inverted U-shaped relationships in strategy research. Strateg. Manag. J. 37, 1177–1195. doi:10.1002/smj.2399

Hall, B., Helmers, C., Rogers, M., Sena, V., 2014. The Choice between Formal and Informal Intellectual Property: A Review. J. Econ. Lit. 52, 375–423. doi:10.1257/jel.52.2.375

Hall, B.H., Ziedonis, R.H., 2001. The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995. RAND J. Econ. 32, 101–128. doi:10.2307/2696400

Hamel, G., 1991. Competition for competence and interpartner learning within international strategic alliances. Strateg. Manag. J. 12, 83–103. doi:10.1002/smj.4250120908

Hannan, M.T., Freeman, J., 1984. Structural Inertia and Organizational Change. Am. Sociol. Rev. 49, 149–164. doi:10.2307/2095567

Hite, J.M., Hesterly, W.S., 2001. The evolution of firm networks: from emergence to early growth of the firm. Strateg. Manag. J. 22, 275–286. doi:10.1002/smj.156

Hitt, M.A., Hoskisson, R.E., Kim, H., 1997. International Diversification: Effects on Innovation and Firm Performance in Product-Diversified Firms. Acad. Manage. J. 40, 767–798. doi:10.2307/256948

Hoang, H., Antoncic, B., 2003. Network-based research in entrepreneurship: A critical review. J. Bus. Ventur. 18, 165–187. doi:10.1016/S0883-9026(02)00081-2

Holgersson, M., 2013. Patent management in entrepreneurial SMEs: a literature review and an empirical study of innovation appropriation, patent propensity, and motives. RD Manag. 43, 21–36. doi:10.1111/j.1467-9310.2012.00700.x

Hsieh, C.-T., Huang, H.-C., Lee, W.-L., 2016. Using transaction cost economics to explain open innovation in start-ups. Manag. Decis. 54, 2133–2156. doi:10.1108/MD-01-2016-0012

Hsu, D.H., Ziedonis, R.H., 2013. Resources as dual sources of advantage: Implications for valuing entrepreneurial-firm patents. Strateg. Manag. J. 34, 761–781. doi:10.1002/smj.2037

Huang, F., Rice, J., Galvin, P., Martin, N., 2014. Openness and Appropriation: Empirical Evidence From Australian Businesses. IEEE Trans. Eng. Manag. 61, 488–498. doi:10.1109/TEM.2014.2320995

Jensen, P.H., Webster, E., 2009. Knowledge management: does capture impede creation? Ind. Corp. Change 18, 701–727. doi:10.1093/icc/dtp025

Katila, R., Rosenberger, J.D., Eisenhardt, K.M., 2008. Swimming with Sharks: Technology Ventures, Defense Mechanisms and Corporate Relationships. Adm. Sci. Q. 53, 295–332. doi:10.2189/asqu.53.2.295

Katila, R., Shane, S., 2005. When Does Lack of Resources Make New Firms Innovative? Acad. Manage. J. 48, 814–829. doi:10.5465/AMJ.2005.18803924

Katz, R., Allen, T.J., 1982. Investigating the Not Invented Here (NIH) syndrome: A look at the performance, tenure, and communication patterns of 50 R & D Project Groups. RD Manag. 12, 7–20. doi:10.1111/j.1467-9310.1982.tb00478.x

Ketchen, D.J., Ireland, R.D., Snow, C.C., 2007. Strategic entrepreneurship, collaborative innovation, and wealth creation. Strateg. Entrep. J. 1, 371–385. doi:10.1002/sej.20

Larson, A., Starr, J.A., 1993. A network model of organization formation. Entrep. Theory Pract. 17, 5–16.

Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. Strateg. Manag. J. 27, 131–150. doi:10.1002/smj.507

Laursen, K., Salter, A.J., 2014. The paradox of openness: Appropriability, external search and collaboration. Res. Policy, Open Innovation: New Insights and Evidence 43, 867–878. doi:10.1016/j.respol.2013.10.004

Lavie, D., 2007. Alliance portfolios and firm performance: A study of value creation and appropriation in the U.S. software industry. Strateg. Manag. J. 28, 1187–1212. doi:10.1002/smj.637

Lechner, C., Dowling, M., 2003. Firm networks: external relationships as sources for the growth and competitiveness of entrepreneurial firms. Entrep. Reg. Dev. 15, 1–26. doi:10.1080/08985620210159220

Leeuw, T., Lokshin, B., Duysters, G., 2014. Returns to alliance portfolio diversity: The relative effects of partner diversity on firm's innovative performance and productivity. J. Bus. Res. 67, 1839–1849. doi:10.1016/j.jbusres.2013.12.005

Leiponen, A., Helfat, C.E., 2010. Innovation objectives, knowledge sources, and the benefits of breadth. Strateg. Manag. J. 31, 224–236. doi:10.1002/smj.807

Levin, R.C., Klevorick, A.K., Nelson, R.R., Winter, S.G., Gilbert, R., Griliches, Z., 1987. Appropriating the Returns from Industrial Research and Development. Brook. Pap. Econ. Act. 1987, 783–831. doi:10.2307/2534454

Levitt, B., March, J.G., 1988. Organizational Learning. Annu. Rev. Sociol. 14, 319–338. doi:10.1146/annurev.so.14.080188.001535

Lin, E.S., Hsiao, Y.-C., Lin, H., 2013. Complementarities of R&D strategies on innovation performance: Evidence from Taiwanese manufacturing firms. Technol. Econ. Dev. Econ. 19, S134–S156. doi:10.3846/20294913.2013.876684

Lippman, S.A., Rumelt, R.P., 2003. A bargaining perspective on resource advantage. Strateg. Manag. J. 24, 1069–1086. doi:10.1002/smj.345

López, A., 2011. The effect of microaggregation on regression results: an application to Spanish innovation data. Univ. Libr. Munich Ger.

Love, J.H., Roper, S., Vahter, P., 2014. Learning from openness: The dynamics of breadth in external innovation linkages. Strateg. Manag. J. 35, 1703–1716. doi:10.1002/smj.2170

Luker, W., Lyons, D., 1997. Employment Shifts in High-Technology Industries, 1988-96. Mon. Labor Rev. 120, 12–25.

Marx, M., Hsu, D.H., 2015. Strategic switchbacks: Dynamic commercialization strategies for technology entrepreneurs. Res. Policy 44, 1815–1826. doi:10.1016/j.respol.2015.06.016

Mazzoleni, R., Nelson, R.R., 1998. The benefits and costs of strong patent protection: a contribution to the current debate. Res. Policy 27, 273–284. doi:10.1016/S0048-7333(98)00048-1

Milgrom, P., Roberts, J., 1995. Complementarities and fit strategy, structure, and organizational change in manufacturing. J. Account. Econ., Organizations, Incentives, and Innovation 19, 179–208. doi:10.1016/0165-4101(94)00382-F

Miozzo, M., Desyllas, P., Lee, H., Miles, I., 2016. Innovation collaboration and appropriability by knowledge-intensive business services firms. Res. Policy 45, 1337–1351. doi:10.1016/j.respol.2016.03.018

Moghaddam, K., Bosse, D.A., Provance, M., 2016. Strategic Alliances of Entrepreneurial Firms: Value Enhancing Then Value Destroying. Strateg. Entrep. J. 10, 153–168. doi:10.1002/sej.1221

Neyens, I., Faems, D., Sels, L., 2010. The impact of continuous and discontinuous alliance strategies on startup innovation performance. Int. J. Technol. Manag. 52, 392–410. doi:10.1504/IJTM.2010.035982

OECD, 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd ed. Paris: Organisation for Economic Co-operation and Development.

Oerlemans, L.A.G., Knoben, J., Pretorius, M.W., 2013. Alliance portfolio diversity, radical and incremental innovation: The moderating role of technology management. Technovation 33, 234–246. doi:10.1016/j.technovation.2013.02.004

Pangarkar, N., Wu, J., 2013. Alliance formation, partner diversity, and performance of Singapore startups. Asia Pac. J. Manag. 30, 791–807. doi:10.1007/s10490-012-9305-9

Pisano, G., 2006. Profiting from innovation and the intellectual property revolution. Res. Policy, Special issue commemorating the 20th Anniversary of David Teece's article, "Profiting from Innovation", in Research Policy 35, 1122–1130. doi:10.1016/j.respol.2006.09.008

Presutti, M., Boari, C., Fratocchi, L., 2007. Knowledge acquisition and the foreign development of high-tech start-ups: A social capital approach. Int. Bus. Rev. 16, 23–46. doi:10.1016/j.ibusrev.2006.12.004

Rindova, V.P., Yeow, A., Martins, L.L., Faraj, S., 2012. Partnering portfolios, value-creation logics, and growth trajectories: A comparison of Yahoo and Google (1995 to 2007). Strateg. Entrep. J. 6, 133–151. doi:10.1002/sej.1131

Rothaermel, F.T., Deeds, D.L., 2004. Exploration and exploitation alliances in biotechnology: a system of new product development. Strateg. Manag. J. 25, 201–221. doi:10.1002/smj.376

Sapienza, H.J., Autio, E., George, G., Zahra, S.A., 2006. A Capabilities Perspective on the Effects of Early Internationalization on Firm Survival and Growth. Acad. Manage. Rev. 31, 914–933. doi:10.5465/AMR.2006.22527465

Schmiedeberg, C., 2008. Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. Res. Policy 37, 1492–1503. doi:10.1016/j.respol.2008.07.008

Schumpeter, J.A., 1934. The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle. Transaction Publishers.

Shan, W., Walker, G., Kogut, B., 1994. Interfirm cooperation and startup innovation in the biotechnology industry. Strateg. Manag. J. 15, 387–394. doi:10.1002/smj.4250150505

Shane, S., 2000. Prior Knowledge and the Discovery of Entrepreneurial Opportunities. Organ. Sci. 11, 448–469.

Shane, S., Venkataraman, S., 2000. The Promise of Entrepreneurship as a Field of Research. Acad. Manage. Rev. 25, 217–226. doi:10.5465/AMR.2000.2791611

Somaya, D., 2012. Patent Strategy and Management: An Integrative Review and Research Agenda. J. Manag. 38, 1084–1114. doi:10.1177/0149206312444447

Somaya, D., Teece, D., Wakeman, S., 2011. Innovation in Multi-Invention Contexts: Mapping Solutions to Technological and Intellectual Property Complexity. Calif. Manage. Rev. 53, 47–79. doi:10.1525/cmr.2011.53.4.47

Stefan, I., Bengtsson, L., 2017. Unravelling appropriability mechanisms and openness depth effects on firm performance across stages in the innovation process. Technol. Forecast. Soc. Change Complete, 252–260. doi:10.1016/j.techfore.2017.03.014

Stinchcombe, A.L., 1965. Organizations and social structure. Handb. Organ. 44, 142–193.

Stuart, T.E., 2000. Interorganizational alliances and the performance of firms: a study of growth and innovation rates in a high-technology industry. Strateg. Manag. J. 21, 791–811. doi:10.1002/1097-0266(200008)21:8<791::AID-SMJ121>3.0.CO;2-K

Teece, D., Pisano, G., 1994. The Dynamic Capabilities of Firms: an Introduction. Ind. Corp. Change 3, 537–556. doi:10.1093/icc/3.3.537-a

Teece, D.J., 2000. Managing Intellectual Capital: Organizational, Strategic, and Policy Dimensions. OUP Oxford.

Teece, D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Res. Policy 15, 285–305. doi:10.1016/0048-7333(86)90027-2

Teirlinck, P., Dumont, M., Spithoven, A., 2010. Corporate decision-making in R&D outsourcing and the impact on internal R&D employment intensity. Ind. Corp. Change 19, 1741–1768. doi:10.1093/icc/dtq038

Teirlinck, P., Spithoven, A., 2013. Research collaboration and R&D outsourcing: Different R&D personnel requirements in SMEs. Technovation 33, 142–153. doi:10.1016/j.technovation.2012.11.005

Teirlinck, P., Spithoven, A., 2008. The Spatial Organization of Innovation: Open Innovation, External Knowledge Relations and Urban Structure. Reg. Stud. 42, 689–704. doi:10.1080/00343400701543694

Terjesen, S., Patel, P.C., Covin, J.G., 2011. Alliance diversity, environmental context and the value of manufacturing capabilities among new high technology ventures. J. Oper. Manag., Special Issue Operations management, entrepreneurship, and value creation:Emerging opportunities in a cross-disciplinary context 29, 105–115. doi:10.1016/j.jom.2010.07.004

Un, C.A., Asakawa, K., 2015. Types of R&D Collaborations and Process Innovation: The Benefit of Collaborating Upstream in the Knowledge Chain. J. Prod. Innov. Manag. 32, 138–153. doi:10.1111/jpim.12229

Usman, M., Vanhaverbeke, W., 2017. How start-ups successfully organize and manage open innovation with large companies. Eur. J. Innov. Manag. 20, 171–186. doi:10.1108/EJIM-07-2016-0066

Villena, V.H., Revilla, E., Choi, T.Y., 2011. The dark side of buyer–supplier relationships: A social capital perspective. J. Oper. Manag. 29, 561–576. doi:10.1016/j.jom.2010.09.001

Vries, G.D., Pennings, E., Block, J.H., Fisch, C., 2016. Trademark or patent? The effects of market concentration, customer type and venture capital financing on start-ups' initial IP applications. Ind. Innov. 0, 1–21. doi:10.1080/13662716.2016.1231607

Wang, B., Subramanian, A.M., Chai, K.H., 2015. Patent strategy in exploration and exploitation alliances: The case of biotechnology start-ups, in: 2015 Portland International Conference on Management of Engineering and Technology (PICMET). Presented at the 2015 Portland International Conference on Management of Engineering and Technology (PICMET), pp. 1054–1060. doi:10.1109/PICMET.2015.7273153

West, J., Bogers, M., 2017. Open innovation: current status and research opportunities. Innovation 19, 43–50. doi:10.1080/14479338.2016.1258995

Williamson, O.E., 1991. Comparative Economic Organization: The Analysis of Discrete Structural Alternatives. Adm. Sci. Q. 36, 269. doi:10.2307/2393356

Zahra, S.A., Ireland, R.D., Hitt, M.A., 2000. International Expansion by New Venture Firms: International Diversity, Mode of Market Entry, Technological Learning, and Performance. Acad. Manage. J. 43, 925–950. doi:10.2307/1556420

Zobel, A.-K., 2013. Open Innovation: A dynamic Capabilities Perspective. Maastricht University, Maastricht.

Zobel, A.-K., Balsmeier, B., Chesbrough, H., 2016. Does patenting help or hinder open innovation? Evidence from new entrants in the solar industry. Ind. Corp. Change 25, 307–331. doi:10.1093/icc/dtw005

Appendix

Table A5.1. OLS regression with fixed effects for startups with an internationalization strategy

	Model I	**Model II**	**Model III**	**Model IV**	**Model V**
Internal R&D	0.003	-0.002	-0.001	-0.005	-0.002
	[0.033]	[0.033]	[0.033]	[0.033]	[0.033]
Size (Ln)	1.264	0.945	0.676	0.543	1.13
	[2.344]	[2.315]	[2.340]	[2.314]	[2.312]
Group	-5.868	-7.324*	-5.516	-6.941*	-6.05
	[4.250]	[4.187]	[4.231]	[4.177]	[4.216]
Scope	-4.950***	-4.509**	-4.273**	-3.990**	-4.364**
	[1.840]	[1.811]	[1.844]	[1.817]	[1.821]
Coop. Breadth		8.745***		8.512***	
		[1.769]		[1.766]	
Coop. Breadth^2		-1.052***		-1.057***	
		[0.302]		[0.301]	
Formal App. Strat.			3.931***	3.160**	
			[1.253]	[1.249]	
Open&IPR					15.612***
					[3.102]
Open&NoIPR					7.397**
					[2.981]
Closed&IPR					1.276
					[3.171]
Constant	37.581***	30.488***	34.499***	28.255***	29.634***
	[8.941]	[8.891]	[8.951]	[8.908]	[8.993]
R-squared	0.010	0.046	0.021	0.053	0.043
rho	0.500	0.494	0.490	0.488	0.487
No of Obs	1105	1105	1105	1105	1105
F test	2.35***	7.14***	3.87***	7.07***	5.68***

Note: Standards errors in brackets.
* p < 0.10; ** p < 0.05; *** p < 0.01

Table A5.2. OLS regression with fixed effects for startups without an internationalization strategy

	Model I	**Model II**	**Model III**	**Model IV**	**Model V**
Internal R&D	0.029	0.023	0.026	0.021	0.024
	[0.029]	[0.029]	[0.030]	[0.029]	[0.029]
Size (Ln)	2.045	1.782	1.906	1.697	1.671
	[1.858]	[1.864]	[1.864]	[1.869]	[1.870]
Group	-4.619	-4.539	-4.355	-4.36	-4.301
	[4.055]	[4.035]	[4.065]	[4.045]	[4.059]
Scope	3.034	2.722	3.053	2.741	2.708
	[2.560]	[2.549]	[2.561]	[2.550]	[2.561]
Coop. Breadth		6.069***		5.968***	
		[1.765]		[1.772]	
Coop. Breadth^2		-0.932***		-0.920***	
		[0.320]		[0.321]	
Formal App. Strat.			1.356	0.930	
			[1.407]	[1.407]	
Open&IPR					5.361
					[3.258]
Open&NoIPR					6.582**
					[2.814]
Closed&IPR					1.008
					[3.264]
Constant	8.283	6.518	7.928	6.305	6.861
	[5.927]	[5.919]	[5.938]	[5.929]	[5.952]
R-squared	0.006	0.018	0.007	0.018	0.012
rho	0.469	0.461	0.464	0.458	0.461
No of Obs	1244	1244	1244	1244	1244
F test	1.43	2.95***	1.33	2.59**	1.69

Note: Standards errors in brackets.
* p < 0.10; ** p < 0.05; *** p < 0.01

Chapter 6: Discussion and Conclusion

6.1 Introduction

The goal of this dissertation was to understand the OI phenomenon in the context of startups. In particular, I investigated how startups create and capture value from a diversity of external sources, and to which extent startups can benefit to a greater extent from cooperation breadth. Over the last years, firms' business model for innovation is changing. Most of the firms are opening their innovation models to respond to some erosion factors, such as increased labor mobility, knowledge diffusion, the access of startups to venture capital, and the rise of the Internet (Chesbrough and Bogers, 2014; Chesbrough, 2003). Although the use of external sources is not a new phenomenon (Chesbrough, 2006; Dahlander and Gann, 2010; Spithoven et al., 2013), the definition of a business model by the purposively combination and integration of external knowledge with internal knowledge is the base of open innovation. Given this transformation, the fundamental assumption of this dissertation is that firms that seek for a competitive advantage are increasingly open their boundaries.

This dissertation was motivated by a literature review where I found that startups and incumbent firms both play important roles in generating innovations and economic growth, but they contribute to the innovation ecosystem and economic development in different ways. For example, startups are better suited to develop radical innovations (Schumpeter, 1934), and they contribute to markets where diversity in approaches to innovation is high, while incumbent firms operate in markets where innovation routines are standardised (Katila and Shane, 2005). Moreover, it is argued that startups have more innovative capabilities to introduce innovations in service sectors due to the intangibility of services and the low capital intensity relative to manufacturing, whereas incumbent firms are more likely to introduce innovations in manufacturing (Criscuolo et al., 2012).

Given these differences, the theoretical argumentations used to explain the innovation processes of incumbent firms cannot be directly applied to startups. Startups are different from other firms because they suffer from the liabilities of smallness and newness (Stinchcombe, 1965), so they suffer a structural lack of resources (Wymer and Regan, 2005). However, they have an innate innovation potential (Michelino et al., 2017). While prior open innovation literature has developed a wide understanding of how firms engage in external relationships to enhance their innovation performance, it has, so far, been less clear how startups create and capture value from external sources and to which extent startups benefit from an open innovation strategy.

As theoretical foundations of this dissertation, I linked OI to the entrepreneurship theory, backing my argumentations in the RBV -with especial attention to IPRs-, KBV as knowledge becomes a crucial resource for innovation, and the DC perspective as an extension of the RBV. The application of the OI paradigm has proved to be a useful framework to explain the startups role in the innovation ecosystem and to understand how they use external knowledge to enhance their innovation performance. Nevertheless, the consideration of the particular features of startups is needed when applying different theory frameworks, otherwise it would fail to explain the startup phenomenon. In this context, this dissertation investigated how startups use a diversity of knowledge sources to create value, and how they appropriate the value from their innovations, so they enhance their innovation performance. Against this background, the aim of this dissertation was to shed light on the following overarching research question:

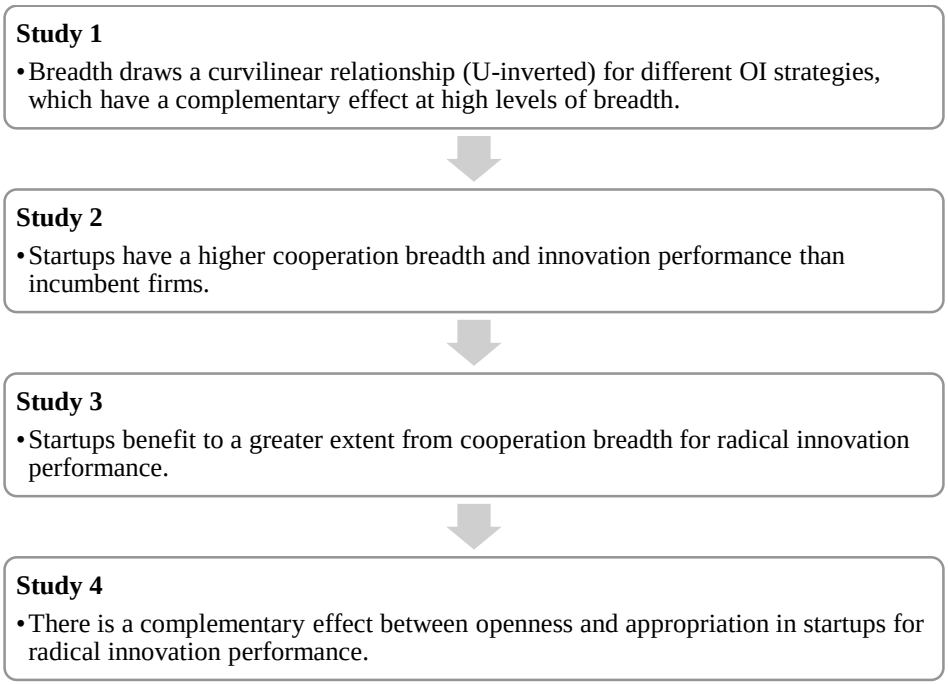
Will the diversity of external sources of knowledge contribute to the innovation performance of start-ups?

At the outset if this dissertation, the breadth of cooperation was identified as a key strategy for innovation. Cooperation breadth was defined as the number of different types of sources with which the firm cooperates (Laursen and Salter, 2014). To shed light on how cooperation breadth contributes to startups' innovation performance, I firstly deepened on the concept of breadth, applying it to different inbound OI strategies, and I analysed the complementarity between cooperation breadth and R&D outsourcing breadth for the innovation performance, controlling by startups, I discovered the importance of breadth, and that startups are positively related to innovation performance. It suggested the idea for the second study where I compared startups to incumbent firms. The significant differences between startups and incumbent firms in cooperation breadth and radical innovation performance resulted in the convenience to test the impact of being a startup on the relationship between cooperation breadth and radical innovation performance. Thus, in the third study I analysed whether startups benefit more from cooperation breadth. Finally, I focused on a sample of startups and I argued how openness and appropriation both independently and jointly influence startups' radical innovation performance. Hence, this dissertation went from the general concept of breadth to its application to startups. Figure 6.1 summarizes the flow of this dissertation. The four studies of this dissertation aimed at developing a better understanding of the differences between startups and incumbent firms, and how startups contribute to the innovation ecosystem. Each of the four empirical studies in this dissertation provides unique insights into the overarching research question by addressing various facets on the analysis of OI in the startup context.

In the following, the main findings of these studies are summarized. Subsequently, the overall theoretical and empirical contributions are discussed. Then, some practical

implications and policy recommendations are laid out. Finally, I will highlight some limitations of this work, which also provide directions for future research.

Figure 6.1. Dissertation flow



Source: Own elaborated.

6.2 Summary of main findings

In the following I will present the main findings of the studies of this dissertation. A summary of the hypotheses proposed and their support can be found in Table 6.1.

Table 6.1. Summary of the hypotheses and findings

Study	Hypothesis	Support
1	H1.1: There is an inverted U-shaped relationship between R&D outsourcing breadth and innovation performance.	Yes
	H1.2: The relationship between R&D outsourcing breadth and innovation performance is positively moderated by cooperation breadth.	Partial
2	H2.1: Startups have a higher cooperation breadth than incumbent firms.	Yes
	H2.2: Startups have a higher radical innovation performance than incumbent firms.	Yes
	H2.3: Startups have a higher incremental innovation performance than incumbent firms.	Partial
3	H3.1: Startups will benefit to a greater extent from cooperation breadth for their radical innovation performance.	Yes
	H3.2: Startups operating in high-tech sectors will benefit to a greater extent from cooperation breadth for their radical innovation performance.	Yes
4	H4.1: Cooperation breadth draws an inverted-U shape with startup's radical innovation performance.	Yes
	H4.2: The formal appropriation strategy is positively related to startup's radical innovation performance.	Yes
	H4.3: The openness innovation strategy and the formal appropriation strategy will have a complementary effect on startup's radical innovation performance.	Partial

Study 1 –Modes of inbound knowledge breadth. Are cooperation and R&D outsourcing really complementary?

Study one examined the relationship between breadths of two different modes of external knowledge: R&D outsourcing and cooperation. They are two different strategies to integrate external technology, but they are utilized in a different way as R&D outsourcing is usually performed to reduce costs, reinforce specialization, and achieve economies of scale, while cooperation is motivated by strategic rather than cost considerations. The study of the interaction of these two inbound OI strategies is relevant since firms may create mutual relational capital that generates synergies and economies of scale and scope.

Study one therefore investigated the moderator effect of cooperation breadth on R&D outsourcing breadth, as well as the direct effect of R&D outsourcing breadth on innovation performance, controlling, between other variables, by being a startup firm. Basing my arguments on costs, asset specificity, type of knowledge and learning considerations, I developed a framework around the concept of breadth to understand how the idea can be applied to different inbound innovation activities, and how firms could apply the capabilities acquired to govern one type of inbound innovation strategy into another strategy.

The results showed that there is an inverted U-shaped relationship between R&D outsourcing breadth and the innovation performance of a firm. It means that R&D outsourcing is beneficial for firms since it avoids risks about uncertain R&D, decreases internal research costs and accelerates the innovation process, but investing too much in external technology acquisition could create an external dependence. That external dependence would prevent firms from developing their own internal R&D and absorbing external knowledge. Hence, the diversity of sources on R&D outsourcing is positive up

to a point where the increase in the number of sources of R&D outsourcing decreases the innovation performance.

This study acknowledged that firms frequently use multiple innovation strategies at the same time, so it is valuable to cover different strategies in a same study, and analyse their differences and similarities. Hence, this study focused on the combination of the breadth of two main inbound innovation strategies used by Spanish firms: cooperation and R&D outsourcing. I found that cooperation moderates positively that relationship, but not in all situations. It was only true for medium to high levels of R&D outsourcing breadth. When firms develop the capacities to simultaneously manage different OI strategies, they are able to benefit from the breadth of both strategies. A synergetic effect is created thanks to two common mechanisms: absorptive capacity and relational capital. On the contrary, there are negative effects between cooperation and low and medium levels of R&D outsourcing breadth. It could be due to the substitutive effect between OI strategies as consequence of dynamic in which the lower transactions costs of R&D outsourcing breadth make it a viable option that outweighs the benefits of diverse tacit knowledge, but with higher costs, from cooperation.

Finally, this study introduced the startup phenomenon as a control variable. The significant and positive effect found in this study suggests that startups might be more innovative than other firms, and there is a room for more research.

This study offers another perspective with regard to the traditional ‘buy’, ‘make’ or ‘ally’ trade-off. While previous research has addressed their single impact on innovation performance (e.g. Laursen and Salter, 2006; Leiponen and Helfat, 2010), I compared and combined both R&D strategies—cooperation breadth and R&D outsourcing breadth—in

a same model. Measuring R&D outsourcing in terms of breadth allowed to look for the synergies in the use of different OI strategies.

Study 2 – Open innovation and the comparison between startups and incumbent firms in Spain

In study two I proceeded to compare the open innovation strategy between startups and incumbent firms. I acknowledged that startups and incumbent firms play different roles the innovation ecosystem since they are differently featured. As a consequence, they contribute from their specific positions to the economic development and innovation generation in different ways. To address this issue and see the differences in the innovation strategy between startups and incumbent firms, I compared and contrasted two longitudinal samples of startups and incumbent Spanish firms.

The results concluded that startups and incumbent firms differ in terms of cooperation breadth, radical innovation performance and incremental innovation performance. First, I found that cooperation breadth in startups is higher than in incumbent firms. It means that the number of different types of external sources is higher for startups than for incumbent firms. It might be due to the lack of all types of resources –financial, human, and reputational- that startups suffer, so they need a wider degree of openness than incumbent firms. Startups cooperate with external agents to overcome their liabilities of smallness and newness, seeking to enhance their innovation performance.

Second, regarding radical innovation performance, I found that it is higher for startups than for incumbent firms during all the years analysed. Startups do not suffer from internal restrictions that block the innovative capacity, and they are willing to be involved in risky

innovation processes with uncertain outcomes. As a result, they boost their competitive advantage, pursuing for radical innovations that threaten the position of incumbent firms. Before routinizing their innovation processes and lose their flexibility, startups bet on revolutionary innovations, which imply a risk that they are willing to face.

Finally, I found that on average incremental innovation performance is higher for startups than for incumbent firms. Since startups enjoy the benefit of newness, so they do not have previous own products in the market, they do not cannibalize their existing products, as could happen for incumbent firms, for which introducing an enhanced verion of a previous product would mean to lose sales from the former version. Thus, startups may be encouraged to introduce incremental innovations. However, I found that the difference between startups and incumbent firms disappears approx. 5 years after a startup was established. Given the nature of the startups, they are expected to focus their energy on introducing radical innovations to the market, leaving little or no resources to pursue incremental innovation. Moreover, after five years of running a business, startups are expected to have already launched a product in the market, so pursuing incremental innovations would cannibalize their relatively new products.

This study contributes the limited research that has studied the OI phenomenon in the context of startups. In particular it advances on the understanding of the innovation ecosystem, and how startups and incumbent firms contribute to the economic prospects from their specific positions. I extracted how firms are similar or different in their approaches to OI, and accordingly how they should adapt their innovation strategies, which generates important implications for managers.

Study 3 – Do startups benefit more from opening to external sources? An analysis of the role of startups for radical innovation performance

In study three I investigated whether startups benefit to a greater extent from cooperation breadth for the radical innovation performance. This study is a complement from the previous study, where I found that startups have a higher cooperation breadth, so it suggested that its contribution could be higher in startups, and it was needed to analyse. Focusing on the particularities of startups to manage external knowledge, I performed a longitudinal Tobit analysis, and the findings demonstrated that the liabilities of smallness and newness that startups suffer are not a limitation for these firms, rather they are a major boost for openness and innovation.

Although engaging in relationships with external sources is key for all types of firms, this study evidenced that startups benefit to a greater extension from cooperation breadth than incumbent firms. In this study, I deepened in the understanding of cooperation in startups and their motivations to use external sources, and I found that the impact of cooperation breadth on innovation performance is higher in startups than in other type of firms. In particular, I argued the steepening of the curve for the relationship between cooperation breadth and innovation performance was due to startups' need to access to more knowledge and learn from their partners in their exploration activities, and to access to partners' complementary assets and commercial channels, to get legitimacy, and to share the risks of the innovation processes. The initial liabilities of startups make that startups can tap external resources into their innovation processes, so they can get more benefits from a diversity of external sources than incumbent firms. On the contrary, the needs of resources of incumbent firms are more focused and specialised, not needing to broaden the diversity of partners to the same extent than startups.

The study further revealed that the diversity of external knowledge is more important for startups in high-tech sectors since, accordingly to the KBV, knowledge becomes a strategic asset in this type of industries. Moreover, the urgent need of R&D resources for high-tech startups, the search for new business opportunities linked to their inventive capability, the support to continuously adapting to environmental changes, and the emergence of new markets make high-tech startups to be more prone to adopt OI strategies. In this way, I analysed the fact of being a startup as a contingency of the application of openness in knowledge-intensive sectors.

This study contributes to the literature since it advanced in the integration of OI with the entrepreneurship literature. To our knowledge no previous studies had analysed whether startups benefit to a greater extent from inbound OI strategies. I concluded that the startups' smallness and newness liabilities, rather than being a limitation, they are an incentive for openness. This study further contributes to understand the contingencies on OI strategies. While previous literature has argued that the effect of the technology intensity sector tend to disappear when smallness factor is taken into consideration, I explained that the technology intensity sector effect does not disappear when newness factor is taken into consideration.

Study 4 – The paradox of openness in startups

Study four shed light and clarified how openness in the value creating process and appropriation strategy as part of the value capturing process interrelate and influence the innovative performance in startups. In particular, this study focused on a sample of startups, and it analysed the impact of cooperation breadth and the appropriation strategy

on startups' innovation performance, as well as the complementarity between those strategies.

First, I analysed the impact of startups' cooperation breadth on innovation performance, and I tested for the non-linear relationship.As predicted, I found an inverted-U shape relationship, so cooperating with different types of partners is beneficial for startups' innovation performance, but there is a point where there are decreasing returns from cooperation.

Second, I found that the formal appropriation strategy draws a linear relationship with startups' innovation performance. It means that the use of patents, trademarks, copyright, and design rights allows startups to protect their innovations, as well as to connect with partners with complementary assets to get more commercial channels, so startups can capture the rents generated from their innovations.

Third, I tested for the complementarity between openness and appropriation for startups' innovation performance, finding that startups benefit from having an open innovation process and a formal appropriation strategy at the same time. An emphasis on legal appropriability reduces startups fears of partners' opportunistic behaviour, and also provides a sign of quality that attract partners with complementary assets. Moreover, first-runners are more vulnerable to unintended knowledge spillovers so the relationship between openness and appropriability is stronger. I therefore demonstrated that using both strategies is better than the sum of performing either.

This study contributes to literature by linking OI with entrepreneurship theory, and explaining how startups use openness to create value, and how they can benefit from IPRs to capture the value of their innovations. It also contributes to the recent debate about the trade-off between openness and appropriation, evidencing a complementary effect.

6.3 Theoretical and empirical contributions

In the following I will present the main theoretical and empirical contributions of this dissertation in terms of its contributions to research on open innovation and entrepreneurship theory.

6.3.1 Theoretical contributions

From a theoretical perspective, this dissertation contributes to the OI literature since it advances in the integration of OI with the entrepreneurship literature. So far, existing OI research has focused on the role of openness for large and established companies (Gassmann et al., 2010), with scant papers focused on small and medium firms (SMEs) (Brunswicker and Vanhaverbeke, 2015) and startups (Alberti and Pizzurno, 2017; Criscuolo et al., 2012; Segers, 2015; Spender et al., 2017; Usman and Vanhaverbeke, 2017). The analysis of OI in the context of startups is therefore an underdeveloped topic of research. OI scholars have underlined the important role of external actors for the startups' innovation processes and have remarked the need for future studies to focus on startups (Bogers et al., 2016; Brunswicker and Van De Vrande, 2014; Eftekhari and Bogers, 2015). However, a specific framework for OI in startups is still neglected in mainstream studies, thus this dissertation contributes to this relevant topic.

As I have argued along this dissertation, startups are different from SMEs and large firms because they are bounded by the liability of newness and smallness. Hence, through a focus on startups, the contributions of this dissertation can be summarized in terms of three main aspects. First, startups create and capture value from their innovations, contributing to the innovation ecosystem from their particular position. Second, startups

need to open their boundaries to a bigger extent than other firms. Third, startups benefit from the use of IPRs when open their boundaries. In the following, I will discuss these three aspects in some more detail.

First, this dissertation supports previous literature, which has stated that startups are source of innovation (Gruber et al., 2008; Schumpeter, 1934; Shane and Venkataraman, 2000), so this dissertation contributes to this research stream by explaining and evidencing their role for innovation. The unit of analysis along this dissertation has been the startup business, which contributes to highlight the importance of the role of startups for the innovation ecosystem. Previous studies has tended to analyse the contribution of startups to innovation from the perspective of the large firm (e.g. Weiblen and Chesbrough, 2015). The positive effect of startups for innovation performance observed in study one confirms the idea that startups perform a special role in the innovation ecosystem. The sign of a possible different contribution of startups was included on Laursen and Salter's (2006) study, which also included startups as a variable control, but they did not find a significant effect of these firms on radical nor incremental innovation performance. Despite this control, their study did not advance on theoretical explanations regarding the differences between startups and incumbent firms. This dissertation explains these differences, and the particular role of startups in terms of the degree of novelty of innovation. Criscuolo et al. (2012) referred to the differences between startups and incumbent firms, but they compared them in relation to the activity sector, arguing that startups are more advantageous in service sectors. I justify that startups compared to incumbent firms play a key role for the generation of radical innovations, which supports previous literature that has argued the role of startups for introducing disruptive innovations (Almeida and Kogut, 1997; Christensen and Bower, 1996). This contribution is in line with Almeida and Kogut's (1997) study, which found that startups are more

oriented to the exploration of diversity on new technology areas. As Katila and Shane (2005), I explained that the particular features of startups, such as flexibility, absence of routines, and not be leaded by structural inertia, successfully make startups to be able to create value.

Second, the core of this dissertation certainly lies in the insights into how startups benefit from openness. The startups' smallness and newness liabilities, rather than being a limitation, they are an incentive for openness. This leads to the understanding of the nature of cooperation breadth, and why startups can benefit to a greater extent from cooperation breadth than incumbent firms. Little is known about OI in startups, although some authors have claimed that startups and SMEs might achieve greater benefits from OI than larger firms due to their less bureaucratic processes, their willingness to take risks, and their agility to react to changing environments (Vanhaverbeke, 2017). This dissertation advances on the understanding of the role of the cooperation as a strategy for innovation in startups. Developing an OI strategy is an integral part of entrepreneurship in these days because it has been demonstrated that startups need from the resources and experience from other parties. In line with the strategic alliances literature, which underlined the role of alliances for startups to access to tangible and intangible resources (Eisenhardt and Schoonhoven, 1996; Hite and Hesterly, 2001), I contribute to the explanation of how startups use a diversity of cooperation partners to explore and exploit external knowledge, and so create and capture value. Cooperation breadth is a mechanism to reduce market and technological uncertainty that captures complementary assets, and it explains why startups benefit to more extent. Incumbent firms already have a pool of resources that makes cooperation less necessary. Accordingly, it has been evidenced that startups are more likely to cooperate than incumbent firms (Shan et al., 1994). Furthermore, this dissertation complements recent qualitative studies that explain why a

startup would be willing to cooperate with other firms. Between the benefits for startup of collaborating with a corporation, they can be summarized as support, ability to test, learning opportunities, and propriety right exposure and brand recognition (Vanhaverbeke, 2017).

This dissertation further contributes to understand the contingencies on OI strategies. In study three I deepened in the relationship between knowledge-intensive industries and openness in startups, and I found that startups in high-tech sectors are the one that benefit the most from cooperation breadth. While previous literature has argued that the effect of the technology intensity sector tend to disappear when the smallness factor is taken into consideration (Tether, 2002; Chesbrough and Crowther, 2006), I explained that the technology intensity sector effect does not disappear when the newness factor is taken into consideration. It contributes to understand how knowledge is a key foundation of value creation, extending the literature that analyses knowledge-intensive firms (Giudice et al., 2017).

Third, this dissertation contributes to understand the called 'paradox of openness' in startups. Recent literature has explained the trade-off between openness and appropriation (Arora et al., 2016; Huang et al., 2014; Jensen and Webster, 2009; Laursen and Salter, 2014; Miozzo et al., 2016; Zobel et al., 2016), providing arguments and contingences on the relationship between them. However, these studies did not focus on startups, with the exception of Zobel et al. (2016), who analysed startups in the solar industry, and found that patenting increases new entrants' number of open innovation relationships. Through study four, I contribute to this recent debate by evidencing a complementary effect between these two strategies for startups' innovation performance. Value creation and

value capture are positively interrelated and they together form the startups' innovation strategy.

A further contribution of this dissertation to the OI literature refers to the understanding of the concept of breadth. Literature has mainly studied breadth in cooperative activities (Collins and Riley, 2013; Faems et al., 2005; Laursen and Salter, 2006, 2014; Oerlemans et al., 2013; Rothaermel and Deeds, 2006), but in study one, I applied the concept of breadth to R&D outsourcing, in an analogous manner to that used for cooperation breadth. In this way, this dissertation contributes to literature by offering another perspective with regard to the traditional 'buy', 'make' or 'ally' trade-off, and comparing and combining both external R&D strategies—cooperation breadth and R&D outsourcing breadth—in a same model. Grimpe and Kaiser (2010) had tested that the relationship between R&D outsourcing intensity and innovation performance is positively moderated by the breadth of formal R&D collaborations, but I went a step further since my model considered both strategies in terms of breadth, which allowed to analyse the synergies between both OI strategies.

From the perspective of entrepreneurship, this dissertation also contributes to advance on this research stream. In particular, this dissertation makes a contribution to the field of entrepreneurship theory in terms of three main aspects. First, it advances on how entrepreneurial firms look for business opportunities through external partners as a strategy for value creation. Second, it explains how startups use external partners to gain more knowledge exploitation opportunities. Third, it sheds light on the importance of formal appropriation mechanisms for startups.

First, this dissertation advances on the understanding of how startups' strategy for innovation is based on the search of business opportunities through engaging in a diversity

of external relationships. Previous entrepreneurship scholars have argued the benefits of different types of ties –family vs business ties, weak vs strong ties- for firm growth (Hite and Hesterly, 2001; Larson and Starr, 1993; Lechner and Dowling, 2003) and innovation (Baum et al., 2000). In this line, this dissertation focused on the role of cooperation breadth as a strategy to create value by cooperating with a diversity of knowledge sources. The diversity of external relationships provides diverse knowledge insights, which foster the identification of more business opportunities. This idea is in line with the entrepreneurship literature, which considers that the source of entrepreneurship lies in the differences in information about opportunities (Shane, 2000); and with the knowledge spillover perspective, which emphasizes the role of external relationships in knowledge dissemination and economic growth (Cockburn and Henderson, 1998), and considers that knowledge spillovers are a source for opportunity creation and exploitation by entrepreneurs (Acs et al., 2013; Audretsch and Lehmann, 2005). The use of cooperation breadth becomes a mechanism to connect with diverse knowledge. I argue that startups related to incumbent firms are more dynamic on the integration of that knowledge because they are more flexible and do not follow a rigid organisational routine. I explained that startups use cooperation breadth to identify opportunities with value creation potential, such that cooperation breadth involves a distant knowledge search. Startups are more prone to benefit from those relationships, so they should integrate the search of heterogeneous external knowledge as a strategy for innovation. This dynamism of startups to integrate external knowledge is in line with the concept of entrepreneurial absorptive capacity, introduced by the knowledge spillover theory of entrepreneurship (Qian and Acs, 2013). While, the traditional absorptive capacity theory explains that firms need an extensive knowledge base to be able to absorb external knowledge (Cohen and Levinthal, 1990), which startups lack due to their newness liabilities of smallness and

newness; the absorptive capacity theory of knowledge spillover entrepreneurship explains that startups can absorb external knowledge through the ability of entrepreneurs to understand new knowledge, recognise its value, and commercialize it (Qian and Acs, 2013). It would entail that the dynamic to integrate heterogeneous external knowledge is more important for startups than the total amount of internal R&D knowledge.

Second, another core contribution of this dissertation is the explanation of how startups use external partners to gain more knowledge exploitation opportunities. Burgelman and Hitt (2007) explained how individually or collaboratively, entrepreneurs can take action to exploit opportunities and create value; and Gans and Stern (2003) theoretically argued the 'markets for ideas' and how startups can commercialise their innovations and the implications for industrial dynamics. This dissertation supports those studies and emphasizes the use of cooperation breadth as a strategy to enhance startups' innovation performance. As I previously explained, cooperation breadth is a mechanism to capture complementary assets, and commercial complementary assets have been identified as a driver of the formation of exploitative alliance in high-tech startups (Colombo et al., 2006). This is in line with the finding that startups and, in particular, high-tech startups are the firms that can benefit more from cooperation breadth. In addition, the spillover theory of entrepreneurship discusses that knowledge stock has a positive effect on the level of entrepreneurship (Acs et al., 2013) and that startups take advantage of knowledge spillovers from the stock of knowledge (Acs and Audretsch, 1988). In this sense, the effect of new knowledge entrepreneurship depends on how efficient incumbent firms are at exploiting knowledge flows (Acs et al., 2013). I contribute to extend this research stream since I argued that startups can benefit to a greater extent from cooperation breadth and I found that startups related to incumbent firms are more efficient in using cooperation breadth for innovation performance. In the way that startups cooperate with

a diversity of external sources, they are exposed to more knowledge spillovers, so they have more knowledge exploitation opportunities.

Third, entrepreneurial literature has analysed the role of appropriation mechanisms for startups, arguing the preference of informal mechanisms over formal appropriation mechanisms (Arundel, 2001). Although, at first sight, informal mechanisms could seem a better option due to the costs of IPRs, through study four, I shed light on the importance of IPRs for startups, and how the formal appropriation strategy is a mechanism to shift the resource trajectory of startups. In this sense, Hsu and Ziedonis (2013) discussed that patents perform a signalling quality mechanism for startups, especially for those lacking successful prior experience in sourcing a prominent venture capital (VC) in the initial financing round and those without the backing of prominent VCs at the time of an IPO. Baum and Silverman (2004) also referred to the quality signal of startups' patents as sign of innovative capacity to obtain venture capital financing. I extent those studies by analysing not only patents, but the impact of formal appropriation strategy, which includes the combination of four mechanisms, on innovation performance. It avoids to exclude startups that lack economic resources for apply for a patent, but that have evidenced their quality or the effectiveness to exploit their innovations through other IPRs. Hence, the formal appropriation strategy performs as a lever of innovation performance. Moreover, the benefits of the formal appropriation strategy are stronger in the context of openness to external sources. In this sense, Usman and Vanhaverbeke's (2017) cases study revealed that OI can and should go hand in hand with eminent value capturing strategies, as long as it remains a win-win for all the parties involved in the network. From the entrepreneurship theory, Katila et al. (2008) argued that the tie formation is a negotiation that depends on resources needs, defence mechanisms, and

alternative partners. I contribute to this research stream by discussing the causes why openness and appropriation are complementary in startups for innovation.

In sum, this dissertation contributes to the link between open innovation and entrepreneurship. While, so far, it has existed two differentiated research fields, on the one hand, entrepreneurship theory linked to the opportunity discovery; and on the other hand, open innovation literature applied to SMEs and startups, this dissertation links both streams of research to explain how startups create and capture value when they engage with a diversity of external knowledge sources.

6.3.2 Empirical contributions

From the empirical perspective, this dissertation contributes to literature on several ways. First, literature has commonly employed the concept of breadth to analyse the search of external sources (Laursen and Salter, 2006, 2014) or the diversity of cooperation agreements (Laursen and Salter, 2014; Leeuw et al., 2014; Oerlemans et al., 2013). I extended the application of the concept of breadth and I measured R&D outsourcing in terms of breadth, in an analogous manner to that used for cooperation breadth. It allowed to discover the synergies between them. Empirical research has barely analysed the interaction effect between R&D outsourcing and cooperation, with some exceptions, such as Grimpe and Kaiser (2010), who evidenced a positive moderator role of cooperation breadth on the R&D intensity. However, they did not analyse both strategies in terms of breadth. A significant contribution of this dissertation is the study of the interrelationships between outsourcing and cooperation. Findings revealed that the impact of cooperation breadth on the relationship between R&D outsourcing breadth and innovation performance depends on the level of R&D outsourcing breadth. The combination of these

strategies has a negative effect on innovation performance between low and medium levels of R&D outsourcing breadth because these strategies might be substitutes. However, between medium to high levels of R&D outsourcing breadth, cooperation exerts a positive effect because firms build relational capital that can be used by both strategies, generating economies of scale and scope.

Second, this dissertation contributes to clarify the linearity of the curve between cooperation breadth and innovation performance. Previous OI empirical literature has found mixed results, evidencing a positive effect (Chesbrough and Appleyard, 2007; Leiponen and Helfat, 2010; Zobel, 2013), inverted-U shaped (Laursen and Salter, 2006; Leeuw et al., 2014; Oerlemans et al., 2013), or even a negative effect (Bengtsson et al., 2015). I complement previous literature since I evidenced that startups draw an inverted-U relationship between cooperation breadth and innovation performance. This study also complements previous entrepreneurship literature, which also argued an inverted-U shape between external sources and different measures of performance (Deeds and Hill 1996; Moghaddam et al. 2016; Pangarkar and Wu 2013).

Third, the interaction effects sometimes generate difficulties in interpretation, especially when variables with an U-shaped relationship are in play. In this dissertation I contribute to understand those interactions by graphing the X-Y relationship. In this way, study one graphs the relationship between cooperation breadth and R&D outsourcing breadth; study three graphs the relationship between cooperation breadth and startups. Many empirical papers do not graph these relationships, and it is advisable to demonstrate that the curve takes the expected shape and that the turning point lies well within the data range (Haans et al., 2016).

Fourth, in study four I analysed the complementarity between openness and appropriation by applying the theory developed by Milgrom and Roberts (1995). While literature tends to analyse the complementarity between two factors by calculating the interaction between them, I went a further step and tested for the complementarity between openness and appropriation by evidencing that the use of both strategies is better than the sum of performing either.

Finally, this dissertation uses longitudinal data. While most of literature performs cross-sectional studies (e.g Huggins and Thompson, 2017; Laursen and Salter, 2006), I considered data from 2004 to 2013. However, not all studies included in this dissertation are based on panel analyses since each study should apply the most appropriate technique for answering to its research aim; and I could not claim for causal inferences, mostly due to the highly changing nature of the startups. Despite these caveats, the longitudinal perspective has allowed to study the evolution of the OI strategy for startups and incumbent firms; at the same time that it sheds light on startups' maturity process and their evolution to becoming incumbent firms.

6.4 Managerial and public policy implications

In terms of managerial implications, this dissertation highlights the role of external sources for startups and reveals interesting insights, not only for startups but also for incumbent firms.

First, it is clear the positive impact of OI strategies for innovation outcome, and thus R&D external relationships, must be an integral part of the business model for new product development. Nevertheless, the fact of I evidenced inverted U-shaped relationships in this

dissertation warns managers to not surpass a certain level of external breadth. It applies to both cooperation and R&D outsourcing, and for all types of firms –startups and incumbent firms-. As Rindova et al. (2012) and Leeuw et al. (2014) outlined, the development of external relationships is a strategic process that firms can proactively manage, so managers should select the optimal number of different external sources. A few types of external sources is positive for firms because partners bring more knowledge and resources; but having too many different types of partners might harm the innovation performance because it increases the risk of external dependence, blocks the creation of firms' knowledge base and hampers the firms' absorptive capacity, increases the coordination costs, as well as the risks of partners opportunistic behaviours, especially for startups.

Second, this dissertation has evidenced that OI strategies are especially relevant for startups, and the positive effects of cooperation breadth are increased I the case of startups because they find in their partners the resources and legitimacy that they lack. OI is a key strategy for startups to create and capture value and, subsequently, outperform their competitors, especially if the startup operates in knowledge-intensive sectors, so managers should include OI strategies in their business models. Managers of new firms who have not implemented an OI model should consider the benefits of opening their innovation processes and engaging with external partners to improve innovation performance. To successfully implement OI strategies, managerial capabilities and experience, for example, having worked in a larger firm, is essential (Usman and Vanhaverbeke, 2017).

Third, as I have advanced in the first implication, OI strategies should be an integral part of the business model of any innovative firm. In recent decades, models of innovation

suggest that managers should cooperate with external partners to enhance innovation outcomes, to increase market share and to survive in the current competitive market. Cooperation activities by large incumbent firms are often in the public eye. However, I found that incumbent firms are less open than startups. I recommend that managers from incumbent firms increase their breadth of cooperation, since they could benefit from more diverse knowledge in their innovation activities and enhance their innovation performance. In this sense, Chiaroni et al. (2011) described a three-stage model that comprises the stages of unfreezing, moving and institutionalising to move from a closed innovation model to an open model.

Fourth, in this dissertation I point out of the different role that startups and incumbent firms play in the innovation ecosystem, and managers should lead their firms accordingly. Startups' flexibility and their absence of formal routines boost their innovative capabilities, thereby leaving room for the creation of radical innovations. Managers at startups are therefore operating in a very different setting than that of managers in incumbent firms. While startups' managers have more freedom because they are not restricted by internal routines and procedures, managers of incumbent firms are operating in organizations with set structures and routines, and employees expecting certain approaches to innovation. To improve the radical innovation outcome in incumbent firms, the latter should engage with startups, in a way that larger firms provide resources to startups to develop their innovative activities, and commercialise together the final products. This implication goes hand in hand with Christensen & Overdorf's (2000) research, in which they suggested that the best way to address radical innovations is through the creation of new organizational spaces to develop these innovative activities. They propose three mechanisms for this: 1) create new organizational structures within the company, 2) spin out an independent organization that carries out the new processes,

and 3) acquire a new organization whose processes and values fit with the new processes and integrate that firm into the organization. In a same way, (Weiblen and Chesbrough, 2015) presented a series of corporate mechanisms to larger firms engage with startups.

Fifth, startups should be aware that the advantages of newness are temporary. The use of longitudinal data in this dissertation revealed the evolution of startups' innovation strategies. I evidenced how the startups' incremental innovation performance sharply decreases after some years. There is a time when the startup becomes an incumbent firm, with a portfolio of products and a set of values and routines. If the startup's strategy is to remain with a startup culture and exploit the benefits of high innovation performance, managerial focus on not routinizing firm structures must be maintained, despite the temptation to "fall into old routines". In this sense, Christensen and Overdorf (2000) pointed out that radical innovations are not limited to startups, but big firms also can introduce disruptive innovations. However, their capabilities often reside in processes and values embedded in the organisational culture, and it is difficult to change.

Sixth, this dissertation has argued that startups often lack the complementary assets to commercialize their innovations. The possession of that assets commonly determines who is going to appropriate from the rents of the innovation. In order to capture the rent from their innovation processes I encourage startups' managers to apply for IPRs. Gans and Stern (2003) recommended undertaking a systematic analysis of the level of excludability and the degree to which key complementary assets are controlled by established firms who could serve as competitive threats. The need for formal appropriation mechanisms is stronger in open contexts as evidenced in this dissertation.

Seventh, when deciding about the innovation strategies, managers should integrate and align their internal and external strategies. It means that the use of external knowledge

should be combined with internal knowledge, and the new knowledge recombination could be protected. As suggested by Laursen and Salter (2014), it is not only the external appropriation regimen which shapes the firm behaviour, but managers have a choice in determining the level of the appropriation strategy with regard to the opening of the firm.

Finally, I point out that it could take time before managers develop their capacities to successfully implement an open innovation strategy. As previously noted, there is a process for successfully implementing OI strategies (Chiaroni et al., 2011). The use of longitudinal data to analyse the firms' OI strategy allowed to observe how firms' reliance on OI processes changes over a period of time. The rather low levels of OI shown along this dissertation could be due to difficulties in implementing OI. Many firms experience a wealth of managerial challenges in effectively implementing OI strategies (e.g. dealing with employee attitudes affected by the "Not Invented Here" syndrome). In this sense, Usman and Vanhaverbeke (2017) summarized the main challenges that startups face and the benefits they earn when performing OI strategies. From study one I inferred that the interaction of different OI strategies does not always exhibit complementarities. As the study showed, there is a potential for diseconomies in OI combining deployment between low to medium levels of outsourcing breadth because of the costs and managerial capacities needed to deal with them. I warn managers that the positive outcomes of OI processes might not be easily achieved, especially in the case of incumbent firms with deeply rooted routines that need to be challenged. I recommend that managers be patient, and ensure that the right incentive structures are in place to unfold OI activities properly.

From a policy marker perspective, given the current role of openness in the innovation ecosystem, this dissertation suggests that policy makers should support cooperative programs that enhance the flow of knowledge between firms, making a special emphasis

on the relationships between startups and incumbent firms. This implication has already been pointed out by previous literature (e.g. Colombo et al., 2009; Usman and Vanhaverbeke, 2017) since it is recognised the importance of funding programmes for sharing knowledge and for startups' efficiency. Startups are the innovator motor of many countries, but they cannot perform the innovation processes by themselves. Engaging startups with larger firms would improve the innovation outcomes of a country.

That cooperative policies should be designed in a target way. This means that these policies should take into account the different roles of startups and incumbent firms for the national economy and innovation system. Large and high-intensive R&D firms are currently those that benefit most from policies that provide incentives for cooperation (Barge-Gil, 2010), but policies should also target to startups because, as I found in this dissertation, they are more innovative and they are implementing OI strategies even in a higher extent than incumbent firms. As outlined by Barge-Gil (2010), policies should support other types of firms, such as SMEs and startups since they are the motor of the economy for many countries, such as Spain.

6.5 Limitations and suggestions for future research

This dissertation is subject to a number of limitations, which also provide directions for future research at the topic at hand. A first problem potentially affecting all studies in this dissertation refers to the use of secondary data. This dissertation used secondary data from the database Spanish Technological Innovation Panel (PITEC). The analysis of secondary data does not let the researcher take into account questions other than those included in the externally pre-established questionnaire. The use of primary data would have introduced the benefits of direct observational methods research (Laursen and Salter,

2006). Using an own elaborated questionnaire would improve the analysis of the research questions of this dissertation. For example, the variables could have been measured in a different way. In particular, in study one I considered a restrictive definition of relational capital because PITEC does not provide information for a broader concept, such as the one used in Capello and Faggian (2005). Moreover, firms pursuing OI do not attribute the same importance to different types of partners, so certain types of external knowledge partners might be more relevant than others. One limitation of this dissertation is that the variable breadth was operationalised as the addition of the different partner with who the firm cooperates, without considering their importance. One option to capture the relevance of this issue would have been to use weights in the operationalisation of cooperation breadth as a construct. However, PITEC provides that information about the search strategies of the firm, but not for their cooperation and outsourcing activites. Similarly, in study four I examined the impact of the appropriation strategy only considering formal appropriation mechanisms and measuring them as binary variables. Future studies could create a measure weighting by the degree of importance of the different mechanisms. Although all the studies of this dissertation are based on secondary data, I undertook some interviews with some startups to understand the internal processes of their OI activities. The findings on this dissertation are in line with startups managers' comments, so I hope that the measure of the variables do not bias the results. Furthermore, several robustness checks were conducted to reassure the truthfulness of the findings.

Second, this dissertation used a panel database to test the hypotheses. The nature of a panel data implies to have repeated observations on the same cross section of economic agents over time. As a consequence the big sample of startups is introduced when the panel was created or with the two main enlargements (2004, 2005). The startup phenomenon is therefore observed during the first years of the panel, with few

observations at the end. Even in 2004, when the bigger sample of startups was introduced, the startup sample represents 4% of the sample of PITEC firms. This figure is slightly lower than the proportion of startups in Spain, since the birth rate in 2004 was almost 10% (INE, 2016) of the total number of firms. It means that the sample of startups used in this dissertation is relatively underrepresented.

Third, PITEC has been anonymised to avoid the identification of firms. As a consequence, some variables cannot be examined because they are not the directly observable. For example, firms' gross income in one of the variables anonymised. I only focused on innovation performance, but future studies could analyse startups' performance by using other variables such as the growth in sales.

Fourth, although this dissertation used longitudinal data, the highly changing nature of startups makes it difficult to draw strong causal inferences. Drawing from a longitudinal sample, I realised that openness might fluctuate over time. The networks theory argues that startups' network evolve to obtain the necessary resources during the early growth (Hite and Hesterly, 2001). Future research could analyse how the degree of openness changes over time, and how startups' external relationships develop and evolve according to their interests, for example, whether during the first years of a firm their relationships are focused on research, engaging with universities; and later widening to vertical alliances.

Fifth, the sample used in this dissertation could suffer from some survivorship bias since it is difficult to trace firms once they have left the business, so they might disappear from PITEC. This fact is increased when considering startups because PITEC will only provide information about startups that were alive during data collection for that year. Given that I sample startups this is a limitation to any startup study. Nevertheless, as I conducted

robustness tests and these support my findings, I am not concerned about this. Moreover, I do not expect the results to be biased since PITEC follows a representative method to select the sample of firms.

Sixth, this dissertation is based on a sample of Spanish firms, but it would be desirable to use sampling frames other than just Spain to extend the validity of the findings. I expect that the results are generalizable across countries, but future research could check whether the findings are stronger in technologically-advanced countries, and if the significance of the findings disappear in those countries based on the imitation of technologies since OI literature has informed that the effectiveness of OI depends on the external environment (Huizingh, 2010).

Another potential limitation relates to the analysis of more contingencies on the relationships studied in this dissertation. In study three, I analysed the role of high-tech startups as a moderator variable, but other contingencies could be taken into consideration, such as the appropriation regimen (West et al., 2006). In the same way, in study four, it would be interesting to know whether results are generalizable across startup characteristics, such as the sector in which the firm operates. OI literature has underlined that industry is one of the main external context characteristics that affects the effectiveness of OI (Huizingh, 2010). The benefits of openness could also be dependent on the type of alliance (horizontal, vertical) (Colombo et al., 2009).

Despite these limitations, which may motivate follow-up empirical studies, this dissertation builds the grounds for some additional and related future research questions. First of all, this dissertation illustrated some of the inconveniences of openness. When firms embrace OI strategies they should consider not only the benefits associated with them but also their drawbacks. Few studies have investigated the failures of OI and

whether (and why) OI is abandoned (West and Bogers, 2017). In particular, companies should ask themselves whether they have the resources and organizational capabilities needed to manage OI strategies, and adapt their business models accordingly. Firms' deficiencies in successfully managing OI strategies underscore the need to develop organizational capabilities. These capacities may be complementary when firms combine OI strategies. Thereby, one fruitful area for future research may be to focus on factors that may be complementary to OI strategies. Furthermore, it would be interesting to investigate to what extent organizational capabilities of incumbent firms differ from those of startups. Since the motivation and use of external sources is different between startups and incumbent firms, I expect that the organizational capabilities to manage OI strategies also differ.

As I have outlined in the aforementioned limitations, firms vary in the attribution of importance to the different partners with who they cooperate. Certain types of external knowledge partners might be more relevant than others regarding the innovation objectives and the resources needs. For this reason, some firms pursue a wide range of OI practices and others pursue only a limited subset of these practices. One option to capture the relevance of this issue would be that future studies consider, compare and contrast what type of partners are more important according to the stage of development of a firm. Doing this way new important value would be added in assessing the differences in the nature of external cooperation strategies (and R&D outsourcing strategies) between incumbents and startups and among startups belonging to different industries.

Extending the previos research lines, another fruitful area of analysis would be the understanding of the geography of the cooperation in startups and their internationalization processes. The internationalization theory suggests that international

diversification is an important source of learning (Shukla and Mital, 2016), while the knowledge spillover theory of entrepreneurship argues that knowledge spillovers are relatively located (Acs et al., 2013; Harhoff et al., 2014). Knowledge is heterogeneously distributed, and it would be interesting to advance on the understanding of an international search of opportunities against the specialization from local spillovers. For example, the breadth of cooperation agreements with international partners could have an impact on the degree of internationalization of the startup, while local startups could have a lower breadth and being more specialized. A global perspective of the cooperation breadth could enrich the OI literature and the international entrepreneurship perspective.

A final stream of future research is a more detailed investigation of the internationalization processes in the case of born-global firms. The Uppsala model (Johanson and Vahlne, 1977) and the innovation-related model (Cavusgil, 1980) have explained the international involvement of firms, describing that startups follow a learning process when they operate in the international markets, but some streams of literature are evidencing that many startups success in the international market from inception, emerging the called 'born global firms' (Cavusgil and Knight, 2015; Knight and Cavusgil, 2004; Zhang et al., 2009). Although several studies have deepened on the explanation of the success of this type of firms, there is a room for more research. In particular, studies that link the OI phenomenon with the internationalization from inception are scarce. Future studies could analysis the role of cooperation on startups' international expansion. An internationalization perspective of cooperation would help to understand the knowledge networks spread of a firm and its evolution.

6.6 Conclusion

In this dissertation I developed a framework to understand the OI phenomenon in startups. Differences between startups and incumbent firms motivated this dissertation as each of them play a different role in the innovation ecosystem and economic development of a country. Given these differences, the theoretical argumentations used to explain the innovation processes of incumbent firms cannot be directly applied to startups. The findings of the four empirical studies of this dissertation help to explain how startups create and capture value from external sources, and to which extent startups can benefit to a greater extent from an open innovation strategy. Overall, this dissertation contributes to the link between OI literature and entrepreneurship theory.

References

Acs, Z.J., Audretsch, D.B., 1988. Innovation in Large and Small Firms: An Empirical Analysis. Am. Econ. Rev. 78, 678–690.

Acs, Z.J., Audretsch, D.B., Lehmann, E.E., 2013. The knowledge spillover theory of entrepreneurship. Small Bus. Econ. 41, 757–774. doi:10.1007/s11187-013-9505-9

Alberti, F.G., Pizzurno, E., 2017. Oops, I did it again! Knowledge leaks in open innovation networks with start-ups. Eur. J. Innov. Manag. 20, 50–79. doi:10.1108/EJIM-11-2015-0116

Almeida, P., Kogut, B., 1997. The Exploration of Technological Diversity and Geographic Localization in Innovation: Start-Up Firms in the Semiconductor Industry. Small Bus. Econ. 9, 21–31. doi:10.1023/A:1007995512597

Arora, A., Athreye, S., Huang, C., 2016. The paradox of openness revisited: Collaborative innovation and patenting by UK innovators. Res. Policy 45, 1352–1361. doi:10.1016/j.respol.2016.03.019

Arundel, A., 2001. The relative effectiveness of patents and secrecy for appropriation. Res. Policy 30, 611–624. doi:10.1016/S0048-7333(00)00100-1

Audretsch, D.B., Lehmann, E.E., 2005. Does the Knowledge Spillover Theory of Entrepreneurship hold for regions? Res. Policy, Regionalization of Innovation Policy 34, 1191–1202. doi:10.1016/j.respol.2005.03.012

Barge-Gil, A., 2010. Open, Semi-Open and Closed Innovators: Towards an Explanation of Degree of Openness. Ind. Innov. 17, 577–607. doi:10.1080/13662716.2010.530839

Baum, J. a. C., Calabrese, T., Silverman, B.S., 2000. Don't go it alone : Alliance network composition and startups' performance in canadian biotechnology. Strateg. Manag. J. 21, 267–294.

Baum, J.A.C., Silverman, B.S., 2004. Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology startups. J. Bus. Ventur., Evolutionary approaches to entrepreneurship: Honoring Howard Aldrich 19, 411–436. doi:10.1016/S0883-9026(03)00038-7

Bengtsson, L., Lakemond, N., Lazzarotti, V., Manzini, R., Pellegrini, L., Tell, F., 2015. Open to a Select Few? Matching Partners and Knowledge Content for Open Innovation Performance. Creat. Innov. Manag. 24, 72–86. doi:10.1111/caim.12098

Bogers, M., Zobel, A.-K., Afuah, A., Almirall, E., Brunswicker, S., Dahlander, L., Frederiksen, L., Gawer, A., Gruber, M., Haefliger, S., Hagedoorn, J., Hilgers, D., Laursen, K., Magnusson, M.G., Majchrzak, A., McCarthy, I.P., Moeslein, K.M., Nambisan, S., Piller, F.T., Radziwon, A., Rossi-Lamastra, C., Sims, J., Wal, A.L.J.T., 2016. The open innovation research landscape: established perspectives and emerging themes across different levels of analysis. Ind. Innov. 0, 1–33. doi:10.1080/13662716.2016.1240068

Brunswicker, S., Van De Vrande, V., 2014. Exploring Open Innovation in Small and Medium-Sized Enterprises, in: New Frontiers in Open Innovation. Oxford University Press, Oxford.

Brunswicker, S., Vanhaverbeke, W., 2015. Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators. J. Small Bus. Manag. 53, 1241–1263. doi:10.1111/jsbm.12120

Burgelman, R.A., Hitt, M.A., 2007. Entrepreneurial actions, innovation, and appropriability. Strateg. Entrep. J. 1, 349–352. doi:10.1002/sej.28

Capello, R., Faggian, A., 2005. Collective Learning and Relational Capital in Local Innovation Processes. Reg. Stud. 39, 75–87. doi:10.1080/0034340052000320851

Cavusgil, S.T., 1980. On the internationalization process of firms. Eur. Res. 8, 273–281.

Cavusgil, S.T., Knight, G., 2015. The born global firm: An entrepreneurial and capabilities perspective on early and rapid internationalization. J. Int. Bus. Stud. Basingstoke 46, 3–16. doi:http://0-dx.doi.org.cisne.sim.ucm.es/10.1057/jibs.2014.62

Chesbrough, H., 2006. Open Innovation: A new paradigm for understanding industrial innovation, in: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), Open Innovation: Researching a New Paradigm. Oxford University Press, Oxford.

Chesbrough, H., Appleyard, M., 2007. Open Innovation and Strategy. Bus. Adm. Fac. Publ. Present.

Chesbrough, H., Bogers, M., 2014. Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation, in: New Frontiers in Open Innovation. Oxford University Press, Oxford, pp. 3–28.

Chesbrough, H.W., 2003. The era of open innovation. Sloan Manage. Rev. Summer, 35–41.

Chiaroni, D., Chiesa, V., Frattini, F., 2011. The Open Innovation Journey: How firms dynamically implement the emerging innovation management paradigm. Technovation, Open Innovation - ISPIM Selected Papers 31, 34–43. doi:10.1016/j.technovation.2009.08.007

Christensen, C.M., Bower, J.L., 1996. Customer Power, Strategic Investment, and the Failure of Leading Firms. Strateg. Manag. J. 17, 197–218.

Christensen, C.M., Overdorf, M., 2000. Meeting the Challenge of Disruptive Change. Harv. Bus. Rev. 78, 66–76.

Cockburn, I.M., Henderson, R.M., 1998. Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery. J. Ind. Econ. 46, 157–182. doi:10.1111/1467-6451.00067

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: A new perspective on learning and innovation. Adm. Sci. Q. 35, 128–152. doi:10.2307/2393553

Collins, J., Riley, J., 2013. Alliance Portfolio Diversity and Firm Performance: Examining Moderators. J. Bus. Manag. 19, 35–50.

Colombo, M.G., Grilli, L., Murtinu, S., Piscitello, L., Piva, E., 2009. Effects of international R&D alliances on performance of high-tech start-ups: a longitudinal analysis. Strateg. Entrep. J. 3, 346–368. doi:10.1002/sej.78

Colombo, M.G., Grilli, L., Piva, E., 2006. In search of complementary assets: The determinants of alliance formation of high-tech start-ups. Res. Policy, Special issue commemorating the 20th Anniversary of David Teece's article, "Profiting from Innovation", in Research Policy 35, 1166–1199. doi:10.1016/j.respol.2006.09.002

Criscuolo, P., Nicolaou, N., Salter, A., 2012. The elixir (or burden) of youth? Exploring differences in innovation between start-ups and established firms. Res. Policy 41, 319–333. doi:10.1016/j.respol.2011.12.001

Dahlander, L., Gann, D.M., 2010. How open is innovation? Res. Policy 39, 699–709. doi:10.1016/j.respol.2010.01.013

Deeds, D.L., Hill, C.W.L., 1996. Strategic alliances and the rate of new product development: An empirical study of entrepreneurial biotechnology firms. J. Bus. Ventur. 11, 41–55. doi:10.1016/0883-9026(95)00087-9

Eftekhari, N., Bogers, M., 2015. Open for Entrepreneurship: How Open Innovation Can Foster New Venture Creation. Creat. Innov. Manag. 24, 574–584. doi:10.1111/caim.12136

Eisenhardt, K.M., Schoonhoven, C.B., 1996. Resource-Based View of Strategic Alliance Formation: Strategic and Social Effects in Entrepreneurial Firms. Organ. Sci. 7, 136–150.

Faems, D., Van Looy, B., Debackere, K., 2005. Interorganizational Collaboration and Innovation: Toward a Portfolio Approach*. J. Prod. Innov. Manag. 22, 238–250. doi:10.1111/j.0737-6782.2005.00120.x

Gans, J.S., Stern, S., 2003. The product market and the market for “ideas”: commercialization strategies for technology entrepreneurs. Res. Policy, Special Issue on Technology Entrepreneurship and Contact Information for corresponding authors 32, 333–350. doi:10.1016/S0048-7333(02)00103-8

Gassmann, O., Enkel, E., Chesbrough, H., 2010. The future of open innovation. RD Manag. 40, 213–221. doi:10.1111/j.1467-9310.2010.00605.x

Giudice, M.D., Carayannis, E.G., Maggioni, V., 2017. Global knowledge intensive enterprises and international technology transfer: emerging perspectives from a quadruple helix environment. J Technol Transf 42, 229–235. https://doi.org/10.1007/s10961-016-9496-1

Grimpe, C., Kaiser, U., 2010. Balancing Internal and External Knowledge Acquisition: The Gains and Pains from R&D Outsourcing. J. Manag. Stud. 47, 1483–1509. doi:10.1111/j.1467-6486.2010.00946.x

Gruber, M., MacMillan, I.C., Thompson, J.D., 2008. Look Before You Leap: Market Opportunity Identification in Emerging Technology Firms. Manag. Sci. 54, 1652–1665. doi:10.1287/mnsc.1080.0877

Haans, R.F.J., Pieters, C., He, Z.-L., 2016. Thinking about U: Theorizing and testing U- and inverted U-shaped relationships in strategy research. Strateg. Manag. J. 37, 1177–1195. doi:10.1002/smj.2399

Harhoff, D., Mueller, E., Van Reenen, J., 2014. What are the Channels for Technology Sourcing? Panel Data Evidence from German Companies. J. Econ. Manag. Strategy 23, 204–224. doi:10.1111/jems.12043

Hite, J.M., Hesterly, W.S., 2001. The evolution of firm networks: from emergence to early growth of the firm. Strateg. Manag. J. 22, 275–286. doi:10.1002/smj.156

Hsu, D.H., Ziedonis, R.H., 2013. Resources as dual sources of advantage: Implications for valuing entrepreneurial-firm patents. Strateg. Manag. J. 34, 761–781. doi:10.1002/smj.2037

Huang, F., Rice, J., Galvin, P., Martin, N., 2014. Openness and Appropriation: Empirical Evidence From Australian Businesses. IEEE Trans. Eng. Manag. 61, 488–498. doi:10.1109/TEM.2014.2320995

Huggins, R., Thompson, P., 2017. Entrepreneurial networks and open innovation: the role of strategic and embedded ties. Ind. Innov. 24, 403–435. doi:10.1080/13662716.2016.1255598

Huizingh, E.K.R.E., 2010. Open innovation: State of the art and future perspectives. Technovation 31, 2–9. doi:10.1016/j.technovation.2010.10.002

INE, 2016. Instituto Nacional de Estadística. (National Statistics Institute) [WWW Document]. URL http://www.ine.es/jaxi/menu.do?type=pcaxis&path=%2Ft37%2Fp204&file=inebase&L=0 (accessed 1.18.17).

Jensen, P.H., Webster, E., 2009. Knowledge management: does capture impede creation? Ind. Corp. Change 18, 701–727. doi:10.1093/icc/dtp025

Johanson, J., Vahlne, J.-E., 1977. The Internationalization Process of the Firm—A Model of Knowledge Development and Increasing Foreign Market Commitments. J. Int. Bus. Stud. 8, 23–32.

Katila, R., Rosenberger, J.D., Eisenhardt, K.M., 2008. Swimming with Sharks: Technology Ventures, Defense Mechanisms and Corporate Relationships. Adm. Sci. Q. 53, 295–332. doi:10.2189/asqu.53.2.295

Katila, R., Shane, S., 2005. When Does Lack of Resources Make New Firms Innovative? Acad. Manage. J. 48, 814–829. doi:10.5465/AMJ.2005.18803924

Knight, G.A., Cavusgil, S.T., 2004. Innovation, organizational capabilities, and the born-global firm. J. Int. Bus. Stud. Basingstoke 35, 124–141.

Larson, A., Starr, J.A., 1993. A network model of organization formation. Entrep. Theory Pract. 17, 5–16.

Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. Strateg. Manag. J. 27, 131–150. doi:10.1002/smj.507

Laursen, K., Salter, A.J., 2014. The paradox of openness: Appropriability, external search and collaboration. Res. Policy, Open Innovation: New Insights and Evidence 43, 867–878. doi:10.1016/j.respol.2013.10.004

Lechner, C., Dowling, M., 2003. Firm networks: external relationships as sources for the growth and competitiveness of entrepreneurial firms. Entrep. Reg. Dev. 15, 1–26. doi:10.1080/08985620210159220

Leeuw, T., Lokshin, B., Duysters, G., 2014. Returns to alliance portfolio diversity: The relative effects of partner diversity on firm's innovative performance and productivity. J. Bus. Res. 67, 1839–1849. doi:10.1016/j.jbusres.2013.12.005

Leiponen, A., Helfat, C.E., 2010. Innovation objectives, knowledge sources, and the benefits of breadth. Strateg. Manag. J. 31, 224–236. doi:10.1002/smj.807

Michelino, F., Cammarano, A., Lamberti, E., Caputo, M., 2017. Open innovation for start-ups: A patent-based analysis of bio-pharmaceutical firms at the knowledge domain level. Eur. J. Innov. Manag. 20, 112–134. doi:10.1108/EJIM-10-2015-0103

Milgrom, P., Roberts, J., 1995. Complementarities and fit strategy, structure, and organizational change in manufacturing. J. Account. Econ., Organizations, Incentives, and Innovation 19, 179–208. doi:10.1016/0165-4101(94)00382-F

Miozzo, M., Desyllas, P., Lee, H., Miles, I., 2016. Innovation collaboration and appropriability by knowledge-intensive business services firms. Res. Policy 45, 1337–1351. doi:10.1016/j.respol.2016.03.018

Moghaddam, K., Bosse, D.A., Provance, M., 2016. Strategic Alliances of Entrepreneurial Firms: Value Enhancing Then Value Destroying. Strateg. Entrep. J. 10, 153–168. doi:10.1002/sej.1221

Oerlemans, L.A.G., Knoben, J., Pretorius, M.W., 2013. Alliance portfolio diversity, radical and incremental innovation: The moderating role of technology management. Technovation 33, 234–246. doi:10.1016/j.technovation.2013.02.004

Pangarkar, N., Wu, J., 2013. Alliance formation, partner diversity, and performance of Singapore startups. Asia Pac. J. Manag. 30, 791–807. doi:10.1007/s10490-012-9305-9

Qian, H., Acs, Z.J., 2013. An absorptive capacity theory of knowledge spillover entrepreneurship. Small Bus. Econ. 40, 185–197. doi:10.1007/s11187-011-9368-x

Rindova, V.P., Yeow, A., Martins, L.L., Faraj, S., 2012. Partnering portfolios, value-creation logics, and growth trajectories: A comparison of Yahoo and Google (1995 to 2007). Strateg. Entrep. J. 6, 133–151. doi:10.1002/sej.1131

Rothaermel, F.T., Deeds, D.L., 2006. Alliance type, alliance experience and alliance management capability in high-technology ventures. J. Bus. Ventur., Entrepreneurship and Strategic Alliances 21, 429–460. doi:10.1016/j.jbusvent.2005.02.006

Schumpeter, J.A., 1934. The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle. Transaction Publishers.

Segers, J.-P., 2015. The interplay between new technology based firms, strategic alliances and open innovation, within a regional systems of innovation context. The case of the biotechnology cluster in Belgium. J. Glob. Entrep. Res. 5, 1–17. doi:10.1186/s40497-015-0034-7

Shan, W., Walker, G., Kogut, B., 1994. Interfirm cooperation and startup innovation in the biotechnology industry. Strateg. Manag. J. 15, 387–394. doi:10.1002/smj.4250150505

Shane, S., 2000. Prior Knowledge and the Discovery of Entrepreneurial Opportunities. Organ. Sci. 11, 448–469.

Shane, S., Venkataraman, S., 2000. The Promise of Entrepreneurship as a Field of Research. Acad. Manage. Rev. 25, 217–226. doi:10.5465/AMR.2000.2791611

Shukla, D.M., Mital, A., 2016. Effect of firm's diverse experiences on its alliance portfolio diversity: Evidence from India. J. Manag. Amp Organ. 1–25. doi:10.1017/jmo.2016.26

Spender, J.-C., Corvello, V., Grimaldi, M., Rippa, P., 2017. Startups and open innovation: a review of the literature. Eur. J. Innov. Manag. 20, 4–30. doi:10.1108/EJIM-12-2015-0131

Spithoven, A., Vanhaverbeke, W., Roijakkers, N., 2013. Open innovation practices in SMEs and large enterprises. Small Bus. Econ. 41, 537–562. doi:10.1007/s11187-012-9453-9

Stinchcombe, A.L., 1965. Organizations and social structure. Handb. Organ. 44, 142–193.

Usman, M., Vanhaverbeke, W., 2017. How start-ups successfully organize and manage open innovation with large companies. Eur. J. Innov. Manag. 20, 171–186. doi:10.1108/EJIM-07-2016-0066

Vanhaverbeke, W. 2017. *Managing Open Innovation in SMEs*. Camdridge University Press.

Weiblen, T., Chesbrough, H.W., 2015. Engaging with Startups to Enhance Corporate Innovation. Calif. Manage. Rev. 57, 66–90. doi:10.1525/cmr.2015.57.2.66

West, J., Bogers, M., 2017. Open innovation: current status and research opportunities. Innovation 19, 43–50. doi:10.1080/14479338.2016.1258995

West, J., Vanhaverbeke, W., Chesbrough, H., 2006. Open Innovation: A research agenda, in: Chesbrough, Henry; Vanhaverbeke, Wim; West, Joel (Ed.). Open Innovation: Researching a New Paradigm. Oxford University Press, pp. 285–307.

Wymer, S.A., Regan, E.A., 2005. Factors Influencing e-commerce Adoption and Use by Small and Medium Businesses. Electron. Mark. 15, 438–453. doi:10.1080/10196780500303151

Zhang, M., Tansuhaj, P., McCullough, J., 2009. International entrepreneurial capability: The measurement and a comparison between born global firms and traditional exporters in China. J. Int. Entrep. 7, 292–322. doi:10.1007/s10843-009-0042-1

Zobel, A.-K., 2013. Open Innovation: A dynamic Capabilities Perspective. Maastricht University, Maastricht.

Zobel, A.-K., Balsmeier, B., Chesbrough, H., 2016. Does patenting help or hinder open innovation? Evidence from new entrants in the solar industry. Ind. Corp. Change 25, 307–331. doi:10.1093/icc/dtw005