The breadth of open innovation activities: antecedents and outcomes, a dynamic capability perspective

By

Nicole El Maalouf

Newcastle University Business School

A thesis submitted to the Faculty of Humanities and Social Sciences at Newcastle University, in partial fulfilment of the requirements for the degree of Doctor of Philosophy

May 2021

Abstract

Building on the theory of dynamic capabilities, this study seeks to examine the implementation of open innovation at the firm level. Specifically, this research focuses on the breadth of open activities, a potential first-order dynamic capability to examine its antecedents and outcomes. It examined (a) the effect of the breadth of open innovation activities (e.g., external technology acquisition, crowdsourcing, customer co-creation in R&D projects) as a potential first-order dynamic capability, on firm innovativeness. Additionally, this research studied (b) the effect of a potential second-order routine, representing open innovation training, and potential second-order dynamic capabilities including social information systems capabilities, the anticipation of new technologies, and relational capability on the breadth of open innovation activities.

A pilot test of six semi-structured interviews was conducted to revise the conceptual model of this study. Then, online surveys, as the main method of data collection used in this research, were distributed mainly to innovation and R&D managers at high value manufacturing companies in the UK. 211 completed surveys, representing a satisfactory response rate of 21.1%, were obtained and used in the hierarchical regression method adopted to analyse the data in this study.

This research found that the breadth of open innovation activities is a first-order dynamic capability resulting in a higher level of firm innovativeness, but only up to certain extent, after which lower firm innovativeness results. Open innovation training, social information systems capabilities and relational capability were found to be key antecedents supporting the breadth of open innovation activities. This study contributed to the inbound open innovation implementation literature at the firm level, in relation to antecedents and outcomes of the breadth of open innovation activities, through the dynamic capabilities theory. It also provided better guidance for managers in this regard, and suggested future research areas.

Acknowledgment

It has been 4 years of hard work, and now that I am approaching the final stages of my PhD journey. I would like to take this opportunity, to express my sincere gratitude to all the people who supported me during this time.

A special appreciation to each of my supervisors, Dr. Hanna Bahemia and Professor Savvas Papagiannidis that were the backbone of my work. Their continuous support throughout, was immense.

Special thanks to Newcastle University Business School for the resources provided, developmental training, various workshops and events, that played a key role in improving my research skills and related knowledge. I am also very thankful for all my friends and colleagues that kept providing me their positive vibes and support when needed.

I would like to thank all my family members who spared no effort to give me the emotional, moral, and financial support during the past 4 years. I would be forever grateful for their love and support.

Last but not least, a huge gratitude goes to William, who was instrumental in his support and motivation.

Finally, I hope that this submission will meet the required objectives to both academia and practice and hopefully, will kick off my academic career I am aiming for!

Table of contents

List of Tables

List of Figures

Related Publications

Conference Paper

Maalouf, N.E., Bahemia H., Papagiannidis S. The firm level antecedents of open innovation: A dynamic capability perspective. *In: British Academy of Management Conference*. 2018, Bristol, UK: British Academy of Management.

Chapter 1. Introduction

1.1 Research background

Considering the dynamic nature of the majority of markets, it is almost impossible to find an industry that is not involved in periodic innovation and reorientation (Hurley and Hult, 1998). Innovation is *"the generation, acceptance and implementation of new ideas, processes, products or services"* (Thompson, 1965, p. 2). It is based on the development of new knowledge and ideas to enable new business outcomes, which seek to enhance internal business procedures and develop market-driven products and services (Du Plessis, 2007). This traditional model of innovation is still adopted nowadays among firms. However, the open approach to innovation also became popular both in academia and practice when Henry Chesbrough published his book on open innovation in 2003. It is worth noting that even before Chesbrough's publication, there have always been collaborative innovation and external interactions taking place between firms and different external partners. For instance, the network model of innovation advocated by Rothwell *et al.* (1985) over 20 years ago focused on the importance of external interactions in innovation. Different scholars of R&D management and innovation management would argue that open innovation illustrates little more than the repackaging and representation of concepts and findings discussed over the past forty years in innovation management research. Open innovation is "old wine in new bottles" (Trott and Hartmann, 2009). Nevertheless, since Chesbrough (2003) presented the concept, open innovation has taken its place as a mainstream innovation process (Slowinski and Sagal, 2010). The concept of open innovation has created an "avalanche of interest" (West *et al.*, 2014). Directed towards a managerial audience, Chesbrough's book in 2003 was envisioned to change practice by supporting companies to expand their boundaries in both the creation and commercialisation of innovations. For several practitioners, open innovation has provided a new language with which to speak about the nature of research and development (R&D), supporting the transition of the dominant logic of R&D from internal discovery to external engagement.

Proctor & Gamble's (P&G) approach to R&D offers an example of the open innovation approach among companies. P&G moved its R&D strategy towards "connect and develop"

instead of focusing on internal R&D to achieve the higher exploitation of external ideas and actors. P&G opened their innovation strategy to a broad set of external sources of innovative ideas. The "connect and develop" strategy refers to the concept that external partners' ideas can often be more valuable than internal ones (Sakkab, 2002). Based on this, open innovators are those who incorporate these external sources into their innovation processes and competitive strategy (Chesbrough, 2006c). Similarly, innovation academics have also embraced open innovation through conferences, special issues, and many books and academic papers. Open innovation studies have been mainly published in highly-ranked academic journals such as "Research Policy", the Journal of Product Innovation Management", "Research & Management", "Industrial and Corporate Change" and the "Strategic Management Journal". This concept has been investigated in both quantitative and qualitative studies, and has also been covered in review papers such as that by West and Bogers (2014) and Randhawa *et al.* (2016).

The main difference between the open and closed model of innovation is that in the closed model the focus is on internal practices during the innovation process (Chesbrough, 2006b). In open innovation, both external and internal knowledge are equally important (Berchicci, 2013). The open innovation literature has clearly presented the advantages of open innovation. It has shown that open innovation improves the probability that organisations will achieve success due to the increasing sales of new products and technologies (Freel, 2006). It can also contribute to business growth by making it possible for firms to leverage ideas from different external partners (Huang *et al.*, 2010a). Thus, there has been a substantial body of literature showing that openness to external sources of knowledge stimulates innovation performance, whilst also suggesting that there are also limits to the benefits of these external relations (Ahuja, 2000; Love and Roper, 2001; Katila and Ahuja, 2002; Laursen and Salter, 2006; Leiponen and Helfat, 2010). Thus, the open innovation literature has mainly focused on the effects of open innovation while specifically conceptualising open innovation in terms of the breadth of the search for external sources (Laursen and Salter, 2006; Garriga *et al.*, 2013; Brunswicker and Vanhaverbeke, 2015; Zobel, 2017).

This chapter provides an overview of the emergence of the open innovation model, and what it is based on. In addition, it outlines the key research gaps in the open innovation implementation literature, as addressed by this study. Following on from this, the research objectives and questions of this study will be discussed. This chapter also gives an overview

of the research methodology used in this study, the findings obtained and their contributions to the open innovation literature and to practice. At the end of this chapter, the thesis structure is presented.

1.2 The emergence of the open innovation concept

The most common model of innovation used in the 20th century was the closed traditional approach. In this model, a firm develops its own ideas within its boundaries instead of externally (Chesbrough, 2003; Huizingh, 2011; Bae and Chang, 2012; Marques, 2014a). In the closed model, firms do not rely on external parties. The traditional closed model of innovation refers to the situation where a proprietary innovation is created in-house and both the process and the outcome are closed. Firms create their own ideas, which they then develop, build, promote, distribute, service, finance and support on their own (Chesbrough, 2003). Although this model worked well until the end of the 20th century, several factors were behind the decline in its adoption and the subsequent shift towards a more open approach to innovation. One driver includes the substantial increase in the number and mobility of knowledge workers, which has complicated companies' control process of their own ideas and expert people, and their proprietary ideas and expertise. Another factor involves the development of private venture capital companies that finance new businesses and their activities to market their ideas (Chesbrough, 2006b). Shorter product life cycles, a shorter time to market, enhancements in Internet and social networking technologies, and widely shared knowledge have also stimulated firms to open-up their innovation process (Chesbrough, 2003; Dodgson *et al.*, 2006; Enkel *et al.*, 2009).

There are some specific key "erosion features" which have strengthened the significance of open innovation (Chesbrough, 2003). These factors include: more capable universities, decreasing U.S. hegemony, the growing access of start-up companies to venture capital, and the supporting information and communication technologies (ICTs) (Chesbrough and Bogers, 2014). The rising expenses and lack of resources of Industrial R&D are also reasons behind the emergence of open innovation (Gassmann and Enkel, 2004). As a result, all these drivers have led to the emergence of "open innovation" and have pushed many firms to use this new model in their innovation activities, which is extensively adopted by companies these days. In open innovation, firms understand that not all good ideas will be generated from within the firm and not all good ideas developed within it can be successfully marketed internally

(Chesbrough and Crowther, 2006). The next section will define open innovation.

1.3 What is open innovation?

The most common definition is the one which views open innovation as *"the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively"* (Chesbrough et al., 2006, p. 1). This definition indicates that open innovation is related to the external knowledge obtained and shared beyond a firm's boundaries when they innovate. As per this new innovation approach, firm boundaries have become more permeable, thus facilitating the increasing flow of resources into and out of the firm at different phases of the innovation process (Chesbrough, 2003). Open innovation is represented by 2 modes: inbound and outbound open innovation. Inbound open innovation is a model that integrates purposively external knowledge with internal R&D. In the outbound mode of open innovation, the internally developed technologies and ideas can be obtained by external organisations with business models that are more appropriate for commercialising a specific technology or idea (Chesbrough, 2003). Studies found that inbound open innovation is widely adopted, being the most dominant mode among firms in comparison to the outbound one (Chesbrough and Crowther, 2006; Bianchi *et al.*, 2011; Sisodiya *et al.*, 2013; Chesbrough and Brunswicker, 2014). Specifically, Chesbrough and Brunswicker (2014) revealed that inbound open innovation practices are far more commonly adopted than the outbound ones. Participants in their survey showed that the share of projects with inbound components was 35%, on average, whereas only about 8 % of projects incorporated outbound innovation practices. Consequently, the current study focuses on inbound open innovation and conceptualises it in terms of the breadth of inbound open innovation activities (Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). The following section highlights the key research gaps in the inbound open innovation literature to show the research objectives and questions of this study.

1.4 Research gaps in the inbound open innovation implementation literature

The open innovation literature offers a clear understanding of the advantages (Cheng and Huizingh, 2014; Love *et al.*, 2014; Bianchi *et al.*, 2016; Lakemond *et al.*, 2016; Bagherzadeh *et al.*, 2019) and limitations of inbound open innovation (Garriga *et al.*, 2013; de Araújo Burcharth *et al.*, 2014; Laursen and Salter, 2014; Ritala *et al.*, 2015). Most of the studies on

the effects of open innovation conceptualise open innovation in terms of the breadth of the search for external partners (e.g., customers, suppliers, universities, research centers, competitors) (Laursen and Salter, 2006; Bianchi *et al.*, 2011; Brunswicker and Vanhaverbeke, 2015; Chen *et al.*, 2016; Zobel, 2017). Nevertheless, there are still many under-researched and important topics related to inbound open innovation, specifically in terms of its implementation. Therefore, in addition to the importance of investigating the effects of open innovation, it is also important to understand how firms can prepare and what key learning routines and capabilities they have to develop for an effective open innovation implementation. Some studies have started to focus on the implementation of open innovation at the firm level. However, some of them were based on qualitative research from which it is not possible to generalise more from the results, and hence did not examine the effect on firm performance (Mortara and Minshall, 2011; Salter *et al.*, 2014; Lifshitz-Assaf, 2018). Some others have simply focused on one type of inbound open innovation activity such as "collaboration with external partners" (Laursen and Salter, 2014), "search for external partners" (Laursen and Salter, 2006; Bianchi *et al.*, 2011; Brunswicker and Vanhaverbeke, 2015), "interactions with customers" (Foss *et al.*, 2011), "opportunity exploitation" (Foss *et al.*, 2013), and "outsourcing" (Bianchi *et al.*, 2016). Others have simply considered "open innovation" in their study, neither in terms of the breadth of the search for external partners, nor in terms of the breadth of open innovation activities (Lee *et al.*, 2010; Mortara and Minshall, 2011; Mount and Martinez, 2014; Salter *et al.*, 2014; Popa *et al.*, 2017; Bogers *et al.*, 2018; Bagherzadeh *et al.*, 2019).

Recently, a few studies have begun to look beyond one open innovation activity in isolation. They have included two or more open innovation activities (Cheng and Huizingh, 2014; Chesbrough and Brunswicker, 2014; Cano-Kollmann *et al.*, 2017; Podmetina *et al.*, 2018; Stephan *et al.*, 2019; Teplov *et al.*, 2019). For instance, Chesbrough and Brunswicker (2014) only showed the rate of adoption and importance of these activities for firms. Podmetina *et al.* (2018) only studied what can help undertaking these activities without examining the effect these activities have on performance. As for Teplov *et al.* (2019), their study only aimed to compare the perceptions of "open innovation" that are present in both the academic and business worlds. In practice, managers have different open innovation activities they can choose from when implementing open innovation. Therefore, it is important to understand how firms ought to manage openness to different open innovation activities, and their effect on innovation performance.

Even though some studies have started to move from considering one type of open innovation activity in isolation to look at two or more different types of open innovation activities, it is not clear yet in the literature how specific capabilities and routines can support open innovation, and in particular the breadth of open innovation activities, and what can be their effect on innovation outcomes. Accordingly, the first research gap is related to the effect of the breadth of open innovation activities on firm innovativeness. The second research gap is related to the key routines and capabilities that support the breadth of open innovation activities.

By examining these two research gaps, the key antecedents and outcomes of the "breadth of open innovation activities" will be addressed, in order to help begin to close the inbound open innovation implementation research gap in the literature, and at the same time to contribute to practice where open innovation and specifically different open innovation activities are being conducted. For instance, Lego began the "Lego Ideas" that enables them to get open innovation Lego sets. Specifically, Lego consumers can design their own Lego sets. Lego puts the consumer in the heart of the innovation process through a co-created platform, minimising the risk of innovation. The feedback from the website can provide business analysts an idea. Similarly, General Electric (GE) is one of the top companies that have used several open innovation models hoping to address world challenges through the "GE Open Innovation" message. They do so through implementing crowdsourcing innovation. One of GE's projects is the "First Build", which is a co-create collaboration platform. Therefore, companies desire to be at the cutting edge of innovation, executing this through participating in corporate venturing. They invest in external projects and start-ups (Bureau, 2020). Accordingly, beside the theoretical contributions that this research seeks to provide based on the aforementioned gaps, it will also contribute to practice. Different open innovation activities such as idea and start-up competitions, co-creation and crowdsourcing are undertaken by firms, and it is hence extremely important to shed light on the breadth of open innovation activities that companies can undertake, along with the antecedents and outcomes of these activities.

1.5 Overview of the research objectives

Drawing on the theory of dynamic capabilities (Teece *et al.*, 1997; Eisenhardt and Martin, 2000), this study seeks to depart from prior work by emphasising the breadth of openness to a diverse set of nine open innovation activities, which involve: Intellectual property (IP) in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing, customer co-creation in R&D projects and scanning for external ideas (Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). *"A dynamic capability is a learned and stable pattern of collective activity through which the organisation systematically generates and modifies its operating routines in pursuit of improved effectiveness"* (Zollo and Winter, 2002, p. 340). The first research objective of this study is to shed light on the effect of the first-order dynamic capability, represented by the breadth of open innovation activities on firm innovativeness or competitive advantage (Schilke, 2014). The second research objective is to examine the effect of a potential second-order learning routine and capabilities (open innovation antecedents) on first-order dynamic capability, i.e., the breadth of open innovation activities. The four antecedents considered in this study include open innovation training, social information systems capabilities, the anticipation of new technologies, and relational capability. While open innovation training represents a potential second-order learning routine (Nelson Richard and Winter Sidney, 1982; Zollo and Winter, 2002), social information systems capabilities, anticipation of new technologies and relational capability represent second-order dynamic capabilities. These four antecedents potentially support the breadth of open innovation activities, a potential first-order dynamic capability (Ambrosini *et al.*, 2009; Schilke, 2014). As will be shown in Chapters 3 and 4 of this thesis, these four antecedents in particular are among the most fundamental and relevant factors for firms when it comes to implementing open innovation, not yet examined within the breadth of open innovation activities. Therefore, this study seeks to contribute to the implementation literature regarding open innovation by first (a) examining the effect of the breadth of open innovation activities on firm innovativeness, then by (b) studying the effect of key factors on the breadth of open innovation activities.

Based on the aforementioned research objectives, the research questions of this study are as follows:

1) Does the breadth of open innovation activities result in a higher level of firm innovativeness, regardless of the number of open innovation activities undertaken?
2) How do different organisational routines and capabilities affect the breadth of open innovation activities at firm level?

1.6 Overview of the research methodology

Seeking to address the aforementioned research objectives and questions, a "positivist" research philosophy is used in this study. This is to develop the most objective approach possible and get the closest estimation of reality without including the perspective of the researcher in the results obtained (Ulin *et al.*, 2005). Thus, as the researcher seeks to objectively discuss and justify the findings obtained in this study as they are (Marczyk and DeMatteo, 2005; Ulin *et al.*, 2005), "positivism" is highly appropriate for this research. In turn, as positivism is mostly linked to quantitative methods (Cohen *et al.*, 2000) such as questionnaires, used to collect data to test the research hypotheses (Luft and Shields, 2014), this study has adopted a quantitative method of data collection using online surveys as the main method of data collection. Before collecting any data, ethical approval was obtained from Newcastle University. Moreover, prior to collecting this quantitative data, the researcher conducted a pilot test as will be explained in Chapter 4. This pilot test consisted of six pilot interviews to test and revise the conceptual model and refine the research hypotheses and survey of this study. The target sample of this research was high-value manufacturing firms in the UK, and the key respondents were mainly innovation and R&D managers along with any other types of managers that deal with open innovation such as general managers and managing directors. Once the data was collected, all data screening stages were conducted to ensure its suitability for data analysis (Field, 2013; Hair *et al.*, 2014). Then, a confirmatory factor analysis (CFA) was conducted using AMOS 24 statistical software to ensure the fitness of the model. This was followed by the "hierarchical multiple regression" data analysis method that the researcher ran, using the Statistical Packages for Social Sciences (SPSS) software, to analyse the data and test the research hypotheses of this study.

1.7 Overview of the research findings

The findings of this study have filled two important research gaps while also contributing to the open innovation literature through the dynamic capabilities theory. On the first level, the current study revealed that the breadth of open innovation activities is an important first-order dynamic capability that has a positive effect on firm innovativeness. While previous studies on the breadth of open innovation activities as discussed above (Chesbrough and Brunswicker, 2014; Cano-Kollmann *et al.*, 2017; Podmetina *et al.*, 2018; Teplov *et al.*, 2019) have not investigated the effect of these activities on performance, excepting Cheng and Huizingh (2014) who focused on only three open innovation activities, and Stephan *et al.* (2019) on two activities, this study investigated the effect of nine open innovation activities on firm innovativeness.

Nevertheless, this study has also shown that the breadth of open innovation activities is a first-order dynamic capability to some extent: conducting a manageable controllable number of open innovation activities simultaneously provides firms with competitive advantage in terms of firm innovativeness, after which a lower level of firm innovativeness could be obtained if too many open innovation activities are undertaken. The curvilinear effect can be associated with the different challenges that can arise when conducting different types of open innovation activities together, such as knowledge leakage, attention level and the costs of doing different activities (Koput, 1997; Ritala *et al.*, 2015; Bianchi *et al.*, 2016). By studying the effect of the breadth of open innovation activities on firm innovativeness, the current research found a curvilinear relationship (inverted U-shape). Equally important, these findings are in line with previous studies that found a curvilinear relationship, but between the breadth of the search for external partners and innovation outcomes (Laursen and Salter, 2006; Garriga *et al.*, 2013) and between outsourcing and innovation performance (Bianchi *et al.*, 2016).

On the second level, this research found that open innovation training is a second-order learning routine, and social information systems capabilities and relational capability are key second-order dynamic capabilities that support the breadth of open innovation activities. Thus, this study has contributed to the open innovation implementation literature by investigating the effect of the breadth of open innovation activities on firm innovativeness, and by examining the role this routine and capabilities have in supporting the breadth of open innovation

activities. Through the current study, it can be understood that training helps firms undertake different open innovation activities together and understand what is required and expected from conducting each open innovation activity. Training can be a guidance tool to perform these activities effectively and simultaneously. Developed mainly from the use of social information systems such as social media (Kaplan and Haenlein, 2010), social information systems capabilities were found to be crucial capabilities facilitating the process of managing these different types of open innovation activities together. Moreover, the relational capability was revealed to be another essential capability that firms should also create in order to be able to manage, structure and organise their relationships with external partners through different open innovation activities. As will also be shown in this study, these three antecedents do not only support and facilitate the breadth of open innovation activities, but also help in mitigating some of the challenges that can be faced throughout the process, hence their supporting role. The only capability that was not found to have a supporting role in the breadth of open innovation activities was "the anticipation of new technologies". Through these findings, managers can understand better the key routines and capabilities to be developed internally to support the implementation of open innovation at the firm level. The discussion of these results is presented in Chapter 6.

Overall, based on the dynamic capabilities theory, this study has contributed to the open innovation implementation literature. It examined the under-researched effect of the breadth of open innovation activities by showing a curvilinear relationship with firm innovativeness. It has also shed light on specific enabling routines and capabilities that support the breadth of open innovation activities.

1.8 Structure of the thesis

This thesis is structured as follows: Chapter 2 reviews the literature on open innovation in terms of conceptualisations, benefits and limitations. Chapter 2 also focuses on the implementation literature about inbound open innovation to show what has been covered so far and accordingly to identify the main research gaps, objectives and questions of this study. Then follows Chapter 3, which explains the theory of "dynamic capabilities" which this study draws on and its fit with the research objectives of this study. It also includes and explains the conceptual model and the research hypotheses developed to be tested in this research. Chapter 4 explains and justifies the different methods of data collection and analysis used in this study. Chapter 5

shows the results obtained from the data analysis. Regarding Chapter 6, it explains the results of this study and what they have contributed to the literature. Finally, Chapter 7 provides a summary of the findings of this research while presenting the theoretical and practical contributions. It also shows the limitations of this research and suggests areas for further study.

Chapter 2. Literature Review

2.1 Introduction to chapter two

This chapter starts first with "the evolution of the innovation model" to show how the open innovation approach has gradually emerged. It then shows how open innovation differs from the closed type. Then will follow a clear explanation about the fundamentals of open innovation, including its definitions, modes, benefits and challenges. Additionally, this chapter will review the literature on the implementation process of open innovation to show what it has covered so far and what it still lacks. Based on that, the key research gaps, objectives and questions addressed in this study will be highlighted.

2.2 The evolution of the innovation model

In the 1950s, industrial technological innovation was considered to be almost a linear process characterised by scientific discovery, industrial R&D, engineering and manufacturing activities towards a marketable new product or process (Rothwell, 1992). This first generation, or "technology push", model of innovation suggested that "more R&D in" led to "more successful new products out" (Rothwell, 1994). Despite the pioneering work of Carter and Williams (1957), this "technology-push" model of innovation remained until about the mid to late 1960s when new empirical findings started to be published. For instance, Myers and Marquis (1969) mainly focused on the role of the marketplace in innovation. During this period, the linear "market-pull", also known as the "need-pull", model of innovation, as the second generation, started to gain currency. This refers to innovations emerging due to a perceived and sometimes clearly communicated customer requirement. During the 1970s, the linear technology-push and need-pull models of innovation began to gradually be viewed as over-simplified, and atypical examples of a more general process of coupling between science, technology and the market. Then there were developments from the simple linear sequential "technology push" and "need pull" models of the 1960s and early 1970s to the "more interactive coupling" model, representing the third generation of the innovation model. This model was prevalent until the early to mid-1980s. During this latter period, there was a strong focus on an integration across the R&D and marketing interface. Adopting this coupling model presented a catching up of

theory with practice, and was a more realistic, if still oversimplified, conceptualisation of current innovations in firms. The 4th generation or integrated model of the latter half of the 1980s followed. This model showed a move from views of innovation as a strictly successive process, from R&D to prototype development to manufacturing, and to innovation viewed as a largely parallel strategy. During the 1980s, there was a major focus on a closer collaboration with suppliers and leading-edge customers coupled with joint ventures and strategic alliances, which greatly increased. As for the fifth-generation innovation process, a process of systems integration and networking (SIN) illustrated to some extent the idealised development of the integrated model, but with added features, such as much closer strategic integration between collaborating firms. Many of the attributes of this 5th generation model of innovation are also present within innovators that led the fourth generation, such as early and effective supplier interactions, engagement with major customers and horizontal alliances. SIN views innovation as a cross-functional process, and also as a multi-institutional networking process (Rothwell, 1992). The advantages of this model result from the effective and real-time management of information across the entire innovation process, involving internal units, suppliers, customers and collaborators. In this model, the electronic information processing and the more traditional informal face-to-face human interaction complement each other (Rothwell, 1994). Accordingly, in this 5th generation approach, Rothwell (1992) focused on the necessity for more outward emphasis using information technologies. The need for companies to use a more outside-looking focus to their R&D, technology management and new product development was constantly stressed by several scholars. For instance, Tidd (1995) showed how an open and connected model of innovation enables the creation of products and services that cross traditional technological and market boundaries in the home automation sector. Based on that, the open innovation model developed by Chesbrough (2003) emerged in this 5th and most recent model of innovation. The following 2 sections will discuss respectively the drivers of open innovation and how open innovation differs from the closed type.

2.3 The drivers of open innovation

Beside the gradual evolution of innovation through the 5 different models leading to the open innovation approach, there are factors that played a role in the emergence of the open innovation model. As an example, the rise of globalisation and the innovative capability of high-technology start-ups supported by venture capitalists have disrupted the traditional

innovation model of many firms from a closed to an open one (Chesbrough, 2006b). Globalisation has enlarged the extent of the market, which facilitated an increased division of labour, whereas the improved market institutions such as intellectual property rights (the collection of legal doctrines that control the usage of different kinds of ideas (Fisher, 2001)), venture capital, and technology standards enabled firms to exchange ideas (Dahlander and Gann, 2010). In addition, technologies and innovation, including new information and communication technologies, organisational procedures and business models' potential played a role in its emergence (Gassmann and Enkel, 2004). As an example, the information and communication technologies played a facilitating role in Procter and Gamble's open innovation adoption (Dodgson *et al.*, 2006). Therefore, open innovation has been found to be more appropriate in contexts with globalisation, technology intensity, technology fusion, new business models, and knowledge leveraging (Gassmann, 2006). Specifically, new technologies enabled new ways to collaborate and coordinate across geographical distances (Dahlander and Gann, 2010). Moreover, the rising mobility of technical professionals and knowledge workers, as well as the development of a market for technologies ,were among the reasons why the closed approach to innovation has become no longer sustainable in many industries (Gassmann and Enkel, 2004). More particularly, the major reasons behind outsourcing R&D in UK pharmaceutical companies include having access to expertise not available within the firm, minimising development time and expenses, having access to technology competencies and sharing risks (Howells *et al.*, 2008). In addition, other studies found, for instance, that the adoption of a more technologically-advanced innovative approach such as "open source software" supply strategies across software firms is linked to having highly educated employees (Harison and Koski, 2010).

2.4 Differences between the closed and open model of innovation

The traditional closed model of innovation represents a situation where a proprietary innovation is created in-house and both the process and outcome are closed. Through this model, firms create their own ideas, which then they develop, promote, finance and support on their own (Chesbrough, 2003). The open innovation model differs from the closed one in several ways. The main difference is that in the closed approach, the firm is the locus of innovation, and its internal activities are the main object investigated (Chesbrough, 2006b). This could be mainly related to the fact that the closed innovation model stimulates organisations to be highly self-reliant while managing innovation in internal R&D departments

(Chesbrough, 2003). In the closed model, firms develop their own ideas and create them within their boundaries rather than externally (Chesbrough, 2003; Huizingh, 2011; Marques, 2014b). They do not rely on external parties (Chesbrough, 2006b). With such an approach, a firm may miss many opportunities since most of them are outside the firm's existing businesses requiring to be mixed with external technologies to show their efficiency (Huang *et al.*, 2010b). However, in open innovation, external knowledge has an equal role to that of internal knowledge in the closed model of innovation (Chesbrough, 2006b). Firms understand that not all good ideas will be generated from within the firm and not all good ideas developed within it can be successfully marketed internally (Chesbrough and Crowther, 2006). In this open approach to innovation, the focal firm is no longer the exclusive locus of innovation, but external and internal knowledge are similarly significant (Berchicci, 2013).

Another difference is that in the closed innovation approach, firms historically accumulated intellectual property to offer design freedom to their internal staff to prevent costly litigation. In open innovation, intellectual property is a new class of assets that can generate more revenues to the current business model, and also enable entry into new firms and new business models (Chesbrough, 2006b). Accordingly, with open innovation, companies should be both active sellers of intellectual property when it is not appropriate for their business model, and active buyers of intellectual property, when external intellectual property is appropriate (Chesbrough, 2012).

In terms of knowledge and technology flows, closed innovation gave little or no acknowledgement to these purposive outbound flows. However, when it comes to the open approach, enabling outward flows of technologies helps such technologies (with no clear path to market internally) to seek such a path externally. This means that firms in the open innovation approach compete with external channels to market their new technologies (Chesbrough, 2006b). Moreover, they can use internal and external paths to market as they improve their technologies (Chesbrough, 2003).

2.5 Definitions of open innovation

The fundamentals of inter-firm R&D collaboration are dominant in research investigating the involvement of different external partners in innovation, such as suppliers (Hakansson and Eriksson, 1993; Ragatz *et al.*, 2002; Petersen *et al.*, 2003; Handfield and Lawson, 2007), customers (Von Hippel, 1978; Atuahene-Gima, 1995), competitors (Hamel, 1991) and universities (Santoro, 2000). However, the emphasis has mainly been on the function of one type of external partner as befitting particular studies, such as supply chain management (suppliers), marketing (customers, competitors), and research policy (universities, research centres). Therefore, the distinguishing aspects between prior research on inter-firm collaboration approaches to innovation and those of open innovation focus on the significance of striking a balance between the inbound (inflow of knowledge to the firm) and outbound (outflow of the knowledge from the firm) dimensions of open innovation. The only distinctive difference is that in the open innovation approach, ideas can freely "fly in" and "fly out" of the channel, going from opportunity scanning to business incubation. The funnel comprises holes that facilitate the sharing of ideas (Trott and Hartmann, 2009). Carter and Williams (1959) showed that a major characteristic of technically-progressive companies was the quality of incoming knowledge. Thomas Allen's work on "gate-keepers" in the 1960s revealed the significance of good external interactions in obtaining knowledge from outside the firm (Allen and Cohen, 1969). Therefore, firms have integrated resources from external partners for decades, whether through working with suppliers or accessing university research projects. Nevertheless, the use of greater external resources, along with the delivery to others of unused internal resources, has increased in the years that have passed since the publication of Henry Chesbrough's book on open innovation (2003) (Chesbrough and Brunswicker, 2014). Clearly, Chesbrough has been very effective in popularising the concept of technology transfer and the necessity to share and exchange knowledge. In particular, it appeared that from a business strategy point of view, the open innovation concept may have reached new audiences, such as CEOs of technology-intensive firms, that the innovation and R&D literatures failed to grasp for several years. Also, the idea that large multinational firms such as "Procter and Gamble" and "Philips" have integrated the principles of open innovation and stimulated conferences and publications around the field merits admiration and praise (Trott and Hartmann, 2009).

Based on acquiring external knowledge in the innovation process, open innovation was developed by Chesbrough in his (2003) seminal book. He stated that a firm can improve its innovative capabilities through interacting with other firms (Chesbrough, 2003). Several definitions were provided by Chesbrough for open innovation. For instance, open innovation refers to the use and incorporation of external inputs as a methodical and organised form of new product development (Chesbrough, 2003; Chesbrough, 2006b). Beside acquiring knowledge, open innovation is also based on acquiring technologies. It has been defined as an approach considering that companies can and should use external and internal ideas as they seek to advance their technology (Chesbrough, 2006b). Open innovation is *"a distributed innovation process based on purposively managed knowledge flows across organisational boundaries"* (Chesbrough *et al.*, 2014, p. 17). This definition indicates that open innovation is related to the external knowledge obtained and shared beyond a firm's boundaries when undertaking innovation.

There are also other scholars beside Chesbrough who have provided definitions of open innovation. A simple definition is that open innovation represents the flow of ideas into and out of a firm (Sloane, 2011). Open innovation is based on accumulating strategic flexibility in the strategic procedure and developing an important momentum in innovation to generate consumer acceptance and develop industry standards (Gassmann and Enkel, 2004). Open innovation also refers to systematically stimulating and discovering different internal and external sources for innovation opportunities, consciously incorporating that exploration with firm competences and resources, and widely exploiting those opportunities via different channels (West and Gallagher, 2006). In addition, open innovation can be understood in the context of new product development. It is the maintained and systematic approach of being involved in the search for and then incorporation of new product inputs from sources that cross both the firm's boundaries and sometimes technology ones (Sisodiya *et al.*, 2013).

Open innovation is illustrated by two modes (Chesbrough *et al.*, 2006; Gassmann *et al.*, 2010; Huizingh, 2011; Mazzola *et al.*, 2012). In the inbound mode of open innovation, new ideas flow into a firm. Inbound open innovation is based on leveraging the discoveries of others, where firms need not and indeed should not fully rely on their own R&D (Chesbrough and Crowther, 2006). For instance, it is based on leveraging technologies, necessitating the opening up to, and the creation of, inter-organisational relationships with external partners to access their technical and scientific capabilities (Bianchi *et al.*, 2011). Sisodiya *et al.* (2013)

emphasised inbound open innovation as the acquisition and leveraging of external inputs for new product development.

In the outbound mode of open innovation, the internally developed technologies and ideas can be obtained by external organisations with business models that are more appropriate to commercialising a specific technology or idea (Chesbrough, 2003). Firms that develop the outbound procedure as a key, emphasise externalising their knowledge and innovation to take ideas to market more quickly than they could do via internal development (Enkel *et al.*, 2009). Also, outbound open innovation is based on exploiting technology capabilities by adopting not only internal, but also external, tracks of commercialisation (Chesbrough, 2003; Chesbrough and Crowther, 2006). It is based on developing relationships with external partners in which proprietary technologies are used for commercial exploitation (Bianchi *et al.*, 2011). Van de Vrande *et al.* (2009) referred to purposive outflows of knowledge or outbound open innovation as "technology exploitation". This activity represents innovation activities to leverage existing technological capabilities outside the boundaries of the organisation.

The inbound and outbound modes of open innovation were further divided into interactions that are pecuniary and non-pecuniary. The inbound-outbound categorisation was supplemented with monetary (pecuniary) and non-monetary (non-pecuniary) dimensions. When it comes to the logic of exchange, non-pecuniary interactions refer to indirect benefits, whereas in pecuniary ones, money is included in the exchange (Dahlander and Gann, 2010). Taking for instance "free revealing" by Podmetina *et al.* (2018) and Teplov *et al.* (2019), it is an outbound innovation non-pecuniary, based on how internal resources are exposed to the external sources. This activity deals with how companies expose internal resources without immediate financial rewards, seeking indirect profits for the main organisation. As for selling unutilised technologies, it is another form of outbound open innovation, discussed by Podmetina *et al.* (2018) and Teplov *et al.* (2019) as well. Selling in general is an outbound innovation—pecuniary practice that shows how firms commercialise their inventions and technologies by selling or licensing out resources created in other firms (Dahlander and Gann, 2010).

Coupled open innovation was initially viewed simply as a mixture of the inbound and outbound modes (Gassmann and Enkel, 2004). The concept of coupled open innovation evolved to represent the situation where firms actively cooperate to jointly create products or process innovations (Piller and West, 2014). Coupled activities have been extensively investigated,

such as the incorporation of internal and external innovative information (West and Gallagher, 2006) and the coordination of coupled activities among partners (Fang *et al.*, 2008).

As shown in the introduction chapter, firms undertake more inbound than outbound open innovation (Chesbrough and Crowther, 2006; Chiang and Hung, 2010; Bianchi *et al.*, 2011; Chiaroni *et al.*, 2011; Chesbrough and Brunswicker, 2014). Moreover, in a study conducted by Sisodiya *et al.* (2013), the concept of open innovation, at least its inbound mode, was intuitive for the majority of managers. They appeared much more concerned about inbound open innovation and its prospective effects, in comparison to the outbound mode. In contrast, outbound open innovation did not have the same level of attention. Managers rarely referred to their outbound open innovation practices in that study. Accordingly, the current study focuses on the dominant inbound mode of open innovation and the following section discusses the breadth of open innovation activities and sources of openness that define inbound open innovation.

2.5.1 Inbound open innovation

2.5.1.1 The breadth of open innovation activities

Inbound open innovation can be defined in terms of the different types of practices or activities that illustrate the types and nature of external relationships. As highlighted before, open innovation activities have been categorised as pecuniary and non-pecuniary (Dahlander and Gann, 2010; Chesbrough and Brunswicker, 2014). In a non-pecuniary mode of inbound open innovation, firms source external knowledge without providing monetary compensation for ideas and contributions. This can happen when companies are able to access freely revealed knowledge, such as knowledge shared through donations. For instance, “sourcing” is an inbound innovation that is non-pecuniary, and relates to how organisations can use external sources of knowledge. “Acquiring” is an inbound open innovation activity, and is pecuniary. It represents obtaining input for innovation via the market place. Chesbrough and Brunswicker (2014) have also classified other open innovation activities as pecuniary and non-pecuniary ones. Their non-pecuniary inbound open innovation practices cover activities such as customer and consumer co-creation and crowdsourcing. Their pecuniary inbound open innovation activities include IP in-licensing and idea and start-up competitions. All these activities are discussed as well by Podmetina *et al.* (2018) and Teplov *et al.* (2019) as explained below.

During the new product development (NPD) process, the resources in terms of ideas and technologies that firms adopt can already exist within the organisation or can be obtained externally through collaborating with external partners. This collaboration represents the "open innovation" process (Rubera *et al.*, 2016). Laursen and Salter (2014) studied formal collaboration as an inbound open innovation activity, while emphasising the breadth of the company's formal collaboration relationships in innovation. For instance, a firm opens up its strong boundaries to make it possible for valuable knowledge to flow in from the external context to develop opportunities for co-operative innovation procedures (Gassmann and Enkel, 2004).

Beside inbound open innovation activities that are related to external knowledge, there are also different inbound open innovation activities related to technology. Technology exploration and external technology acquisition activities are among the most common and dominant ones in the literature (Veugelers and Cassiman, 1999; Van de Vrande *et al.*, 2006; Van de Vrande *et al.*, 2009; Hung and Chou, 2013; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). For example, "technology exploration" refers to innovation activities to benefit from external sources of knowledge in order to improve current technological developments (Van de Vrande *et al.*, 2009). There have also been other types of inbound open innovation activities related to technology, but they are less common than technology exploration. They include technology scouting, vertical technology collaboration, horizontal technology collaboration and technology sourcing in small-medium sized enterprises (SMEs) (Parida *et al.*, 2012). The aim of technology scouting is to develop an understanding about important patterns of change in the external context (van Wyk, 1997). As for vertical technology collaboration, it captures collaborative relationships with customers or suppliers (Baum *et al.*, 2000), whereas horizontal technology collaboration is about collaborating with partners that do not belong to the value chain of a specific SME (e.g., competitors, non-competitors, large firms or other SMEs). Finally, technology sourcing is an open innovation activity for buying or using external technology via IP contracts (Parida *et al.*, 2012).

Although different studies introduce and define different types of inbound open innovation activities, Podmetina *et al.* (2018) and Teplov *et al.* (2019) present a concise and comprehensive list of inbound open innovation activities that they developed based on Chesbrough and Brunswicker (2014). They sought to group nine different types of activities together in a list instead of having only a few. These activities represent and combine both

technology and non-technology related activities. They include IP in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing, customer co-creation in R&D projects and scanning for external ideas. This list provides a clear classification of the different and novel types of open innovation activities that can occur, other than the most dominant and common ones such as "sourcing" and "acquiring" (Dahlander and Gann, 2010). Table 2.1 below provides a definition for each of these inbound open innovation activities (Podmetina *et al.*, 2018; Teplov *et al.*, 2019). Beside these studies that focused on different open innovation activities, Cheng and Huizingh (2014), Cano-Kollmann *et al.* (2017) and Stephan *et al.* (2019) focused as well on open innovation activities. But each of these three studies did not cover more than two to three open innovation activities such as collaboration, scanning for external ideas, subcontracting R&D, and IP in-licensing.

Table 2.1 Definition of the breadth of inbound open innovation activities

Breadth of open innovation activities	Definition	Key papers
1- Scanning for external ideas	Scanning for external ideas can cover relying on different external knowledge sources, discovering new knowledge fields, creating models that encourage knowledge recombination in product innovation. It can also cover looking for actual innovations, technical inventions or knowledge, market knowledge, or other beneficial information to stimulate business innovation practices.	(Bogers and West, 2012; Laursen, 2012)
2-Crowdsourcing	Crowdsourcing is based on outsourcing a task to a "crowd," and not to a designated "agent" such as a contractor, in the form of an open call. It also refers to outsourcing innovation problem solving for scientific issues as well through open calls to outside firms to present and propose ideas.	(Howe, 2006; Howe, 2008; Jeppesen and Lakhani, 2010; Afuah and Tucci, 2012; Chesbrough and Brunswicker, 2014)
3-Idea and start-up competition	Idea and Start-up competition refers to the invitation to entrepreneurial	(Chesbrough, 2006b; Van de Vrande *et al.*, 2006; Chesbrough and Brunswicker, 2014)

	teams and start-ups to present business ideas through open competitive calls, with collaboration with and venture support for winning groups.	
4-Using external networks or "external networking"	External networking incorporates all activities to obtain and sustain connections with external sources of social relations. It also involves both formal collaborative projects and more general and informal networking activities. Additionally, it includes a set of relationships that link a group of independent firms together.	(Gulati, 1998; Chesbrough *et al.*, 2006; Vanhaverbeke, 2006; Nieto and Santamaría, 2007; Zhou *et al.*, 2007; Van de Vrande *et al.*, 2009; Zeng *et al.*, 2010)
5-Collaborative innovation with external partners or collaborating	Collaboration refers to the cooperative creation of knowledge through relationships with external partners. It can also be viewed as close, functionally inter-reliant interactions characterised by common influence, open and direct communication, support for innovation and experimentation, as well as the objective of developing beneficial outcomes for all participants.	(Meyers and Athaide, 1991; Udwadia and Kumar, 1991; Hagedoorn, 1993; Baum *et al.*, 2000; Jap, 2001; Athaide *et al.*, 2003; Faems *et al.*, 2005; Laursen and Salter, 2006; Lee *et al.*, 2010; Laursen and Salter, 2014)
6-Customer co-creation in R&D projects	Co-creation in general is defined as *"the practice of developing systems, products, or services by a firm through collaboration with customers, managers, employees, and other company stakeholders".* As for customer co-creation in R&D projects, it is the engagement of consumers or customers in the creation, assessment, and testing of new ideas for products and services.	(Prahalad and Ramaswamy, 2004; West and Gallagher, 2006; Ramaswamy and Gouillart, 2010; Chesbrough and Brunswicker, 2014)
7-External technology acquisition	External technology acquisition is related to the absorption of external technologies, such as through in-licensing agreements or strategic alliances.	(Pisano, 1990; Granstrand *et al.*, 1992; Kurokawa, 1997; Lane and Lubatkin, 1998; Veugelers and Cassiman, 1999; Jones *et al.*, 2001; Edler *et al.*, 2002; Chesbrough, 2006c; Van de Vrande *et al.*, 2006)
8-Subcontracting R&D	Contracting mechanisms are related to acquiring knowledge on a market basis, which can be referred to as "the buy decision".	(Prahelad and Hamel, 1990; Ulset, 1996; Mangematin and Nesta, 1999; Veugelers and Cassiman, 1999; Beneito, 2006; Santamaría *et al.*, 2009)

9-IP in-licensing	IP in licensing refers to the licensing of external intellectual property rights such as trademarks and patents through formal licensing contracts.	(Chesbrough, 2006b; Chesbrough and Brunswicker, 2014)

2.5.1.2 Sources of openness

When firms undertake inbound open innovation activities, such activities illustrate interactions with different types of external partners. Therefore, inbound open innovation is also defined in terms of sources of openness, which are investigated much more in the open innovation literature in comparison to the breadth of open innovation activities.

Open innovation focuses on the significance of using a wide variety of knowledge sources for a firm's innovation and invention activities (West and Gallagher, 2006). Inbound open innovation, the most dominant type of open innovation, is largely defined in terms of the breadth of firms' search for different types of external partners (Laursen and Salter, 2006; Bianchi *et al.*, 2011; Garriga *et al.*, 2013; Brunswicker and Vanhaverbeke, 2015; Cano-Kollmann *et al.*, 2017). Based on Katila and Ahuja (2002), Laursen and Salter (2006) discussed the different sources of openness through the concepts of "external search breadth" and "external search depth". The external search breadth represents the number of external sources or search channels that companies refer to in their innovative activities (Laursen and Salter, 2006; Laursen and Salter, 2014). The purpose of the external search breadth is to seize the firm's openness to external knowledge (Laursen and Salter, 2006). Additionally, Laursen and Salter (2006) have discussed the external search depth in relation to the extent to which companies draw deeply from these different external partners or search channels (Laursen and Salter, 2006). This means that the level of cooperation and integration between the main firm and external partners includes the depth dimension, based on which managers can legislate for an appropriate implementation of inbound open innovation (Bahemia and Squire, 2010). Rooted in networks via geography, prevailing industry relationships, and with public research networks, companies have the chance to use networks as an external source of knowledge. They can also use them as enablers to stimulate the commercial success of their own internally and externally acquired innovations (Vanhaverbeke, 2006).

In particular, the external sources or search channels can include suppliers (Li and Vanhaverbeke, 2009; Schiele, 2010), customers (Gassmann *et al.*, 2005; Grimpe and Sofka, 2009), research institutions (Perkmann and Walsh, 2007), competitors (Lim *et al.*, 2010), universities (Fabrizio, 2009; Cassiman *et al.*, 2010) and users (West and Lakhani, 2008). Beside these most common types of external partners, there are also a few other studies on

open innovation that have investigated other types of partners. In their conceptual paper, Bahemia and Squire (2010) included three new types of external parties, consisting of small players such as start-ups, entrepreneurs, and individual innovators, followed by the open innovation intermediaries and members of the public (networking sites such as Facebook and Twitter). Specifically, intermediaries have developed as as a vital actor in the open innovation network supporting innovating companies to look for information about possible collaborators in the network (Verona *et al.*, 2006; Sieg *et al.*, 2010).

Similarly, Chesbrough and Brunswicker (2013) studied internal employees, contracted R&D service providers, external consultants, restricted communities and unrestricted communities as other types of sources. Open innovation communities are a continuing voluntary association of people or even firms that are managed or leveraged by for-profit actors (West and Lakhani, 2008). They are different from networks in that they have membership, identity, and group loyalty (Von Hippel, 2007). There are also other types of external partners that can be used in open innovation, such as "experts on intellectual property rights" and "network partners" (Brunswicker and Vanhaverbeke, 2015). Also, beside discussing openness in terms of open innovation activities as noted before, Cano-Kollmann *et al.* (2017) relied on openness in the context of external partners as well. The way they referred to open innovation partners in their study was as follows: "partnering or collaborating with the original developer/supplier of the products/processes", and "partnering with experts such as consultants, universities, etc.", among a few others that they also included in their list.

Based on the aforementioned definitions, inbound open innovation represents an inbound flow of knowledge into the firm through undertaking different types of activities with external partners. The majority of the studies define inbound open innovation in the context of external partners (i.e., sources of openness) with many fewer studies in the context of the breadth of activities. A few studies have discussed open innovation activities, as highlighted before, but without much emphasis and elaboration in comparison to the sources of openness. They simply highlighted a few activities and defined them. Furthermore, as will be shown in the following sections of this chapter, the effects and implementation process of inbound open innovation research have mainly defined inbound open innovation in terms of partners or one type of inbound open innovation activity in isolation rather than different open innovation activities undertaken simultaneously (i.e., breadth of open innovation activities). Only a few academics such as Cheng and Huizingh (2014), Cano-Kollmann *et al.* (2017) and Teplov *et al.* (2019)

have discussed the breadth of open innovation activities. However, their studies are still underdeveloped and require further attention in terms of the implementation process and effects of open innovation, as will be shown later in this chapter.

Defined in terms of the breadth of open innovation activities and sources of openness, both conceptualisations of inbound open innovation present advantages. In fact, searching broadly and deeply in different search channels, and collaborating with different types of external partners, have positive effects on performance at both the firm and project levels (Laursen and Salter, 2006; Leiponen, 2012; Garriga *et al.*, 2013; Salge *et al.*, 2013; Love *et al.*, 2014; Bahemia *et al.*, 2017). The following section will discuss the benefits of inbound open innovation.

2.6 The benefits of inbound open innovation

2.6.1 Firm level

The literature mainly shows the benefits of inbound open innovation, being the most highly adopted mode of open innovation among firms (Chesbrough and Crowther, 2006; Chiang and Hung, 2010; Bianchi *et al.*, 2011; Chiaroni *et al.*, 2011; Podmetina *et al.*, 2016). In inbound open innovation, a firm's knowledge base gets deeper by incorporating external partners (Chesbrough and Prencipe, 2008). An open model to exchange knowledge can greatly enlarge and speed up a business's innovative potential (Chesbrough, 2006b). This model contributes to business growth by making it possible for firms to leverage ideas from different external partners (Huang *et al.*, 2010b). Accordingly, firms have to identify the breadth of external knowledge sourcing that increases their performance (Laursen and Salter, 2006). The capability of firms to tap into the knowledge base from multiple and diverse external sources improves their innovation performance (Laursen and Salter, 2006; Leiponen and Helfat, 2010; Leiponen, 2012; Roper and Arvanitis, 2012; Love *et al.*, 2014). In effect, openness to external sources helps businesses to obtain ideas from external sources to enrich the pool of technological opportunities available to them. For example, "experts on intellectual property rights" can give companies important information that enables them to close the gap between a technological opportunity and its successful commercialisation (Bessant and Rush, 1995). They can help with searching for technological trends and ideas outside the business's boundaries regarding the way to appropriate value from a company's knowledge assets

(Bennett and Robson, 2005; Vega-Jurado *et al.*, 2008). In addition, "network partners" provide SMEs, for instance, with access to matching innovation assets and operational matching assets, such as manufacturing, marketing, and access channels (Christensen *et al.*, 2005).

The effect of the external search breadth and depth was not only studied on innovation performance, but also on different types of innovation (Laursen and Salter, 2006). The external search depth is linked to radical innovation. In the initial phases of the product life cycle, when the state of technology is in flux, innovative firms have to rely strongly on a small number of sources of innovation, such as lead users, component suppliers, or universities. In such phases, only a few actors may have knowledge of the main technologies underlying the evolution of the product. As the technology and market develop and the network supporting innovation gets larger, more and more actors inside the innovation system preserve specialist knowledge. Thus, to access the variety of knowledge sources in these networks, innovative firms have to scan across a broad number of search channels. This relates to the fact that reaching a wider more varied range of external partners, local and distant, offers more inspiration and diverse problem-solving and collaborative innovation activities (Meulman *et al.*, 2018). In that way, firms find new mixtures of current technologies to help them make significant enhancements in their current products (Laursen and Salter, 2006).

More specifically, "learning" benefits emerge from external partners (Love *et al.*, 2014). With time, firms can have larger payoffs from innovation linkages compared to the previous period since they are now able to better identify and choose productive linkages through their learning from previous experience. These activities are likely to be subject to a "learning process" as over time firms explore which knowledge sources and linkages are most appropriate to their specific requirements. This in turn enables firms to manage these relationships adequately and have a high innovation performance.

The external partners also tend to have effects on firm performance through different sourcing strategies. These strategies can involve minimal searchers, supply-chain searchers, technology-oriented searchers, application-oriented searchers, and full-scope searchers. Each of these strategies illustrates a combination of interactions with external partners that include direct customers, indirect customers, suppliers, universities/research organisations, intellectual property rights experts, and network partners. Minimal searchers are not highly involved in interactions with external sources to combine internal and external ideas. They neither interact

with customers and suppliers, nor with scientific sources of knowledge. As for the supply chain searchers, they interact closely with direct customers and suppliers, whereas technology-oriented searchers interact more with indirect customers and users as the most important sources for them. Regarding full-scope searchers, they search for different sources of external knowledge, such as market, technology and scientific knowledge. Application-oriented sourcing on the whole refers to distant partners in the value chain, such as indirect customers. A full-scope sourcing strategy, for instance, leveraging the whole ecosystems for new information, provides the best opportunities for a higher income from innovation over a minimal sourcing strategy, whereas application-oriented sourcing can drastically enhance the success in commercialising individual innovation projects. It is also superior to a full-scope sourcing strategy. As application-oriented sourcing is an alternative smart shift to improve innovation success, full-scope sourcing is based on very deep collaborations with different sources. Application-oriented sourcing represents an alternative "smart" move to improve innovation success. As full-scope sourcing focuses on very deep, synergetic relations with different sources, an application-oriented approach is more selective. Application-oriented searchers do not increase relations in all directions. However, instead they emphasise relations with distant partners in the value chain when moving beyond interactions with direct customers and suppliers (Brunswicker and Vanhaverbeke, 2015).

In all, searching profoundly enables firms to develop patterns of interaction and common understanding between collaborators, which have been found to be important in developing trust, improving communication and obtaining better performance (Dyer and Nobeoka, 2000; Meek *et al.*, 2011; Chen *et al.*, 2013). In turn, the knowledge obtained through the searching process enables firms to develop new offerings based on new mixtures of technologies and markets, increasing their innovation performance (Cheng and Huizingh, 2014).

In relation to technology-related inbound open innovation activities defined before, they also present benefits, for SMEs in particular (Parida *et al.*, 2012). Taking technology scouting, it does not only have a positive effect on innovation performance, but also a low cost and can be adopted regardless of the innovation ambition of the firm. This type of activity has many advantages, such as fast exploration of emergent technologies, strength of approach when faced with changing terminologies, depth of information on emergent technologies, and support for technologies by outside sources. Nevertheless, such activity may result in negative performance outcomes as it can lead to the exploration of many ideas (Frishammar and Åke

Hörte, 2005). In relation to vertical technology collaboration, it captures collaborative relationships with customers or suppliers (Baum *et al.*, 2000). This type of activity is seen with current customers, potential customers, and end users. As for horizontal technology collaboration, it is related to collaborating with partners that do not belong to the value chain of a specific SME. Thus, this type of activity may have a negative impact on firm performance. In fact, forming strategic alliances with partners beyond the value chain can lead to greater transaction costs since collaborating partners may free-ride through limiting their contribution to collaboration (Prahalad and Hamel, 1994; Bradley *et al.*, 2006). In terms of technology sourcing, many SMEs can benefit from this activity as they have some problems of shortened product life cycles, fast developments in technologies, and lack of capital. In all, the adoption of these open innovation activities is positively related to at least one aspect of innovation performance and with no negative effect. These activities also had specific effects on the type of innovation. In particular, if the main SME is leaning toward new-to-the-industry types of innovation (incremental innovation) that include lower levels of investment, then much can be earned through collaborations with partners outside the value chain (Parida *et al.*, 2012).

Beside the advantages of open innovation at the firm level, there are also benefits for open innovation at the project level, discussed in the next part.

2.6.2 Project level

The few studies that have investigated the benefits of open innovation at the project level mainly defined open innovation in terms of the breadth of external partners. Again, they have not given enough insights into the critical success factors, i.e., enabling capabilities that can support open innovation. Some of them have shown the benefits while considering NPD stages, the timing of openness (Salge *et al.*, 2013; Bahemia *et al.*, 2018) and types of external partners (Du *et al.*, 2014).

Generally, companies that have a varied innovation network of different external partners, involving suppliers, customers and universities, have a better turnover from both technologically new and better products (Faems *et al.*, 2005; Zeng *et al.*, 2010). In fact, network heterogeneity gives access to different sources of knowledge, which can be mixed to create more innovative products in comparison to those created with single partner collaborations (Nieto and Santamaría, 2007). Bahemia and Squire (2010) studied specifically NPD projects, considering that diminishing outcomes, at the firm level, probably result from the long run

increasing impacts of opening up the innovation process too far at the project level. As for Bahemia *et al.* (2017), they found that benefits from involving different types of external partners in the NPD project develop only in the presence of a strong appropriability regime (Laursen and Salter, 2014). An appropriability strategy includes the utilisation of formal approaches, such as patents or trademarks, and informal ones, such as secrecy or lead times. A strong appropriability regime is a facilitator to the involvement of different types of external partners in innovation projects based on products that are new to the market or industry.

NPD stages were also found to have a role in the benefits of open innovation at the project level. Gradually, this search for new ideas stretches beyond firm boundaries to create new NPD ideas by leveraging, incorporating, or recombining ideas and knowledge of external partners such as customers, suppliers, competitors, or universities. For example, in the health care industry, referring to patients at the ideation phase can offer the NPD project important information on favoured attributes of clinical and nonclinical services. In particular, moderate rather than very low or very high levels of search openness at the ideation stage of NPD projects are likely to be most favourable for new product creativity and success (Salge *et al.*, 2013).

Another factor similar to NPD stages was also investigated. It represents the "timing of openness to external sources of knowledge", which has been identified among the main project processes affecting the capability of a firm to boost its profits from the project innovation (Bahemia *et al.*, 2018). Bahemia *et al.* (2018) found that benefits can be obtained at the project level but not at an early phase. The company investigated in their study prevented the trap of early openness by cautiously closing rather than opening the innovation approach to any external sources in the early phases of the project. This is because, as per the profit from the innovation model, the absence of any intellectual property protection facilitates the imitation in the early phases of the project. However, as the project was developing into further stages, higher innovation speed mixed with the necessity for complementary capabilities drove the transition from a closed to an open innovation facilitated by the active change in the intellectual property position, i.e., patent submission, from a weak to a strong position. This presented the investigated firm with appropriate protection against opportunism, and in consequence, reinforced its capability of profiting from innovation prior to its interaction with external sources of knowledge (Bahemia *et al.*, 2018).

Beside timing and NPD stages, "types of partners" were studied in terms of effect on project financial performance, with the moderating role of project management. It was found that R&D projects with open innovation partnerships result in a higher financial performance as long as they are adequately managed. Despite some differences between science-based and market-based partners, they both result in greater financial revenues for R&D projects (Du *et al.*, 2014). Science-based partnerships are shaped by the scientific research conducted at universities and knowledge institutes as a significant input for innovation conducted by firms (Narin *et al.*, 1997; Cockburn and Henderson, 1998). In relation to market-based partnerships, they are composed of sources that are closely related to markets, such as suppliers and customers (Danneels, 2002). By offering the project team the newest market information, market-based partnerships guarantee that market demands are considered and that the innovation in progress will satisfy customers' needs. In fact, those types of partners have lots of information about customer requirements and market trends, giving information about up to date market knowledge. This can increase the market success probability of developed technologies. Moreover, they give information to the business concerning market trends and customer requirements. Subsequently, a greater idea about the market contributes to a more accurate estimate of business opportunities, hence less failure in the market, leading on average to greater business value of knowledge transfers (Vanhaverbeke *et al.*, 2014). In contrast to market-based partners, science-based partners provide scientific knowledge to the R&D project. They may also be used to reach advanced and expensive scientific equipment and research services to do state-of-the-art research (Leten *et al.*, 2013). Thus, both science and market open innovation partnerships offer project teams important learning opportunities to create revenue-generating innovations (Du *et al.*, 2014).

Although customers help firms to reach a wide set of expertise and help in seizing many innovative ideas, they may not have a conceptualisation of the resources required for their proposals. They may experience difficulties in expressing the underlying tacit knowledge in relation to the potential innovation, something which science-based partners are much better at (Katila and Mang, 2003). Science-based partnerships necessitate a less formal project management to be efficient because formal and strict management restrains experimentation, and mitigates the advantages of partnering with science-based sources. Thus, different types of partnerships have different effects on project performance, with different project management tactics also. Market-based partnerships have a positive effect on project performance for projects that are formally managed, and in turn, a negative effect on performance for those that

are carelessly managed. In relation to science-based partnerships, they have a positive effect on financial performance for inadequately managed projects (Du *et al.*, 2014).

Technology partners also present benefits in open innovation at the project level. As an example, collaborating with technology partners can increase the chance of project success. This means that the scientific knowledge given by technology partners complements the applied knowledge of project teams. As a matter of fact, working simultaneously on several tasks leads to a higher project development speed. These types of partners also provide project teams with (basic) scientific knowledge, which is complementary to the applied knowledge of project teams. In fact, partnerships with complementary partners facilitate the partition of project tasks among partners and the division of labour. Moreover, collaboration with those types of partners can result in the creation of new platform technologies, drawing on the newest scientific insights (Vanhaverbeke *et al.*, 2014).

In all, using technology-based and market-based collaboration together may also be useful. There will be more chance for business success when both technology-based and market-based collaboration are mixed. This is because the product is based on both prominent scientific understandings and technologies with a detailed clarification of market trends and requirements. Nevertheless, there is always a drawback. R&D projects where both technology and market partners are incorporated can be more complicated and difficult to control in comparison to closed innovation projects, or those that only involve one type of partner. The reason is related to the fact that such types of partners each have a different nature and their objectives and working habits are not the same (Vanhaverbeke *et al.*, 2014).

Despite its benefits, open innovation presents some limitations and challenges that may obstruct companies when seeking to undertake an inbound open innovation strategy. The next section will discuss the shortcomings of open innovation.

2.7 The limitations and challenges of inbound open innovation

2.7.1 Negative effects on innovation performance

Despite the positive effect of open innovation on firm innovation performance, the advantages of openness may turn into decreasing returns (Laursen and Salter, 2006; Leiponen and Helfat, 2010; Garriga *et al.*, 2013; Salge *et al.*, 2013). Innovation search is costly and can waste time. In addition, there is a point where further search becomes unproductive. Laursen and Salter

(2006) study confirmed Katila and Ahuja (2002) results that "over-search" can definitely obstruct innovation performance. There is some time after which breadth and depth can negatively influence innovative performance. Despite the support of Laursen and Salter (2006) for the optimistic view of search in terms of generating new innovative opportunities, they also claimed that the enthusiasm for openness has to be moderated by an understanding of the expenses of this search. In other words, external sources have to be managed cautiously so that search efforts are not dispersed across several search channels (Laursen and Salter, 2006). Equally important, as coordination via knowledge matching is vital regardless of the number of types of partners, higher partner breadth leads to more divergent motivations to contribute, necessitating the presence of project management to ally and manage the partners (Lakemond *et al.*, 2016).

Similar to what has been found at the firm level, that open innovation may also lead to a negative performance, this risk is also present at the project level. This indicates that not only little, but also a great deal of search openness can be harmful for new product creativity (Salge *et al.*, 2013). One justification could be that non-monetary search expenses can increase fast as project members widen their search. Besides, finding, accumulating and utilising more and more distant and varied knowledge inputs will be progressively challenging (Laursen and Salter, 2006). For example, distant search, as a conscious effort to go beyond the company's existing knowledge base, is more expensive and risky in comparison to local search (Meulman *et al.*, 2018). In turn, new product success can be affected by the monetary expenses related to search openness, such as more staff, training and traveling, which can increase with more search openness, and which can have a gradually negative impact on the overall economic viability of an NPD project (Salge *et al.*, 2013). At the same time, local search activities are self-reinforcing and may lead to myopic behaviours that minimise the diversity of resources and undermine firm competences to create successful innovations (Cohen and Malerba, 2001). Based on these constraints, there may be an ideal level of search openness with declines in new product creativity to avoid the negative effect (Salge *et al.*, 2013). Both financial and human resources have an important role in enabling in-sourcing companies to profit from external knowledge through launching new products and increasing revenues from these new products (Monteiro *et al.*, 2017).

2.7.2 Not-invented-here and not-shared-here syndrome

Two of the most important challenges in open innovation are the negative attitude towards the utilisation of external knowledge represented by the not-invented-here (NIH) syndrome and the negative attitude against the external exploitation of knowledge assets, which is the not-shared-here or not-sold-here (NSH) syndrome (Katz and Allen, 1982; Chesbrough, 2003). Even though related to each other, the NIH and NSH syndromes are different concepts, since they are oriented towards different objects, specifically external knowledge acquisition (inbound) and external exploitation of knowledge (outbound). The NIH syndrome, the most important challenge for open innovation (Chesbrough and Crowther, 2006), represents some knowledge that has been created outside the firm and that can be potentially appropriated and applied internally (Katz and Allen, 1982). Thus, this challenge results in high resistance to open innovation (Mortara *et al.*, 2009).

The NIH syndrome can influence the actual behaviour, referring to the extent to which employees search outside their firm for new technologies, gather industry information, get in touch with external institutes and collaborate with partners to collect knowledge. An employee is thus less likely enthusiastically to try to insource external knowledge if he/she is not favourable to it (de Araújo Burcharth *et al.*, 2014). Employees often feel threatened by new ideas from external parties and, hence, tend to undervalue them in order to stimulate internal projects and in-house capabilities. This means that a kind of knowledge provincialism can arise within firms with NIH tendencies (Reitzig and Sorenson, 2010). This is where firms consider it more legal and prestigious to develop new knowledge in-house instead of reusing knowledge developed somewhere else (Michailova and Husted, 2003). Therefore, de Araújo Burcharth *et al.* (2014) found that the NIH syndrome inhibits the adoption of inbound open innovation. However, they also argued that the negative effect of each of the NIH and NSH syndromes' negative effects can be mitigated through competence-building programs based on the training of employees.

2.7.3 Knowledge leakage risk

Another major challenge in open innovation is the potential of knowledge leakage, through which knowledge flows outside the firm boundaries in an inappropriate and undesired way (Ritala *et al.*, 2015). In such situations, knowledge that firms would prefer to keep private and confidential is accidentally or intentionally exchanged (Ritala *et al.*, 2015). As managers use an open innovation strategy in their firms through getting involved with a wide set of external partners for knowledge exchange, they have to protect their own knowledge from rivals' imitation (Laursen and Salter, 2014). This illustrates a clear paradox, that openness may require more attention to protection. Paraphrasing Arrow (1962), Laursen and Salter (2014) refer to this as the "paradox of openness".

Being able to know where a company emphasises its innovative practices can offer significant information to competent competitors on how to manage their own search activities and reach the same markets (Laursen and Salter, 2014). While revealing internal knowledge, rivals may be better positioned with complementary resources and production facilities to benefit from the technological progress. Thus, it is difficult to be able to determine which internal knowledge to reveal or share with external partners (Dahlander and Gann, 2010). Moreover, as the lack of any intellectual property protection facilitates imitation at the beginning of the project, markets do not work efficiently and the profits from the innovation may increase for others (partners) and not for the focal firm or innovator (Bahemia *et al.*, 2018). For this reason, understanding the disclosure paradox requires attention to the means of appropriability in open innovation. To deal with this paradox, companies often need inventors to have formal intellectual property rights (IPR) appropriately prior to working with others (Dahlander and Gann, 2010). A form of formal intellectual property protection such as the receipt of patents results in open innovation activities of new entrants in a systemic innovation. As new entrants collect patents, they can increase their number of new open innovation interactions, hence enabling their access to complementary resources (Zobel *et al.*, 2016).

However, an extreme focus on appropriability can be linked to lower efforts to rely on knowledge from several external partners in formal collaborations (Laursen and Salter, 2014). Similarly, Monteiro *et al.* (2017) found that the use of secrecy (one form of appropriability) negatively moderates the relationship between openness to external knowledge on innovation performance. This is because sharing knowledge may be mismatched with secrecy sometimes.

Thus, a trade-off is necessary between the two, as they are opposing mind-sets. To profit from relational knowledge sharing, trust and reciprocity are required by firms. If one of the partners seeks to keep their own knowledge secret, the creation of these behaviours will be obstructed (Monteiro *et al.*, 2017).

Despite the fact that these limitations and the challenges of open innovation discussed above tend to be the most common, there are also other challenges that emerge in open innovation, such as low reciprocal commitment, lower social unity and unsafe learning environments, high diversity and cognitive distances, high uncertainty, scarce resources, lack of traditional hierarchical lines, and power differences (Chatenier *et al.*, 2010).

Although open innovation has some obstacles, many companies nowadays are implementing this strategy. Regardless of their size, firms are not able to rely only on their internal capabilities to stay up to date in terms of market and technology changes. They need to interact with different types of external partners through different open innovation activities for better innovation outcomes.

A key understanding in the open innovation strategy that is still not clear in the literature is how companies get ready and prepare themselves for inbound open innovation in terms of facilitating capabilities to be able to do it successfully and overcome its challenges. This is an important question in the implementation literature on open innovation that has still not yet been properly addressed. Some studies have examined the implementation of open innovation, but did not give a clear picture of the implementation process, and did not study the real effect of the effective preparation on the innovation outcome. Some of them studied a neighbouring process to open innovation, such as external collaboration or external knowledge exploration/acquisition, or defined open innovation in terms of external partners. The following section will focus mainly on the implementation of inbound open innovation to show what the current research has covered so far and to reveal what is still missing and that needs to be clearly investigated in this literature.

2.8 The implementation of inbound open innovation

Being a strategic process, the implementation of open innovation necessitates developing new mechanisms and processes to organise the external collaborations and acquire ideas from external partners (Di Minin *et al.*, 2010). The literature regarding the adoption of open innovation (a firm's use of internal and external resources in their innovation process (Mortara and Minshall, 2011)) by firms is developing rapidly and several journals have created special issues to publish useful reviews of open innovation literature in the innovation management area (Enkel *et al.*, 2009; Giannopoulou *et al.*, 2010; Van de Vrande *et al.*, 2010; Huizingh, 2011). However, before studying adoption, studies should focus first on "implementation" to show how firms can prepare to undertake an open innovation strategy, in terms of the development of the relevant capabilities. Studies on open innovation adoption do not give insights into the implementation process as they simply gave a general idea of environmental and emerging factors or reasons and obstacles associated with the adoption of open innovation in firms. There should be a better understanding of the implementation of open innovation.

Despite the emergence of the open innovation model and its dominance in many firms these days, not all companies have moved to an open innovation approach. Many were still using the closed model of innovation. Some others were opening up but to a limited extent. Moreover, different firms can be located on a continuum, from fundamentally closed to fully open. For example, the nuclear-reactor industry relies majorly on internal ideas and has low labour mobility, low venture capital, few and weak start-ups and fairly little research occurring at universities (Chesbrough, 2006c). Both the nuclear and military industries represent archetypal examples of closed innovation industries (Gassmann, 2006). Thus, before discussing the implementation process of open innovation, it is worth showing the different types of open innovation adopters just to show how firms shifted from a closed to an open model of innovation in terms of the extent and timing of openness.

Through reviewing 43 large multinational firms in a broad range of sectors, Mortara and Minshall (2011) identified four types of open innovation adopters. Such types are open innovation conscious adopters, ad-hoc adopters, precursors, and communities of practice. Starting with the open innovation conscious adopters, this type is highly populated by fast moving consumer goods firms, who adopted open innovation as a result of the popularity of Chesbrough's model through his book in 2003. They focus majorly on inbound open

innovation to support their current innovation pipelines, whilst the outbound model is restricted in number and scope. As for the open innovation ad-hoc adopters type, it is populated by firms that adopted open innovation only in specific functions and situations, in part of the company or for particular products or innovation processes for which they found connecting with the outside environment useful. This type of adopters has not yet created any coherent plan to roll out open innovation across the firm (Mortara and Minshall, 2011). Mortara and Minshall (2011) have also found other examples in this particular category, where firms implemented open innovation only for early stage research while the rest of the firm remained more closed. In relation to the open innovation precursors, they adopted open innovation gradually. However, they have a very long history of incorporating internal and external resources, adopting open innovation practices throughout the firm many years before the open innovation term was created. They also described their paths as a progressive transformation in response to changes in their external environment. Finally, the open innovation communities of practice emphasise mainly inbound activities. Innovation managers from R&D and procurement functions in firms falling into this quadrant see the implementation of open innovation as a means to satisfy their difficult innovation objectives. To keep on growing, they feel there is a necessity for greater effectiveness in tapping into outside capabilities. They have a recent adoption of open innovation as a conscious innovation approach, even though collaboration with suppliers and universities preceded this decision (Mortara and Minshall, 2011).

Based on the classification of these types of open innovation adopters, it is vital to understand what organisational capabilities and routines firms develop to make the transition towards an open innovation strategy. When managing external linkages, learning develops through the creation of organisational routines and developments in managerial cognition with time. As firms create mechanisms and routines for managing innovation relationships with external partners, they learn to manage their current external relationships more appropriately, resulting in greater outputs from the breadth of linkages in the next periods (Love *et al.*, 2014). Despite the importance of understanding the drivers, conceptualisations, benefits, limitations and challenges of open innovation, it is also extremely important to understand which enabling factors facilitate inbound open innovation. This represents the main research gap in the implementation of open innovation literature. There are very few studies that examine the process that results in open innovation; i.e., the implementation process (Huizingh, 2011).

Focusing on the dominant firm level, Kirschbaum (2005) discussed how a multinational life sciences and performance materials firm prepared for open innovation through developing a new business group, committing a specific amount to some relevant venture capital funds to increase their contacts with innovative regions worldwide, and participating in different start-up firms externally and internally. Swarovski, for example, demonstrated that being on the journey to open innovation helped them to manage both structural and capability rigidity through opening their firm boundaries and undertaking both exploration and exploitation (Dąbrowska *et al.*, 2019). Other studies on implementation have identified, for instance, top management support, organisational learning culture, and open innovation training as enabling competencies to support open innovation initiatives at the firm level in large companies (Mortara and Minshall, 2011; Salter *et al.*, 2014). Some studies, as will be discussed below, have shown what may support the implementation of open innovation. However, they did not investigate the benefits of open innovation implementation in terms of innovation performance, for instance (Podmetina *et al.*, 2018). Some of the studies on open innovation were mainly derived from case studies and/or interviews, meaning that it is not possible to generalise more from the results.

The next section will show what the current open innovation implementation studies at the firm level, being the most common and dominant level, have covered so far, based on which it will be possible to identify what are the research gaps, objectives and questions that this study addresses.

2.8.1 Review of the current studies on open innovation implementation

Starting with practices and structures developed by firms, there are some studies investigating practices and specific factors that can facilitate open innovation. However, most of these studies conceptualise open innovation broadly without a specific conceptualisation, and are based on qualitative work. In qualitative studies, the effect on firm performance could not be as accurately assessed as in survey-based studies or simply was not examined at all. It is normally slightly difficult to assess the effect on innovation outcomes in qualitative studies where the level of precision will not be the same as with surveys. Nevertheless, it is worth highlighting that the main aim of different qualitative studies on open innovation implementation was to highlight the main factors that support open innovation in generating positive outcomes for the firm (Mount and Martinez, 2014; Salter *et al.*, 2014; Dąbrowska *et al.*, 2019), hence providing rich insights into the benefits and/or drawbacks generated from

open innovation. However, in survey-based studies, performance can be even more easily and precisely measured, and is operationalised with specific items that represent the performance construct investigated. Equally important, this helps in generalising more from the findings. Moving from a closed to an open innovation model incorporates inter-organisational networks, new organisational structures, evaluation processes and knowledge management systems (Chiaroni *et al.*, 2010). Another similar study which adopted an in-depth case study method examined how a firm in a mature industry adopts its organisational and managerial systems to implement inbound and outbound open innovation (Chiaroni *et al.*, 2011). This study supported the facilitating role of top management in stimulating the implementation of open innovation (Vanhaverbeke, 2006; Van der Meer, 2007) and the importance of a champion promoting change across the managerial levers, based on which the implementation of open innovation takes place (Chesbrough, 2006a). Besides, empowering leadership was investigated in relation to both inbound and outbound open innovation (Naqshbandi and Tabche, 2018). Empowering leadership stimulates both inbound and outbound open innovation (Naqshbandi and Tabche, 2018). Other factors were identified in a qualitative study, but without assessing the effect on firm performance. They involve culture (involvement of direct top management), procedures (open innovation teams), skills (open innovation training) and motivation (shifts in the incentive structure). They summarised the approaches to open innovation, comprising practices such as providing the right skills pool, training, and providing support and internal openness. For them, an open innovation team is in charge of managing open innovation and providing the relevant training to employees (Mortara and Minshall, 2011). The literature focused strongly on the importance of training in open innovation. For instance, through different steps of data collection, such as interviews and a case study with large multinational companies, coping strategies to succeed in open innovation and overcome its problems should include developing training and development programs (Salter *et al.*, 2014). Salter *et al.* (2014) found that new and better balanced internally and externally directed R&D incentive systems are required to encourage individuals to take on the challenge of open innovation and to give them rewards for doing so appropriately. Although these studies did not investigate innovation outcomes, they gave important insights into the relevance of training and other supporting factors, when implementing open innovation. Such studies present insights to understand what the potential areas of research are that will help in starting to close the open innovation implementation research gap in the literature.

As the literature discussed the importance of educated employees in open innovation (Harison and Koski, 2010), the most important competencies for open innovation professionals are related to brokering solutions and being socially proficient (Chatenier *et al.*, 2010). A recent study examined the role of employee characteristics in determining firm-level openness (Bogers *et al.*, 2018). The results of this study highlight the importance of taking into consideration the role of employees' educational diversity in open innovation. Their findings gave a more fine-grained picture of the association between employee diversity and innovation performance. Such association includes the use of external knowledge (Crescenzi *et al.*, 2016; Dahlander *et al.*, 2016). If employees have more diverse educational backgrounds, the entire company is characterised by a greater range of different educational knowledge basis, which helps the company to better use external knowledge. In addition, Bogers *et al.* (2018) revealed that education diversity acts as a precursor to work history diversity to affect external knowledge sourcing. This indicates that external networks and distant search options can only be facilitated if the company has a sufficiently wide educational knowledge basis. This is then enacted by a multi-functional search capability (Williams and Charles, 1998; Joshi and Jackson, 2003) or through employees' "gatekeeper" behaviour, even though in a much more distributed way than initially conceived (Allen, 1977; Dahlander *et al.*, 2016).

Regarding other factors, Lifshitz-Assaf (2018) focused on "identity", studying the effect of open innovation on R&D professionals and their work at NASA. They revealed that only R&D professionals that changed their identity truly adopted open innovation and, hence, modified their work procedure, transmitting the locus of innovation outside their traditional work boundaries. The R&D professionals that did not go through identity modification either feigned the adoption of, or clearly refused, open innovation, supporting the boundaries surrounding their work knowledge and ensuring protection for their professional identities. Thus, identity is a fundamental aspect, because doing open innovation without doing identity work leads to no real change in the R&D procedure and relevant knowledge flows. Innovation climate was studied in the context of SMEs (Popa *et al.*, 2017). The innovation climate has a positive impact on both inbound and outbound open innovation, which means that SMEs with a solid innovation climate tend to go more outside their boundaries and strengthen their internal knowledge by doing inbound open innovation.

Beside these factors discussed above, it is worth highlighting and reviewing some papers that focused on technological aspects in open innovation, such as social media, information

technology (IT) strategies and knowledge management systems (Mount and Martinez, 2014; Cui *et al.*, 2015; Santoro *et al.*, 2018). However, there are no studies that investigated the capabilities related to such digital tools. External expertise is important to enable knowledge transfer and internalisation to the firm from the masses of user-generated content developed on social media. As the technology gets incorporated into operational R&D and commercialisation procedures, major adaptation in organisational culture and structure is necessary to socialise managers, and promote openness to users (Mount and Martinez, 2014). In terms of information technologies (IT) strategies, Cui *et al.* (2015) discussed the facilitating role of IT in stimulating open innovation, whereby the alignment of open innovation and IT strategies improves open innovation performance. They also found that the focus of a business's open innovation and IT strategic alignment affects the radicalness and innovation volume outcomes. Additionally, Santoro *et al.* (2018) found that knowledge management systems (KMS) (information systems applied to managing organisational knowledge and to enhancing the development, storage, transfer, and use of knowledge) facilitate the development of an open and collaborative ecosystem, in exploiting internal and external flows of knowledge, and the stimulation of a strong effect on the creation of internal knowledge management capability (KMC) (KMC is the capability of a firm to discover both internal and external knowledge, and to preserve knowledge over time in the business (Chen and Huang, 2009)). Only one study examined capabilities related to digital platforms but in the context of open service innovation (Randhawa *et al.*, 2018). Through a longitudinal case study, Randhawa *et al.* (2018) studied how open innovation intermediaries use capabilities to help clients' capability in open service innovation. They found that technological and marketing capabilities are essential to help clients address barriers that arise in the process. As for co-creation capabilities, they help and determine both technological and marketing capabilities.

In relation to the studies that investigated the effects of open innovation on innovation outcomes, they mainly examined competitive advantage and innovation performance. These studies shed light on interesting and novel facilitators. For instance, Brunswicker and Vanhaverbeke (2015) found that for application-oriented sourcing, only internal practices, such as innovation development processes and innovation project control, are important, whereas a full-scope sourcing is highly related to a balanced mixture of long-term innovation strategy processes, innovation development processes and innovation project control. As for Lakemond *et al.* (2016), they found that project management and knowledge-matching procedures by major organisations have a positive effect on innovation performance through collaborative

inbound open innovation. Zobel (2017) conceptualised different components of the most dominant type of capability in the literature, absorptive capacity, including recognition capacity, assimilation capacity and exploitation capacity. They found that recognition capacity acts as an antecedent to the relationship between external technological resource access and competitive advantage in product innovation. When it comes to the assimilation capacity, there is a significantly positive indirect relationship between external technological resource access and competitive advantage in product innovation when there is high assimilation capacity, which needs to be higher than the average to benefit from open innovation via improved technology related capabilities. As for the exploitation capacity, it has a positive direct relationship with the competitive advantage in product innovation (Zobel, 2017).

As pointed out above, most of the studies in the open innovation literature have conceptualised open innovation in terms of "search for external partners" (Laursen and Salter, 2006; Bianchi *et al.*, 2011; Brunswicker and Vanhaverbeke, 2015), or "collaboration with external partners" (Laursen and Salter, 2014). There are also more studies that focused on one type of open innovation activity in isolation such as Foss *et al.* (2011) that examined "interaction with customers" and Foss *et al.* (2013) that discussed "opportunity exploitation" and Bianchi *et al.* (2016) that took outsourcing. Foss *et al.* (2011) found that the impact of interactions with customers on innovation performance is mediated by organisational practices, including delegation of decision rights, incentives and communications, where businesses are able to acquire the full potential of their interactions with customers if these organisational practices are employed within the firm (Foss *et al.*, 2011). Likewise, Foss *et al.* (2013) investigated the role of external knowledge sources in the process of exploiting strategic opportunities and the effect of a business's organisational design on the effect of external knowledge sources on opportunity exploitation. They found that the positive impact of each of the high coordination, decentralisation and knowledge sourcing on opportunity exploitation is supported by the significant three-way interaction. The same organisational designs that increase interactions with external knowledge sources and stimulate opportunity recognition are also beneficial in opportunity exploitation. Bianchi *et al.* (2016) revealed that engaging external consultants in R&D activities intensifies the effect of inbound open innovation on innovation performance by increasing the marginal benefits of acquiring external technological knowledge via R&D outsourcing.

As most of the studies conceptualised open innovation in terms of the breadth of the search for external partners mainly, or any other one type of open innovation activity in isolation as discussed before, few studies have started to look beyond one open innovation activity with two or more open innovation activities (Cheng and Huizingh, 2014; Chesbrough and Brunswicker, 2014; Cano-Kollmann *et al.*, 2017; Podmetina *et al.*, 2018; Stephan *et al.*, 2019; Teplov *et al.*, 2019). This indicates that although inbound open innovation is mainly conceptualised in terms of the breadth of search from different sources of information, or the breadth of collaboration with different external partners, these represent only two forms of open innovation activities (Laursen and Salter, 2006; Laursen and Salter, 2014). Other important activities include, for instance, crowdsourcing, idea and start-up competitions, using external networks, customer co-creation in R&D projects, and external technology acquisition (Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). Recently, scholars have moved beyond single open innovation activities and they have started to consider two or more open innovation activities. Table 2.2 below summarises the key studies that have conceptualised inbound open innovation in terms of more than one open innovation activity.

Table 2.2 Conceptualisation of Inbound Open Innovation Activities

Authors	Stephan *et al.* (2019)	Cano-Kollmann *et al.* (2017)	Cheng and Huizingh (2014)	Podmetina *et al.* (2018)	Teplov *et al.* (2019)	Chesbrough and Brunswicker (2014)
Name of Construct	External knowledge sourcing practices	Open innovation activities	Outside-in activities	Open innovation activities	Open innovation activities	Inbound practices
1.IP in-licensing			✓	✓	✓	✓
2.External technology acquisition				✓	✓	
3.Subcontracting R&D		✓	✓	✓	✓	✓
4. Using external networks				✓	✓	✓
5.Idea & start-up competitions				✓	✓	✓
6.Collaborative innovation with external partners	✓	✓	✓	✓	✓	
7.Crowdsourcing				✓	✓	✓
8.Customer co-creation in R&D projects				✓	✓	✓

9.Scanning for external ideas	✓			✓	✓		
10.University research grants							✓
11.Publicly funded R&D consortia							✓
12.Supplier innovation awards							✓
13.Specialised services from OI intermediaries							✓
Total number of inbound Activities	**2**	**2**	**3**	**9**	**9**	**10**	

For example, Cano-Kollmann *et al.* (2017) have found that public support for innovation is related to a higher level of engagement in two inbound open innovation activities, namely subcontracting of R&D to other firms, and collaboration with other firms for different types of innovation, such as incremental and radical products, processes and organisational method innovations. Despite their emphasis on what can stimulate open innovation in the context of both partners and activities, which represented an interesting and novel area of study, they have only focused on two types of open innovation activities and have not studied their impact on innovation outcomes. They empirically studied the relationship between publicly funded schemes to stimulate innovation and the "openness" of companies' innovation practices. They also showed the differences in the impact between monetary and non-monetary support schemes. They found that public support for innovation is related to greater levels of engagement in open innovation. They also showed that the effect of public support tends to diminish in companies that are already innovative, proposing the probability of crowding-out, or the substitution of private investment with public funding. Stephan *et al.* (2019) have also focused on only two inbound open innovation activities, external information sourcing and collaboration. They have found a positive relationship between these two open innovation activities and innovation performance. In particular, Stephan *et al.* (2019) found that a company's focus on social goals indirectly affects its innovation performance via the increased utilisation of two key external knowledge sourcing practices, external information sourcing and higher engagement in collaboration, while economic goals are only related to external information sourcing and not to collaboration. In contrast, Cheng and Huizingh (2014) have focused on three open innovation activities: performing all these activities is significantly and positively related to innovation performance. They examined whether performing open

innovation activities results in a greater innovation performance, and to which dimensions of innovation performance open innovation is most strongly linked. They also studied what the moderating effect is of entrepreneurial orientation, market orientation, and resource orientation on the relationship between open innovation and innovation performance. They found that conducting open innovation activities significantly and positively relates to all four aspects of innovation performance, i.e., new product/ service innovativeness, new product/service success, customer performance, and financial performance. Even though open innovation positively relates to all these 4 aspects of innovation performance, the effect sizes do not appear to be the same. In terms of strategic orientations, they argued that entrepreneurial orientation has the strongest moderation effect on the relationship between open innovation and innovation performance. Both market orientation and resource orientation are less efficient in strengthening the positive impact of open innovation on innovation performance. Although Cheng and Huizingh (2014), Cano-Kollmann *et al.* (2017) and Stephan *et al.* (2019) have moved beyond the conceptualisation of inbound open innovation in terms of single open innovation activity and have highlighted the importance of adopting more than one type of open innovation activity, they are still limited to only two to three open innovation activities. In practice, firms can choose among several other open innovation activities that they can undertake, as exemplified in the studies of Chesbrough and Brunswicker (2014), Podmetina *et al.* (2018), and Teplov *et al.* (2019) that explored the adoption of a broad array of nine to ten open innovation activities in several countries (Table 2.2). For instance, Chesbrough and Brunswicker (2014) included ten inbound open innovation activities in their study. They examined the extent to which large companies are conducting open innovation. They focused on inbound and outbound open innovation activities. They generally showed that it is not simple to implement an open innovation strategy. The cultural and firm obstacles can be difficult to manage. Managing the transition from closed to open innovation necessitates different organisational changes at different levels of the company. They also found that large companies are more likely to obtain freely revealed information than they are to give this information. However, they neither highlighted any key facilitating capabilities for open innovation, nor they studied their effect on innovation outcomes. As for Podmetina *et al.* (2018) and Teplov *et al.* (2019), they considered a list of nine inbound open innovation activities that they developed based on Chesbrough and Brunswicker (2014). Podmetina *et al.* (2018) emphasised competency sets for open innovation related to the core open innovation activities across industries and countries. They linked open innovation activities to supporting competencies. Although they focused on competencies, they did not examine the effect of

these open innovation activities on firm outcomes. For instance, among their findings, they showed that inbound and outbound open innovation activities are facilitated by the high significance of external collaboration and internal knowledge sharing, networking, adaptability, capability to work in interdisciplinary settings and cross-functional teams. Teplov *et al.* (2019) considered the same open innovation activities as Podmetina *et al.* (2018). Their study did not aim to investigate any capability or any other aspect related to open innovation implementation. They aimed to compare the perceptions of "open innovation" that are present in both the academic and business worlds, to help in the conceptual development of the phenomenon. They found that there is some confusion in the understanding of the open innovation concept and open innovation activities, not only between academia and business, but also within these groups. Notwithstanding the fact that these large empirical survey-based studies (Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2018; Teplov *et al.*, 2019) have contributed to a more granular and comprehensive view of inbound open innovation by describing the diverse range of open innovation activities, they have not explored the effect between these activities and innovation performance. The literature has so far remained silent about the benefits and risks of adopting a diverse range of open innovation activities. Nevertheless, these studies provided an appropriate, specific and clear list of inbound open innovation activities to focus on and to start closing the implementation gap, building on such conceptualisation of open innovation (Podmetina *et al.*, 2018; Teplov *et al.*, 2019).

2.8.2 Limitations in previous studies related to open innovation implementation

Despite the dominance of open innovation studies in the literature covering different topics and research areas, the "implementation of the open innovation strategy" remains one of the most fundamental issues that should be clearly investigated and understood.

As discussed above, different studies have started to investigate the implementation process of open innovation and have given important insights (Mortara and Minshall, 2011; Bianchi *et al.*, 2016; Cano-Kollmann *et al.*, 2017; Zobel, 2017; Bogers *et al.*, 2018; Randhawa *et al.*, 2018; Stephan *et al.*, 2019). However, despite the importance of such research and other studies in shedding light on what can support open innovation, they do present limitations when it comes to conceptualising open innovation in terms of the breadth of open innovation activities and/or in terms of investigating the effect on innovation outcomes. Additionally, as open

innovation is highly facilitated by information and communication technologies for instance (Gassmann and Enkel, 2004; Chesbrough, 2006b), implementation studies have shown how social media and IT strategies (Mount and Martinez, 2014; Cui *et al.*, 2015) enable open innovation. Nevertheless, there are no studies yet that have shown how relevant capabilities related to such tools can play a role in this process. Beside these capabilities, there must be many other capabilities that firms should develop to manage the problems and challenges associated with open innovation, and to have an effective implementation, specifically when undertaking different open innovation activities together. In fact, the majority of the studies in the open innovation literature have either defined open innovation broadly, without focusing on activities or partners (Lee *et al.*, 2010; Mortara and Minshall, 2011; Mount and Martinez, 2014; Bogers *et al.*, 2018), or have considered a specific inbound open innovation activity in relative isolation from other open innovation activities that may be taking place simultaneously, such as searching for and collaborating with different sources of information (Laursen and Salter, 2006; Bianchi *et al.*, 2011; Brunswicker and Vanhaverbeke, 2015), crowdsourcing (Afuah and Tucci, 2012; Bloodgood, 2013; Wilson *et al.*, 2018; Cappa *et al.*, 2019; Pollok *et al.*, 2019), customer co-creation (Zwass, 2010; Williams, 2012), interactions with customers (Foss *et al.*, 2011), opportunity exploitation (Foss *et al.*, 2013), and outsourcing (Bianchi *et al.*, 2016). In practice, managers have a wide range of different open innovation activities to choose from when implementing an open innovation strategy.

Based on the implementation studies covered by the open innovation literature so far, there tend to be two important and unanswered questions. One is related to the effect of the breadth of open innovation activities on innovation outcomes. The other one is related to the key routines and capabilities that support the breadth of open innovation activities. The research gaps, objectives and questions of this research are developed further in the next section.

2.9 Research gaps in the open innovation literature

The implementation of open innovation is a key issue in this strategy. This is because one of the main issues in this process is understanding which capabilities and routines can contribute

positively to it and to the innovation outcome of the firm, specifically when conceptualising open innovation in terms of the breadth of open innovation activities.

Open innovation should be investigated in terms of the breadth of different activities that describe the type of relationships firms have with external partners. Despite the importance of external partners, one, two or three inbound open innovation activities (Laursen and Salter, 2006; Cheng and Huizingh, 2014; Bianchi *et al.*, 2016; Stephan *et al.*, 2019) in conceptualising open innovation, there can be nine open innovation activities that firms can choose from (Podmetina *et al.*, 2018; Teplov *et al.*, 2019). For instance, open innovation is a process based on organising innovation in a different manner, using new organisational arrangements such as crowdsourcing, and a broad set of incentives and motivations for a varied set of actors to contribute to a company's innovation process (Tucci *et al.*, 2016). There are key specific antecedents that should be investigated to support different types of open innovation activities and hence innovation outcomes. Success is only ensured when a company is internally equipped to do open innovation (Bagherzadeh *et al.*, 2019). For this reason, despite the dominance of studies on open innovation drivers, benefits and limitations, providing insights on the antecedents and outcomes of the breadth of inbound open innovation activities, is a key research gap in the literature that should be addressed.

Based on the specific concise classification of inbound open innovation activities in the study of Podmetina *et al.* (2018) and Teplov *et al.* (2019), the main research objectives of this study are to shed further light on the antecedents (organisational capabilities and routines) that facilitate undertaking the breadth of inbound open innovation activities and to examine the effect of these activities on firm innovativeness. The breadth of these inbound open innovation activities that the current study focuses on include: IP in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing, customer co-creation with R&D projects and scanning for external ideas (Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2018; Teplov *et al.*, 2019).

Accordingly, this study seeks to answer the following research questions:

1) Does the breadth of open innovation activities result in a higher level of firm innovativeness, regardless of the number of open innovation activities undertaken?

2) How do different organisational routines and capabilities affect the breadth of open innovation activities at the firm level?

Chapter 3. Conceptual Framework

3.1 Introduction to the chapter

Based on the research objectives and questions of this study, this chapter develops the conceptual model to show which key capabilities and routines are examined in this study as potential facilitators, i.e., antecedents to the breadth of open innovation activities, and their effect on firm innovativeness. This chapter will also explain the dynamic capabilities theory (Collis, 1994; Teece *et al.*, 1997; Eisenhardt and Martin, 2000; Schilke, 2014) that this study relies on and develops the hypotheses that will be tested in this study.

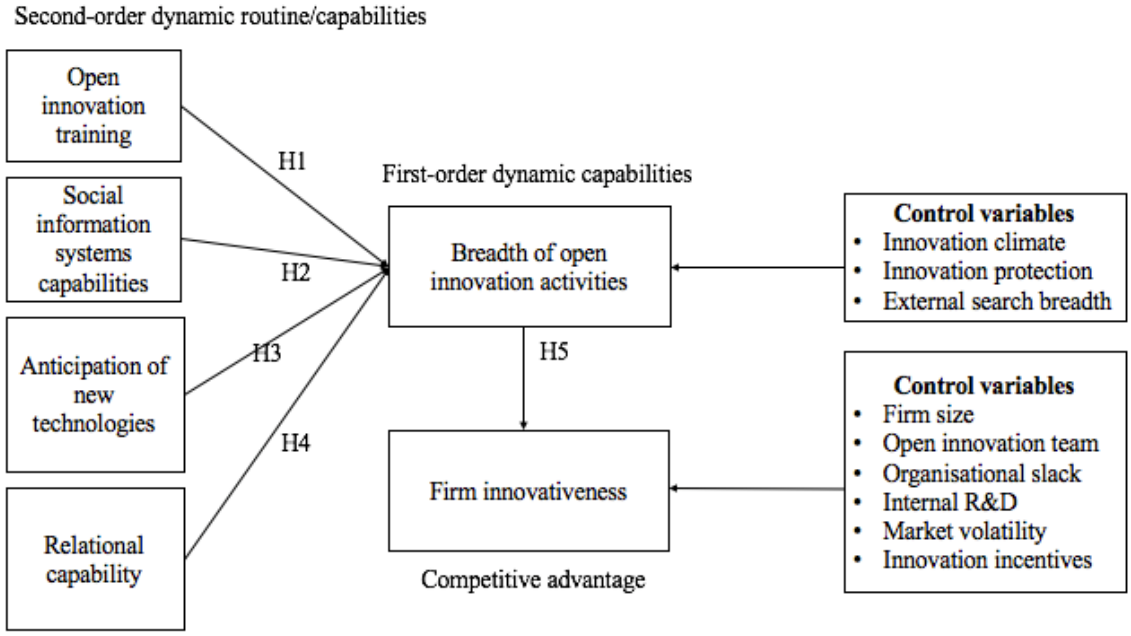
3.2 Development of the conceptual model

Drawing on the theory of dynamic capabilities, this study investigates the relationships between four key antecedents and the breadth of open innovation activities, and between the breadth of open innovation activities and firm innovativeness. Specifically, the four antecedents are open innovation training, social information systems capabilities, the anticipation of new technologies and relational capability. Some of these factors have either been studied with open innovation in general, without focusing on a specific form of openness (Mortara and Minshall, 2011; Sisodiya *et al.*, 2013), or in another literature such as external collaboration (Wang *et al.*, 2015), supply chain management (Beheregarai Finger *et al.*, 2014) and absorptive capacity and innovation (Limaj *et al.*, 2016), but not yet with the breadth of open innovation activities. Open innovation training provides communication skills transferring the value of any relation with external partners for successful relationships (Mortara *et al.*, 2009). Moreover, training is necessary in the preparation process of open innovation because a firm has to have internal skills to be capable to evaluate and review external capacities and resources (Mortara *et al.*, 2009). Thus, this develops within firms the relational capability through identifying and building relationships with appropriate partners (Morgan *et al.*, 2009). They will be potentially able to establish and control their relationships with external sources for higher value creation (Day, 2000). This capability can be further strengthened through social information systems capabilities that derive from the utilisation of

social information systems (Limaj *et al.*, 2016), i.e., web based technologies dominating the relations of employees, customers, and suppliers in innovation (Bughin *et al.*, 2013). There is still a lack of understanding of the effect of technological capabilities on open innovation in general and the breadth of open innovation activities in particular. As an example, social information systems capabilities were only investigated so far in the context of absorptive capacity and innovation (Limaj *et al.*, 2016). However, this type of capability (SIS capabilities) represents a potential facilitator for the breadth of open innovation activities. Finally, to undertake open innovation activities, firms may seek to acquire new manufacturing technologies beside knowledge, representing the anticipation of new technologies capability (Beheregarai Finger *et al.*, 2014). This is because open innovation is not only based on acquiring knowledge, but also technology (Chesbrough, 2006b; Rohrbeck, 2010; Hung and Chou, 2013).

The first part of the model represents the relationships between each of these four antecedents and the breadth of open innovation activities. In this part, the innovation climate, innovation protection and external search breadth are considered as control variables. The innovation culture or climate represents values within firms facilitating innovation (Martín-de Castro *et al.*, 2013). This factor should play a role in open innovation. Innovation protection is among the main aspects considered as firms should protect their own knowledge and innovation (Laursen and Salter, 2014; Bahemia *et al.*, 2017). External search breadth also helps in the implementation process, representing different types of external partners (Laursen and Salter, 2006). Figure 3.1 below summarises the conceptual model of this study. It shows the hypothesised effect of each of the four antecedents or second-order dynamic capabilities on the breadth of open innovation activities for the first part of the model (Hypotheses: H1 to H4). For the second part of the model explained in the following section, Figure 3.1 illustrates the hypothesised effect of the breadth of open innovation activities or first-order dynamic capabilities on firm innovativeness or competitive advantage (Hypothesis 5 (H5)).

Figure 3.1 Conceptual framework



The second part of the model aims to capture the relationship between the breadth of open innovation activities and firm innovativeness. Firm size, open innovation team, organisational slack, internal R&D, market volatility and innovation incentives are considered as control variables. As firms in the sample of this study are different in relation to size, it may be worth taking firm size as a control variable to identify any differences that may exist between large and small firms in open innovation. Also, since the open innovation team manages open innovation implementation (Mortara *et al.*, 2009), it is very likely to play a role in the effect of open innovation activities on firm innovativeness, and hence to represent an important factor in open innovation. Organisational slack is a key, representing resources in a firm exceeding the minimum necessary to generate a specific level of organisational output (Nohria and Gulati, 1997). Internal R&D cannot be ignored due to its complementary relationship with external knowledge acquisition (Cassiman and Veugelers, 2006; Berchicci, 2013). Representing rates of changes in different market factors (Wong *et al.*, 2011), market volatility may drive open innovation activities. Finally, incentives constitute an essential governance mechanism, especially when including high levels of innovative knowledge resources (He and Wang, 2009). Table 3.1 below provides a definition of each of the independent, dependent and control variables constituting the model of this study.

Table 0.1 Description of variables

Variables	Description
Open innovation training	Training is given to support the implementation of open innovation (Mortara and Minshall, 2011). This training is often supported by a framework that explains what open innovation is and what it implies (Mortara *et al.*, 2009).
Social information systems (SIS) capabilities	The fundamental feature of social information systems is social computing tools such as social media (Kaplan and Haenlein, 2010); they have been also represented by different platforms such as web 2.0 technologies (Andriole, 2010) and social technologies (Chui *et al.*, 2012). The creation of appropriate SIS capabilities derives from the regular utilisation of SIS (Limaj *et al.*, 2016).
Anticipation of new technologies	The anticipation of new technologies is the extent to which a firm anticipates the technologies that will be essential to it in the future, learns them, and creates capabilities for their implementation, prior to actually needing them (Hayes and Wheelwright, 1984).
Relational capability	Relational capability illustrates the ability of firms to find the best partners with whom to develop relationships, and plan governance means for adequate collaboration (Day, 2000; Faems *et al.*, 2008; Morgan *et al.*, 2009).
Breadth of open innovation activities	This study defines open innovation in terms of the breadth of inbound open innovation activities that include: IP in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing, customer co-creation with R&D projects and scanning for external ideas (Chesbrough and Brunswicker, 2013; Podmetina *et al.*, 2016).
Firm innovativeness	Firm innovativeness is the result of the innovation process, defined as the capability of the firm to create and launch new products or services (Alexiev *et al.*, 2016).
Innovation climate	Innovation culture draws upon values, principles and suppositions shared by organisation members, enabling innovation processes (Martín-de Castro *et al.*, 2013). Organisational climates that stimulate innovation capability of employees, creativity, risk tendency and personal growth are known as "innovation culture" (Menzel *et al.*, 2007).
Innovation protection	Innovation protection or "appropriability conditions", refers to the degree to which technological knowledge can be protected from others (Becker and

	Dietz, 2004).
External search breadth	The external search breadth refers to the number of external sources or search channels that companies refer to in their innovative activities (Laursen and Salter, 2006; Laursen and Salter, 2014).
Open innovation team	The open innovation team consists of people from R&D, marketing, supply chain management and the legal department within the focal firm, providing different types of skills for effective relationships with external partners (Mortara *et al.*, 2009). Open innovation teams are in charge of the implementation of open innovation developing themselves as the firm's door to the external world (Mortara and Minshall, 2011).
Organisational slack	Slack refers to the pool of resources in a firm which is in excess of the minimum required to produce a specific level of organisational output. Such slack resources involve surplus inputs such as of employees and capital expenses. They can also involve overlooked or unused opportunities to increase outputs such as the revenues to be earned from customers and innovations with associations with the technology frontier (Nohria and Gulati, 1997).
Internal R&D	Investing in internal R&D represents the extent to which an organisation invests in its in-house activities (new product development) and resources (personnel) in research and development (Hung and Chou, 2013).
Market volatility	Market volatility is an external factor of environmental dynamism that represents rates of change in product demands, technologies, rivals' actions, and factor markets (Wong *et al.*, 2011).
Innovation incentives	Innovation incentives are the company's use of strategic compensation strategies that represent employees' learning and innovative practices (Wei and Atuahene-Gima, 2009).

3.3 The theory of dynamic capabilities

This research relies on the theory of dynamic capabilities. This theory emphasises on the capability a firm in a fast changing environment has, to develop new resources, renovate or change its resource mix. Defined, dynamic capabilities are the organisation's capability to integrate, create, and reconfigure internal and external competences to respond to rapidly changing environments. The dynamic capability theory of a firm focuses on the dynamic practice of capability development, stating that competitive success result from continuous development, reconfiguration, and incorporation of organisational resources (Teece *et al.*,

1997). Dynamic capabilities are the company's processes that utilise resources, to incorporate, reconfigure, gain and release resources to match and also develop change in the market. They involve well-known organisational and strategic processes such as alliancing and product development whose strategic value is based on their capability to convert resources into value-creating strategies (Eisenhardt and Martin, 2000). Specifically, the academics of the theory of dynamic capabilities focus on the significance of the reorganisation process. This process indicates that a fundamental to sustained profitable growth is the capability to recombine and to reconfigure assets and organisational structures as the firm develops, and as markets and technologies evolve (Teece, 2007). Through dynamic capabilities, firms can constantly have competitive advantage, and hence can prevent creating core rigidities that hinder development, cause inertia and restrain innovation (Leonard-Barton, 1992). Dynamic capabilities are developed and not bought in the market. They represent organisational processes generally or routines (Zollo and Winter, 2002) that may have become embedded in the company over time, and are used to reconfigure the organisation's resource base by deleting resources or remixing old ones in new ways (Sirmon and Hitt, 2003). Therefore, a dynamic capability can also be a routine, representing a repetitive pattern of activity (Nelson Richard and Winter Sidney, 1982).

3.3.1 First-order and second-order dynamic capabilities

Collis (1994) was the first to suggest that there are different levels of capabilities. At the most basic level, capabilities represent the routines that help firms to use their resources to obtain a living in the present. Such capabilities are sometimes referred to as ordinary, substantive, or zero-order capabilities (Winter, 2003; Zahra *et al.*, 2006). At the subsequent level, are capabilities that help the firm's basic capabilities and resources to change; these are normally called first-order dynamic capabilities (Teece *et al.*, 1997; Eisenhardt and Martin, 2000). At an even greater level, Collis (1994) discussed the second-order dynamic capabilities as those that can be adopted to create first-order dynamic capabilities. Second-order dynamic capabilities can be also referred to as "learning-to-learn" capabilities, "higher-order" (Collis, 1994), "meta" or "regenerative" dynamic capabilities (Ambrosini *et al.*, 2009). Thus, first-order dynamic capabilities are routines that reconfigure the organisational resource base and second-order dynamic capabilities are routines that reconfigure the first-order dynamic capabilities (Schilke, 2014). In fact, a positive relationship between second- and first- order dynamic capabilities can be considered likely, as second-order dynamic capabilities can help businesses know more and do better their first-order dynamic capabilities (Cepeda and Vera, 2007). Therefore, learning is

at the base of dynamic capabilities and manage their evolution (Eisenhardt and Martin, 2000; Zollo and Winter, 2002). Additionally, one of the distinct aspects of second-order dynamic capabilities is that they do not enhance performance in a direct way, but through an indirect way by inserting first-order dynamic capabilities within the firm. Therefore, second-order dynamic capabilities do not lead to performance; they are antecedents to first-order dynamic capabilities, that in turn result in competitive advantage in the organisational resource base. Thus, second-order dynamic capabilities affect performance mostly through their impact on first-order dynamic capabilities (Schilke, 2014).

3.3.2 Dynamic capabilities and routines and open innovation implementation

A possible approach for dynamic capabilities to reconfigure the resources is to allow for external collaborations. In this way, the organisation can access and integrate resources it lacks (Wang *et al.*, 2015). This is because in collaboration or any other form of openness, companies use external and internal ideas, and internal and external paths to market when advancing their technology (Chesbrough, 2004). They also integrate purposively external knowledge with internal R&D (Chesbrough, 2003). Based on that, open innovation represents a dynamic capability, combining external and internal knowledge to match with the market and technology changes when doing innovation - what the dynamic capabilities are based on (Teece *et al.*, 1997; Eisenhardt and Martin, 2000). Thus, similar to dynamic capabilities, open innovation is based on integrating, creating, and reconfiguring internal and external competences to respond to the changes in the market, leading to superior firm performance (Teece *et al.*, 1997). Moreover, as dynamic capabilities represent firm processes which their function is to modify the firm's resource base (Ambrosini and Bowman, 2009), such resource base can be renewed through the external knowledge acquired in open innovation. This is because open innovation is not mainly based on outsourcing R&D to a specific party (Bogers *et al.*, 2019). It is about leveraging and improving internal capabilities, to enhance one's own business model, i.e., inbound open innovation or to discover a new business model, i.e., outbound open innovation (Chesbrough, 2003).

Beside showing how open innovation represents a dynamic capability, it is worth showing as well how the implementation process of open innovation can be well understood from a dynamic capabilities perspective and more specifically by considering first-order and second-order dynamic capabilities (Collis, 1994; Schilke, 2014). As discussed before, second-order

dynamic capabilities are antecedents to first-order dynamic capabilities. They are deployed to support the development of the first-order dynamic capabilities (Collis, 1994; Schilke, 2014), which consequently results in competitive advantage (Schilke, 2014). First-order dynamic capabilities are those that alter and directly reconfigure the core resource base of the firm (Teece *et al.*, 1997; Schilke, 2014). Thus, this research conceptualises the potential supporting open innovation antecedents, including open innovation training as a second-order routine, and social information systems capabilities, the anticipation of new technologies, and relational capability as second-order dynamic capabilities (Collis, 1994; Schilke, 2014). A repeated practice that happen through training, is an important learning mechanism for the development of dynamic capabilities. In turn, practice helps people to understand processes more fully and hence create more efficient routines (Eisenhardt and Martin, 2000) Being an effective learning mechanism, training is considered as a potential second-order learning routine supporting the potential first-order dynamic capability of the breadth of open innovation activities. Social information systems capabilities, the anticipation of new technologies and relational capability are potential second-order dynamic capabilities. These are four potential facilitators for the breadth of open innovation activities. They are expected to facilitate their creation and implementation, which in turn potentially affect firm innovativeness. Therefore, second-order dynamic capabilities and routines do not lead directly to performance (or any other innovation outcome, i.e., innovativeness). They are antecedents to first-order dynamic capabilities, that consequently result in competitive advantage in the organisational resource base (Schilke, 2014). Subsequently, the breadth of open innovation activities is conceptualised as the first-order dynamic capability. Such breadth alters the firm's resource base through the external knowledge acquired by different activities and should potentially provide firms with competitive advantage in terms of firm innovativeness. Therefore, based on the concept of open innovation and specifically its implementation process, it is important to look at the open innovation implementation through first-order and second-order dynamic capabilities and routines. In other words, this theory can be viewed as a framework to clearly understand the strategic management of open innovation, which in turn can enable the understanding of each of the outcomes of open innovation (Bogers *et al.*, 2019).

Beside the fit between this theory and open innovation, it is worth noting that such a link represents a major gap in the literature (Randhawa *et al.*, 2016). Most of the studies related to the theory of dynamic capabilities have been either conceptual (Teece *et al.*, 1997; Eisenhardt and Martin, 2000; Ambrosini and Bowman, 2009; Ambrosini *et al.*, 2009) or investigated in

other contexts. Equally significant, there are no studies yet that have examined second-order and first-order dynamic capabilities in the context of open innovation but in other contexts such as strategic alliances (Schilke, 2014), process innovation (Piening and Salge, 2015), supplier relationships (Mitrega *et al.*, 2017), and knowledge scanning (Brandon-Jones and Knoppen, 2018). Consequently, building on the theory of dynamic capabilities in this study, does not only help in understanding the implementation process and outcomes of open innovation, but also in addressing a key gap of this theory in the context of open innovation.

3.4 Hypotheses development

3.4.1 Open innovation training and the breadth of open innovation activities

Training facilitates the exposure of employees to different knowledge and openness to innovative ideas (Jaw and Liu, 2003). Training and expertise have been linked to innovation and specifically in the context of creative thinking (Weisberg, 2006). Creative thinking represents processes based on producing creative products, which are novel works or innovations brought about via objective-oriented practices. Based on that, skills, knowledge and reasoning processes have major roles in innovation; they are in the necessity for domain-specific training. This indicates that when training is conducted, firms create the organisational proficiency in relation to the demand and content of the innovation (Weisberg, 2006).

When implemented properly, well-constructed human resource programs such as training make employees seeing themselves operating in a social exchange relationship characterised by mutual trust, respect and support (Piening *et al.*, 2013). The reason behind this is that training stimulates employees to learn and experience new aspects and develop innovative minds (Nonaka and Takeuchi, 1995). Such training fosters employees to share their experience, obtain new knowledge, and apply what they learn in their job. Subsequently, these training programs are important for employees in the knowledge management process (Argote *et al.*, 2003). They give information and support to employees and help specifically in the encouragement of innovation (Lenihan *et al.*, 2019).

In the context of external knowledge acquisition for innovation, training tends to also play an important role. It is related to an organisational culture that either facilitates or restrains knowledge acquisition (Gold *et al.*, 2001; Simonin, 2004). Training is a major aspect of a learning environment that continually supports employees as they seize and use external

knowledge, proficiencies, and know-how (Ajmal and Koskinen, 2008). It is mainly based on teaching new approaches of thinking about what open innovation signifies (Mortara *et al.*, 2009). Specifically, training plays a key role in open innovation to an extent that the lack of an adequate combination of skills provided through training within firms can obstruct their implementation of open innovation. For instance, several large multinational firms that are conscious adopters of open innovation have created an internal language for open innovation and provide their employees with training to support the implementation of open innovation (Mortara and Minshall, 2011).

Training programs also seek to mitigate employees' attitudinal biases and improve individuals' capabilities to get involved in knowledge management (Greer and Stevens, 2015; Chowhan, 2016). For example, associated training is based on networking and collaborative abilities to help and encourage employees to reach, incorporate, transfer, and distribute knowledge (De Winne and Sels, 2010; Greer and Stevens, 2015). Thus, training can minimise employees' anxiety, insecurity, and negatively biased attitudes to external sources. This can hence stimulate employees to use more logical methods to assess the external knowledge and exchange the internal one (Kraiger *et al.*, 1993). Training does not only help and support employees in building knowledge and competencies for external knowledge acquisition, but also helps in overcoming the challenges of the not-invented-here and not-shared-here syndromes in open innovation (Katz and Allen, 1982; Chesbrough, 2003). As the not-invented-here (NIH) syndrome inhibits the adoption of inbound open innovation practices, and the not-shared-here (NSH) syndrome hinders the adoption of outbound open innovation, 'professional training' increased the extent of use of both inbound and outbound open innovation. This means that the additional development of skills and capabilities within the area of experience of employees through training programs stimulates the application of inbound and outbound open innovation. Based on that, employee training is one of the ways management may take to get around a high level of internal emphasis on innovation, while developing incentives for external knowledge interactions overcoming the NIH and NSH challenges that can arise (de Araújo Burcharth *et al.*, 2014).

Open innovation training is expected to support the breadth of open innovation activities. This training will be highly essential in order to understand the way each activity of such breadth is conducted. Thus, the following is hypothesised:

H1: Open innovation training is positively related to the breadth of open innovation activities.

3.4.2 Social information systems capabilities and the breadth of open innovation activities

As firms utilise advanced information technology to create and communicate information, they promote trust and reliability between partners (Wang *et al.*, 2015). Such technologies include social information systems (SIS). Social information systems (SIS) are web-based technologies (often available as an open source) that facilitate social relations without having a pre-determined number of members (Schlagwein *et al.*, 2011). An important aspect of such systems is that they develop a social setting which dominate the relations and involvement of employees, customers, and suppliers when doing innovation (Bughin *et al.*, 2013). While the core of social information systems is social computing tools such as social media (Kaplan and Haenlein, 2010), they have also been referred to as network IT (McAfee, 2006), enterprise 2.0 (McAfee, 2009), web 2.0 technologies (Andriole, 2010), social technologies (Chui *et al.*, 2012), enterprise social software (Christidis *et al.*, 2012), and enterprise social media (Leonardi *et al.*, 2013). Additionally, and in order to clarify further what these social information systems could include, the ones covered by Limaj *et al.* (2016) in their survey provide specific examples. For instance, when Limaj *et al.* (2016) measured social information systems utilisation that they developed based on Kilian *et al.* (2008), they considered social networks and microblogging under SIS group for networking, Web conferencing and instant messaging under SIS group for communication, wikis and blogs under SIS group for knowledge communities, and video sharing and shared database under SIS group for sharing communities.

Social information systems enable co-workers to look for, obtain, and exchange important knowledge (Leonardi *et al.*, 2013). These different types of usage prospects of SIS were studied from the perspective of the users (O'Riordan *et al.*, 2012). In this context, the users get involved in a form of relationship with the technology that specifies what can be possible for the user to do based on his capabilities and objectives (Markus and Silver, 2008). Thus, the common utilisation of these systems in firms offers new forms of behaviours and modifies organisational communication procedures (Treem and Leonardi, 2013). This should result in new firm SIS capabilities reinforced by different SIS (Kilian *et al.*, 2008).

SIS capabilities play an important role in enabling firms to access and acquire external knowledge. They include outside-in SIS capabilities, spanning interpretation SIS capabilities, spanning integration SIS capabilities, and inside-out SIS capabilities (Limaj *et al.*, 2016). All

these capabilities represent and describe the process of openness facilitated by SIS. For instance, outside-in SIS capabilities simplify the process of accessing and looking for relevant external information (Boyd and Ellison, 2007). Spanning interpretation social information systems capabilities support the clarification and communication of significant information. As for spanning integration social information systems capabilities, they facilitate the effective mixture of various sources of knowledge while recombining current ideas into new ones. Inside-out SIS capabilities support organisational purposes of exploiting refined or new capacities earned through external knowledge (Leonardi, 2014). For instance, when SMEs rely on external knowledge, utilising SIS and developing outside-in SIS capabilities can enable them to be well connected and to effectually obtain external knowledge. Such capabilities should have the same function as the information capability, that is based on using technology to collect, process, and transfer information to help decision-making, make better business operations, and enable communication and coordination with external sources of knowledge - increasing the chance of a successful collaboration (Wang *et al.*, 2015).

An important aspect to highlight when discussing SIS capabilities and external knowledge acquisition, is the absorptive capacity. It is related to the creation of interaction and connections between individuals of a firm and their specific competences (Cohen and Levinthal, 1990; Zahra and George, 2002). Absorptive capacity depends on firms having an internal knowledge that will help them acquiring and understanding external knowledge. This can be also explained from the perspective that as SIS and their capabilities developed help in the acquisition of external knowledge, they can also help in the development of the absorptive capacity within the firm to be able to acquire such knowledge. Therefore, the use of social information systems groups for communication and sharing communities helps small-to-medium-sized enterprises, for instance, to develop such important capabilities that support the socialisation and development of absorptive capacity (Cohen and Levinthal, 1990; Limaj *et al.*, 2016).

What is also important about SIS capabilities and their role in external knowledge acquisition is that the dynamic effects generated from mixing SIS capabilities with absorptive capacity have a positive effect on both exploratory and exploitative innovation outcomes. As these two types of innovation require the firm to look beyond its boundaries to get new ideas and generate new products and innovations, these can be facilitated by SIS capabilities. In fact, to properly use SIS, a strategy has to be implemented, along with guidelines and roles within the SIS governance, which in turn result in new firm-specific capabilities that alter organisational

routines and processes, and encourage innovation. This implies that managers in SMEs have to take into consideration capability-based management and recognise the main role of SIS in the creation of absorptive capacity to create valued explorative or exploitative innovations (Limaj *et al.*, 2016).

Given the above, it can be concluded that SIS capabilities facilitate the process of connecting and obtaining knowledge from external partners through such advanced systems. As social information systems capabilities facilitate external knowledge acquisition, they enable the management of a diverse range of open innovation activities, such as crowdsourcing, idea and start-up competitions, the use of external networks, and customer co-creation in R&D projects. It is very likely that firms will have a smoother use of such activities when SIS capabilities are created within the firm. Accordingly, the following hypothesis is developed:

H2: Social information system capabilities are positively related to the breadth of open innovation activities.

3.4.3 The anticipation of new technologies and the breadth of open innovation activities

A firm that is skilled in the anticipation of new technologies constantly invests in new processes and manufacturing technologies, supporting its future creation of products. The anticipation of new technologies represents a distinctive attribute of world class manufacturers, whose competitive strategy relies on their manufacturing capabilities (Hayes and Wheelwright, 1984). Therefore, such world class manufacturers are described as dynamic, learning firms that constantly push the boundaries of their expertise and attempt to be better on every front than previously (Hayes and Jaikumar, 1988). This is where forward-looking firms attempt to increase more or solidify their competitive and technological edge through constant innovation activities (Song *et al.*, 2017). Innovation is based on three linked meta-routines that include process and equipment development, searching for new technologies, and cross-functional product development. More specifically, searching for new technologies is related to the external acquisition of technologies; whereby searching for both new technologies and products calls for practices such as "*anticipating technologies*", "*acquiring new technologies as required*", and "*incorporating internal and external technologies*"; i.e., combining a firm's existing technologies with those acquired (Peng *et al.*, 2008). These searching routines are theorised as an "*explorative innovation*" since they include a boundary-spanning search for new technologies and products (Sidhu *et al.*, 2004). Accordingly, for this explorative

innovation, companies can use external technology acquisition which represents the apprehension of external technologies, through in-licensing agreements or strategic alliances (Van de Vrande *et al.*, 2006). Moreover, suppliers and their extended networks can be a significant source of external knowledge concerning technology and future customer requirements. Therefore, an effective anticipation of new technologies necessitates having a fair knowledge about future generations of customers and products, while having the resources to obtain new technologies prior to the need (Beheregarai Finger *et al.*, 2014). A firm that is interested in constantly looking and renewing its manufacturing technologies as part of its innovation process, may find open innovation helpful to obtain and combine external manufacturing technologies with internal ones.

Additionally, the potential link between the anticipation of new technologies and open innovation can be also understood from the absorptive capacity view (Beheregarai Finger *et al.*, 2014). As absorptive capacity emphasises on knowledge, the anticipation of new technologies stresses on a particular type of knowledge, which is the knowledge about both hard technologies and tacit capabilities to appropriately implement them (Beheregarai Finger *et al.*, 2014). Taking the acquisition aspect of absorptive capacity in the anticipation of new technologies, it is based on knowledge regarding technologies that can be important in the future. This involves current technologies that can be vital to future products and technologies, still in the development process (Hayes and Wheelwright, 1984). As for the assimilation, it contains analysing, processing, interpreting and creating an understanding of external knowledge (Zahra and George, 2002). Assimilation works well with the anticipation of new technologies whose filtering function is important in evaluating the future of new technologies. Thus, from this perspective, the anticipation of new technologies enables the acquisition and understanding of external knowledge regarding new manufacturing technologies that play an important role in innovation. Therefore, by concentrating on future technologies, the anticipation of new technologies facilitates environmental scanning and speeds up knowledge acquisition (Beheregarai Finger *et al.*, 2014). Scanning can include activities such as technology scouting, defined by Rohrbeck (2010) as a systematic approach through which businesses assign some of their employees or appoint external consultants to collect information related to science and technology. Knowledge can also be acquired through conducting specific types of activities, such as external technology acquisition and external technology exploitation (Hung and Chou, 2013).

Based on the aforementioned aspects of the anticipation of new technologies, this capability is highly important for firms, to keep up with the latest manufacturing technologies. It is very likely for a firm that seeks to anticipate and identify these technologies to utilise different types of open innovation activities beside technology scouting, external technology acquisition and exploitation. It is hypothesised that:

H3: The anticipation of new technologies is positively related to the breadth of open innovation activities.

3.4.4 Relational capability and the breadth of open innovation activities

Relational capability emerges from knowledge stores that contain socially complex and deeply rooted routines, culminating from experience with creating and managing relationships among firms (Sisodiya *et al.*, 2013). As a result, relational capability is theorised in the context of important knowledge among firms, comprising interactional and functional knowledge stores (Johnson *et al.*, 2004). Organisations and managers have to create the knowledge associated with the establishment of the relationship, which involves finding and contacting potential partners. They have to enhance their interactional competencies in terms of negotiation, collaboration and problem-solving (Sisodiya *et al.*, 2013).

Relational capability facilitates collaboration for several reasons. First, it helps the firm to differentiate among transactional and collaborative relationships and organise them with differential governance tools, hence protecting from any opportunism and other problems (Day, 2000; Faems *et al.*, 2008). Second, it simplifies the exchange of tacit knowledge available within firms by developing relational governance and informal communication networks (Lorenzoni and Lipparini, 1999). Third, the capability to efficiently design contractual and relational governance mechanisms is a resource appreciated by partners because it guarantees an adequate collaboration (Faems *et al.*, 2008). As a result, high relational capability makes collaborators confident that problems that may occur in relationships can be prevented or reduced (Fang *et al.*, 2008). In addition, based on the significance of boundary spanning via inter-firm relationships for their conceptualisation of open innovation, relational capability is important for gaining the potential rewards of open

innovation. More efficient inter-firm involvement offered by relational capability, can support the firm in recognising and choosing workable and beneficial external partners to include in new products. It can also help in assessing the quality of the resources from external sources, which in turn reduces the expenses and increases new product development outcomes (Sisodiya *et al.*, 2013).

Besides, an important aspect that shows the importance of relational capability in external interactions, is discussing one its components, which is the communication capability (De Silva and Rossi, 2018). Studying the effect of relational capabilities on two major practices to sourcing knowledge from universities in particular, De Silva and Rossi (2018) found that communication capability is critical for both knowledge acquisition and knowledge co-creation. As the acquired knowledge is exploited outside the relationship (Lane and Lubatkin, 1998), effective communication is fundamental in making sure that valued knowledge is efficiently transmitted to the business, by minimising possible loss of knowledge in the acquisition. Equally importantly, when firms are involved in acquisition, it is necessary to emphasise on enhancing communication, or to use a team who is effective at communicating with academics at universities for instance (De Silva and Rossi, 2018).

To efficiently involve external partners, companies have to assess their own capabilities in managing not only innovation and information, but also relationships. Such capabilities form the basis for collaboration to do innovation. If these capabilities are not available, collaborations can fail, and hence, businesses should abstain from incorporating external sources (Wang *et al.*, 2015). As a result, relational capability is all about having the right skills and competencies to be able to create and organise the relationships with external partners. It can help firms undertaking different types of open innovation activities. Based on these arguments, it is posited that:

H4: Relational capability is positively related to the breadth of open innovation activities.

3.4.5 The breadth of open innovation activities and firm innovativeness

IP in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing, collaborative innovation with external partners, and scanning for external ideas all form part of the open innovation activities that a firm can conduct (Podmetina *et al.*, 2016). Particularly,

research cooperation and R&D outsourcing provide firms with opportunities to complement the often limited internal research resources (Teirlinck and Spithoven, 2013). Inter-organisational collaboration has a positive effect on firm innovativeness (Alexiev *et al.*, 2016). Similarly, sourcing knowledge and ideas from customers and end-users when developing a new product is helpful and reasonable as customers have close links to markets (Pittaway *et al.*, 2004). They are capable to offer first-hand information, involving important insights with reference to market needs and future demand (Von Hippel, 2005). In addition, engaging customers in the early stages of innovation considerably decreases risks in development and enhance the likelihood of innovation success (Ragatz *et al.*, 2002). Beside customers, companies have to constantly learn from their competitors, suppliers and other sources to earn a reputation as an innovator in the market. These learning practices can reduce the negative effect of path dependence and capability-rigidity developed in the old period, and facilitate new competence exploration (Yu *et al.*, 2013). An open model of knowledge exchange between companies can highly enlarge and speed up a business' innovative potential. This is because in open innovation, important knowledge is broadly shared, and is of a good quality, to an extent that even the most capable and sophisticated R&D firms have to be well connected to external sources of knowledge (Chesbrough, 2006b).

There are also other types of activities that play a role in boosting innovative ideas and innovativeness within firms. For instance, instead of simply collaborating with few known external partners, companies are gradually innovating by using ''crowdsourcing'' (Majchrzak and Malhotra, 2013). Crowdsourcing is the practice of taking a challenge experienced by a firm and, instead of enquiring internal research and development division to solve the challenge, the firm broadcasts an open call to people from outside the firm with related experience to get engaged in solving the challenge (Howe, 2006). As a result, crowdsourcing for innovation has been adopted to acquire ideas, technologies, and whole organisations from outside the firm (Afuah and Tucci, 2012). Equally significant, the theoretical foundation for crowdsourcing creating innovation is the importance of expertise diversity. In other words, external crowds are more diverse in experience than internal research and development team. In turn, with expertise diversity, derives the potential of a higher quantity and diversity of ideas, leading to more innovative ideas (Terwiesch and Ulrich, 2009; Bingham and Spradlin, 2011). Taking also the knowledge co-creation, it can include combining firms' market knowledge and universities' advanced scientific and technical knowledge to generate technological, organisational, service, or marketing innovations (Perkmann and Salter, 2012). For instance,

knowledge co-creation involve close relations between firms and university personnel, in the purpose of innovating together (De Silva and Rossi, 2018).

Many of the studies have discussed the importance of each open innovation activity such as collaboration, crowdsourcing, separately without taking different open innovation activities together. Based on the above studies showing positive effects of single open innovation activity on the level of innovation, it can be assumed that combining different types of open innovation activities together would yield similar benefits in terms of innovativeness. This can be further justified by the fact that the incorporation of knowledge and resources can decrease firm inertia and reinforce innovativeness within a firm (Yu *et al.*, 2013). However, as openness to external partners may not be beneficial in all cases, with some negative outcomes, it may also be the case with the breadth of open innovation activities and firm innovativeness. It can be expected to have a negative relationship with firm innovativeness after a certain point of conducting different open innovation activities. For instance, Laursen and Salter (2006) found that the benefits to openness can face decreasing returns. This indicates that there is a point at which more search becomes unproductive. Experience and anticipation where search strategies reside can make firms over-search the external environment, with an unfavourable outcome due to many ideas to be managed by the firm. Also, several innovative ideas may be derived at the wrong time and wrong place to be effectively exploited. In addition, as there are many ideas, few of them may be taken seriously or allocated the necessary level of attention to implement them (Koput, 1997). A negative outcome may also be expected in a firm's search strategy when thinking of factors such as the resources available for R&D, the constraints on using them, and the availability of external knowledge (Garriga *et al.*, 2013). Specifically, the national context, such as a lack of skilful employees or the presence of entry barriers in important markets, further restrains the use of resources and hence mitigates the probability that a company's innovation will succeed (Shan, 1990). Also, regardless of the effort made in the search, a firm's geographical distance from its collaborators and external partners constrains the success of its collaborations and innovation performance (Phene *et al.*, 2006; Sidhu *et al.*, 2007). Thus, similar to external knowledge search, undertaking different types of open innovation activities may be negatively affected by over–search and resource constraints, resulting in unfavourable innovation outcomes. Thus, it is hypothesised that:

H5: The relationship between the breadth of open innovation activities and firm innovativeness is curvilinear, such that increasing the number of open innovation activities is associated with

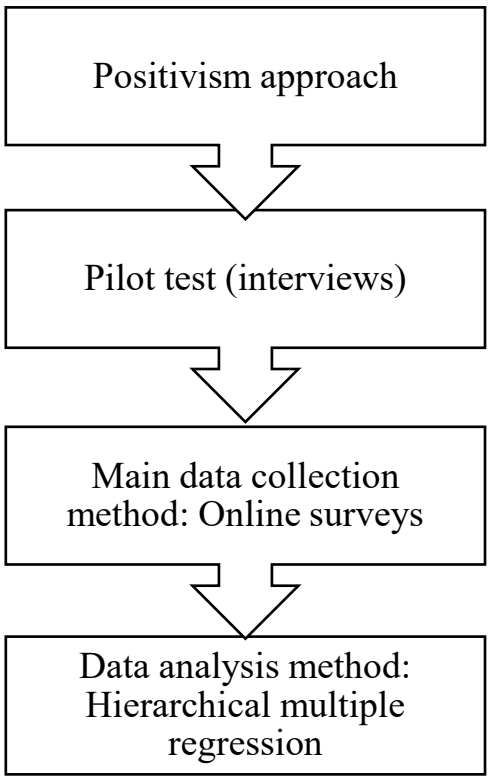
higher firm innovativeness up to a point, after which lower firm innovativeness will set in.

Chapter 4. Methodology

4.1 Introduction to the chapter

This chapter explains the approaches adopted in this study in terms of research philosophy, research ethics, pilot testing, data collection and data analysis. Although the researcher conducted some pilot interviews at the beginning of this research, they only aimed to test and revise the conceptual model of this study before data collection. Such interviews were not included in the analysis and research findings of this study. They only represented a preliminary stage to the main data collection method of this research. The main data collection approach adopted in this study is a quantitative approach using online questionnaires. The use of online surveys was mainly driven by the "positivism" research philosophy, which is consistent with the way the researcher seeks to interpret the results of this study and its research objectives and questions. In terms of the method used to analyse the quantitative data in this study, the researcher adopted "hierarchical multiple regression". Each of the approaches shaping the research design used in this study will be clearly justified in this chapter in terms of their suitability and fit with this research. Figure 4.1 below summarises the methodological approaches followed in this study.

Figure 4.1 Overall research design of this study



4.2 Research philosophy

Academics in any discipline use different research designs, such as quantitative, e.g., questionnaires, and qualitative methods, e.g., observations and interviews or case studies (Tuli, 2010). These 2 methods of data collection are related to different philosophical approaches, such as positivism, interpretivism and critical realism. The relative preference for each research method depends on the philosophical issues related to the question of ontology and

epistemology. Ontology, which etymologically signifies "speaking of being", represents the philosophical discipline that asks, "what is?" and "what does it mean to be" (Heidegger, 1993). In a daily usage, it examines the nature of reality (Stahl, 2007). Researchers make suppositions regarding “what is knowledge”, which represents the ontology, and “how we know it”, which refers to the epistemology (Creswell and Creswell, 2017).

The research objectives and questions of this study correspond with the “positivism”, a suitable research philosophy for this study. In the positivist approach, social observations are viewed as objects in the same manner as physical scientists work with physical phenomena (Cohen *et al.*, 2000). Positivism is a research philosophy based on the ontological doctrine that reality is independent of the researcher (Stahl, 2007). A researcher who adopts a positivist approach sees reality as being “out there”, in the world that has to be discovered through conventional scientific methods (Bassey, 1995). As the researcher in this study aimed to analyse the results as they are, independently of his opinion, positivist philosophy was highly appropriate for this research.

Relying on the positivist approach begins by drawing on a theory, developing hypotheses, collecting data and using it to examine the truth of the hypotheses quantitatively, using statistical methods such as questionnaires (Luft and Shields, 2014). Researchers adopting the positivist approach explain quantitatively how variables are related to each other and result in outcomes (Neuman and Kreuger, 2003). Building on the theory of dynamic capabilities and on the open innovation literature, this study identified research gaps and developed research objectives, questions and hypotheses to test empirically. Viewing the nature of the research questions (Sayer, 2000), which seek to examine the effect of different antecedents on open innovation implementation, then on firm innovativeness as an innovation outcome, a quantitative method of data collection was adopted. Specifically, a web-based survey was distributed to a sample of firms. Questionnaires were used to collect data, which was analysed to test the research hypotheses about the relationships between variables (Luft and Shields, 2014).

Through positivism, empirical facts occur independently of personal ideas or perceptions, led by the laws of cause and effect (Crotty, 1998; Marczyk and DeMatteo, 2005). Accordingly, positivism refers to developing the most objective approach possible to get the closest estimation of reality without any perspective from the researcher (Ulin *et al.*, 2005). As results in this particular research were presented as they are (Marczyk and DeMatteo, 2005;

Sarantakos, 2005), the researcher sought to be objective in presenting the results and, hence, having them as precise as possible. As a result, effects and relationships between these variables were not interpreted with subjectivity (Edwards *et al.*, 2014).

Another major aspect of the appropriateness of positivism in this study is that the researcher was not interested in understanding the reason behind the occurrence of a phenomenon (Easton, 2010). As opposed to critical realism, for instance, the researcher in this study did not refer to external factors or reasons beyond those involved in this research to explain and interpret the results (Edwards *et al.*, 2014). The researcher simply examined the effect of each of the four antecedents: open innovation training, social information systems capabilities, anticipation of new technologies and relational capability) on the breadth of open innovation activities, and then, the effect on firm innovativeness. In critical realism, there is a real world out there and the intrinsic order of things is mind-independent (Tsang and Kwan, 1999). Critical realists explain, analyse and evaluate social circumstances (Edwards *et al.*, 2014). The ability to be engaged in causal analysis makes critical realism appropriate for evaluating social issues and proposing solutions for them (Fletcher, 2017). In critical realism, managers have to think about the reason why some decisions lead to some outcomes (Easton, 2010). Unlike positivism, which is mainly associated with quantitative methods (Cohen *et al.*, 2000), critical realism is mainly associated with qualitative methods such as a case study (Alderson, 2013). Based on such assumptions, critical realism did not fit with the aim of this research.

To conclude, the key aspects of positivism are mostly related to the use of quantitative methods and objectivity – both of which were appropriate and corresponded with the research objectives and design of this study. As highlighted before, a few pilot interviews were conducted at the beginning, prior to sending out the surveys, just to test and refine the conceptual model. The next section will show how the researcher complied with the ethical considerations before starting any data collection. The research ethics section will be followed by the pilot test section.

4.3 Research ethics

Ethics are highly important in business research (Saunders *et al.*, 2011). Ethical concerns are considered not only in the data collection stage, but also in the data analysis and publication stages (Burton, 2000). This research has complied with research ethics. At the beginning of this research study, before collecting any data, the researcher submitted an ethical approval

form to Newcastle University Business School. Accordingly, ethical approval was obtained from "Newcastle University Ethics Committee". What is more, and as will be further demonstrated in the following sections of this chapter, the researcher asked for participants' informed consent prior to their participation in this study, which is a key ethical consideration. To make an informed decision in relation to participating in the online survey, respondents in this study were provided with information regarding the main aim of the questionnaire. The researcher introduced herself and clarified the way data will be utilised in this research. The average duration to fill the questionnaire was specified to them. As this information can be included in the e-mail questionnaire invitation or within the introduction to the survey, the researcher included it in both, the e-mail and introductory section to the survey of this particular research (Ritter and Sue, 2007). The researcher provided participants with the right to withdraw from the research at any time, and ensured the respect of their anonymity and confidentiality. Moreover, the e-mail address of the researcher was included in the survey for any questions or clarifications participants may have regarding this study. The most vital ethical concern tends to be confidentiality and anonymity for participants and the data they give. Particularly, confidentiality and anonymity are extremely important when conducting quantitative studies (Bryman and Bell, 2011). One of the major rigorous necessities in research is protecting the respondent's confidentiality. Once the researcher has promised confidentiality, s/he has an ethical responsibility to guarantee that respondents' identity and information are protected (Ritter and Sue, 2007).

4.4 Pilot test

Prior to the main quantitative data collection undertaken in this research, a pilot test of qualitative semi-structured interviews was conducted. The main aim of this test was to identify important factors in the open innovation context. Additionally, the purpose was to explore the open innovation strategies in the target participants in selected firms and measure the extent of the importance of the capabilities under investigation in this study. More specifically, these semi-structured interviews sought to ensure that every factor in the conceptual model of this study was relevant and clear to the respondent firms. Beside developing open-ended questions directly related to the different capabilities and variables of the initial conceptual model of this research, there were general and open-ended questions formulated in these interviews. These questions help firms to elaborate and provide as much information as possible and come up with new factors and antecedents of open innovation beyond the ones covered in the literature

and conceptual model. Open-ended questions in semi-structured interviews give the researcher the freedom to ask the participant for more details (Berg, 2009; Ryan *et al.*, 2009). The questions prepared for the pilot test of this study were also discussed with a number of academic colleagues before conducting the interviews to assess their clarity and accuracy. They all found them clear enough and no major changes were applied (See Appendix 1 for the pilot test questions).

Six pilot interviews with managers, who mainly deal with open innovation, innovation and R&D practices at high-value manufacturing firms in the UK, being the main target sample of this research, were conducted. Their contact details were obtained from a database purchased from Dun & Bradstreet (UK), a large database provider company. These managers were firstly called over the phone during which the researcher introduced herself, gave an overview about this research, and kindly asked whether a 20-minute phone or face to face interview was possible. For those that accepted, a specific date and time was scheduled at their convenience. The phone call was followed by a confirmation e-mail sent to the managers thanking them for their consent to participate. This e-mail included a calendar invitation with the meeting details and a statement ensuring the confidentiality and anonymity of their responses while highlighting their access to the results' report as soon as the study is completed. In this e-mail, the researcher also attached a list with the definition of each of the nine inbound open innovation activities for clarification and time-saving during the interview. On this list, participants in the pilot test had to tick the box for the activity that is done in their firm. All interviews, except one conducted face to face and another by e-mail, were carried out over the phone due to travel constraints and remote distance (See Appendix 2 for the confirmation e-mail for the pilot interviews, and Appendix 3 for the list of definitions for each of the nine inbound open innovation activities sent to the participants prior to the interview). Each interview was recorded and notes were taken during the conversation after having the respondent's permission to do so.

In relation to the approach used to assess and draw conclusions from these interviews, the researcher has carefully listened to each interview and revised all notes taken during each interview. Through this exercise, the key outputs of each question in each interview were written down. All these outputs were accurately revised, based on which the researcher checked whether each factor in the conceptual model was relevant or not, and whether any factor should be added or removed. Equally significant, from such key outputs from the interviews, the

researcher was able to understand the potential association between variables as per the research hypotheses. Moreover, the researcher was able to revise the clarity and precision of each question in the survey.

The researcher ensured that firms are familiar with all types of open innovation activities and the majority of the open innovation antecedents investigated in this study. Particularly, out of all the antecedents to open innovation initially included in the conceptual model of this study as per Table 2 below, "innovation incentives", "inter-functional coordination", "decentralisation", "analytics capability", and "open innovation team" were not as applicable and relevant as the remaining 4 antecedents, "open innovation training", "social information systems capabilities", "anticipation of new technologies", and "relational capability". Thus, the researcher removed the "inter-functional coordination", "decentralisation", and "analytics capability" factors from the conceptual model and kept "innovation incentives" and "open innovation team" but moved them to be control variables with the other control variables that the researcher had already included in the second part of the model as explained in chapter 3. This is because open innovation teams are the brokers of interactions with potential partners (Mortara *et al.*, 2009). As for innovation incentives, companies can obtain the full potential of their relationships with customers if practices such as incentives are used in the firm (Foss *et al.*, 2011). Based on that, the researcher sought to keep these 2 factors but to include them as control variables while testing the relationship between the breadth of open innovation activities and firm innovativeness. There was only one factor not included in the initial conceptual model, and that emerged as an important one through the pilot test. This factor was the "innovation climate". However, as this factor does not represent a novel factor and capability in the literature, it was also added as a control variable with the other control variables of the first part of the model as per chapter 3. In fact, the innovation climate supports inbound open innovation (Popa *et al.*, 2017).

Like any other context, many potential factors can be investigated in the open innovation implementation context. Nevertheless, conducting such a pilot test with open-ended questions confirmed the importance of the nine inbound open innovation activities and each of the 4 antecedents, including "open innovation training", "social information systems capabilities", "anticipation of new technologies", and "relational capability" in particular. Among all the antecedents tested and those that emerged during these interviews, it was shown that these 4 antecedents specifically are the most relevant for firms. Subsequently, the high importance of

these 4 capabilities, as per the pilot interviews conducted, is another reason (beside the other reasons discussed in chapter 3) behind the focus on these 4 factors in this research. Thus, the researcher covered the main capabilities in relation to open innovation implementation. Moreover, as the nine inbound open innovation activities considered in this study were all applicable to firms and very similar and related to the new ones that emerged during these pilot interviews, the researcher focused in this study on this list of the nine inbound open innovation activities (Podmetina *et al.*, 2016; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). Table 4.1 below presents the profile of the respondents in these pilot interviews in terms of the company sector and manager's position. Then follows Table 4.2, which compares the antecedents of the initial and refined conceptual model.

In all, through these pilot interviews, the relevance of the topic investigated in this study and its applicability in practice were confirmed (See Appendix 4 for the main outputs of these interviews). Therefore, what justifies further the emphasis on these 4 antecedents and not others is that the researcher in this study has collected qualitative data through this pilot test to check the potential antecedents. After conducting this pilot test, there was not any concern about the investigated factors. This pilot test made it possible to deepen the development of the research hypotheses of this study and resulted in a revised conceptual model. In addition, the researcher was able to increase the accuracy of the survey before starting the main quantitative process of data collection, explained in section 4.6 below.

Table 4.1 Profile of the companies and respondents of the pilot test

Company	Company sector	Manager's position
A	Biopharmaceutical company	Vice-President and General Manager (phone interview)
B	Gluten and milk free biscuit manufacturer	Manager (by e-mail)
C	Manufacturer of performance and specialty chemicals	Technical Director (phone interview)
D	Manufacturers of remote intervention equipment operating in hazardous environments worldwide (subsea engineering)	Strategic business & development manager (face to face interview)
E	Manufacturers of medium-size and large crawler	Managing director (phone interview)

	excavators and working gear excavators	
F	Engineering and manufacturing high-performance integrated vessels and equipment, and providing sustainable services	Subsea Products Technical Manager (phone interview)

Table 4.2 Antecedents to the breadth of open innovation activities before and after the pilot test

Before pilot test	After pilot test
Open innovation training	Open innovation training
Social information systems capabilities	Social information systems capabilities
Anticipation of new technologies	Anticipation of new technologies
Relational capability	Relational capability
Open innovation team	
Innovation incentives	
Inter-functional coordination	
Decentralisation	
Analytics capability	

4.5 Survey design

To collect the data for this study, a survey questionnaire was designed. At the beginning of the questionnaire of this study, open innovation or collaborative innovation was defined as a model that integrates external knowledge with the internal research and development (R&D) of a firm during the development of new products, services, or processes (Chesbrough, 2003). It was also specified to respondents in the survey that companies involved in open innovation tend to collaborate with different types of external partners and undertake many open innovation activities, such as intellectual property in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea & start-up competitions, collaborative innovation with external partners, crowdsourcing, customer co-creation in R&D projects, and

scanning for external ideas. Moreover, the researcher indicated in the survey that external partners included in some questions of the questionnaire relate to any of the different types of partners, which include customers, universities, suppliers, public research organisations, entrepreneurs and start-ups, contracted R&D service providers, external consultants, competitors, unrestricted communities and open innovation intermediaries. Also, respondents were asked to consider their firm's general open innovation strategy and not the project one, within the last three years inclusively.

The researcher started the survey with simple general questions about the participant and the firm to ensure that the respondent and the company fit the criteria of the target sample of this study well. For instance, these questions included the position or role of the respondent, years of experience in the company, the industry or sector to which the firm belongs, and the firm size. Additionally, all measures of the variables were taken from previous solid literature in highly-ranked academic journals with high reliability and validity. A seven-point scale (1=strongly disagree, 2=disagree, 3=somewhat disagree, 4=neither agree nor disagree, 5=somewhat agree, 6=agree, 7=strongly agree) was used for all the measures of the scale variables in the survey. Participants were asked to indicate the extent to which they agree or disagree with the statements regarding each of the scale variables.

The survey of this study was carefully designed and prepared. Several rounds of revisions were conducted. Checks were not only conducted in terms of the content and subject or topic under study, but also in terms of clarity, specificity and spelling. It was ensured that every question and every word could be clearly understood without any sort of ambiguity. In fact, this would definitely increase the response rate and accuracy of the results. Furthermore, the survey was piloted with 3 PhD students, one university professor and 7 managers in companies. They found the survey very clear and easy to be understood. However, they had some suggestions and comments, based on which the survey was revised again before data collection. Also, the length of the survey was taken into consideration by the researcher. This is because, as a fundamental rule-of-thumb, the longer the survey, the lower the response rate (Sheehan and McMillan, 1999).

4.5.1 Web-based survey administration

The researcher in this study used "Qualtrics" as a web-based tool for the questionnaire. Qualtrics is a dominant online survey tool that makes it possible to develop questionnaires,

distribute them and analyse responses from one appropriate online location. This convenient and easy to use platform offers several features. For instance, the data (responses) can be easily accessed through this platform and can be exported directly to different programs, such as "IBM SPSS", where data will be cleaned and prepared for data analysis.

The survey link (URL) through Qualtrics was sent to respondents by e-mail after the researcher had called them previously, to have their consent to participate in the study. The survey link was easily accessed and attached in a clear concise e-mail, in which the researcher thanked the respondents again for their consent to participate in the survey and mentioned again what this research study, conducted at Newcastle University, is about. It was also specified that the survey would only take 15 minutes to be completed. They were ensured that all their responses would be anonymous, confidential and only used to complete this research study. In addition, it was highlighted in the e-mail that the report of the results of this study would be shared with them once this study was completed (See Appendix 5 for the survey e-mail sent to respondents following the phone call).

4.5.2 Format of the survey

A questionnaire has to be designed in such a way as to achieve a higher response rate while at the same time obtaining precise and high-quality data (Dillman *et al.*, 2009a; Babbie, 2012). With different question and questionnaire templates to choose from on Qualtrics, a simple clear template was chosen for the survey of this study, visually appealing to respondents. This is because the layout and format of the survey are key aspects in online surveys, stimulating participants to complete the survey (Dillman *et al.*, 2009a). Moreover, a well-structured survey with clear guidelines can lower participants' errors (Dillman *et al.*, 2009b).

The length of the survey plays a key role in the response rate (Sheehan and McMillan, 1999) as well as the completion of the survey (Dillman *et al.*, 2009a; Bryman and Bell, 2011). Consequently, an important aspect is to choose participants that are interested in and highly knowledgeable about the topic (Dillman *et al.*, 2009a). In particular, as the sample of this study was managers that deal with open innovation at high-value manufacturing firms in the UK, the topic studied in this research was highly relevant for them and they completed the questionnaire appropriately.

Matching with the recommendations of Dillman *et al.* (2009a), the researcher guaranteed that each question in the survey of this study and its possible answers were clear on the screen, appearing all at the same time. Also, as respondents may not find each single item of a question relevant for them, an average option stating a "neither agree nor disagree" was given for each of the scale variables in the questionnaire of this research. When different options were given, for instance for "industry types" and "open innovation team diversity" questions, an "other" option was provided to cover any other option that may apply best to the firm. Furthermore, all questions were numbered, and each variable was written in bold to clearly highlight it with its question. Each page was allocated the necessary number of questions without overloading it. The survey clearly ended with a "thank you" to respondents for their participation. Therefore, not only was the content of the survey carefully considered in this study, but also the format, design and layout. This facilitated the process of answering and completing the questionnaire.

4.6 Quantitative method of data collection

A cross-sectional design was used to collect data from the sample of this study. This method is based on the analysis of the collected data at one single point in time (Creswell and Creswell, 2017). In contrast, longitudinal approaches, appropriate to studying the causal directions between factors (De Vaus, 2001), do not apply in this study. The reason behind their irrelevance in this study is the longer period of data collection required in such approaches, hence time constraints. Another reason is simply that the interest and research objectives of this study are to examine the effect of different capabilities on the breadth of open innovation activities and in turn firm innovativeness without a reverse causality.

An online survey was used to collect data for this study and test the research hypotheses. Survey data collection, established on standardised questionnaires, sent to the target sample, is a key data collection method in different contemporary research areas with many advantages. Online surveys are relatively low-cost to be conducted, have the capacity to collect a lot of data in a short period of time and can decrease overall survey error as the data entry chore is eradicated (Ritter and Sue, 2007). Participants in this study were able to complete the questionnaire at the time, location, and speed they preferred and with more privacy. The higher sense of privacy and absence of interviewer-related biases has significantly contributed to greater data quality in this research (Vehovar and Manfreda, 2008).

4.6.1 Sampling frame

A sampling frame represents a list of all prospective participants in an online questionnaire (Ritter and Sue, 2007). The target sample of this study was high value manufacturing firms in the UK. Firms in the high value manufacturing sector were the target sample in this study without focusing on firms in the services sector. This is simply because high value manufacturing companies are more likely to be innovative and technologically advanced, constantly investing in R&D and open innovation in their manufacturing and development of new products processes where open innovation might be more applicable and useful. In fact, the University of Cambridge, for instance, defines high value manufacturing as firms that benefit from highly skilled, knowledge-intensive manufacturing operations while competing on distinctive value and innovation (May, 2015). Based on their conceptualisation and characteristics, high value manufacturing firms tend to be highly engaged in open innovation. Accordingly, due to their high relevance in the open innovation context, the current study has focused on them. Equally important, another aspect that I relied upon when focusing on high value manufacturing sector in this research is that the majority of the studies in the open innovation literature have focused on this sector in their research as a relevant sector and found interesting results and insights (Love and Roper, 2001; Love and Roper, 2004; Laursen and Salter, 2006; Bianchi *et al.*, 2016). Specifically, the sectors to which the companies in the target sample of this research relate to were categorised as per the Organisation for Economic Co-operation and Development (OECD) classification of the manufacturing industries. The sector to which each respondent firm in the sample of this study belongs was classified according to the OECD (2011) categorisation of manufacturing firms as per their R&D intensities. Table 4.3 below shows how the OECD (2011) normally classifies manufacturing firms. As far as firm size is concerned, which was included in the conceptual model of this study, Table 4.4 below shows the number of companies as per different categories of firm size, characterising the respondent companies in this study. However, having a high-value manufacturing company as a respondent characteristic was more important than firm size in this study. In fact, a high-value manufacturing company is highly likely to be engaged in open innovation regardless of its size. Thus, all respondent companies in this research were high-value manufacturers and were classified as per the categorisation of the OECD (2011).

Table 4.3 Technology intensity classification of manufacturing firms

High-technology industries	Medium-high-technology industries	Medium-low-technology industries	Low-technology industries
Aircraft and spacecraft	Electrical machinery and apparatus, n.e.c.	Building and repairing of ships and boats	Manufacturing, n.e.c.; Recycling
Pharmaceuticals	Motor vehicles, trailers and semi-trailers	Rubber and plastic products	Wood, pulp, paper, paper products, printing and publishing
Office, accounting and computing machinery	Chemicals excluding pharmaceuticals	Coke, refined petroleum products and nuclear fuel	Food products, beverages and tobacco
Radio, TV and communications equipment	Railroad equipment and transport equipment, n.e.c.	Other non-metallic mineral products	Textiles, textile products, leather and footwear
Medical, precision and optical instruments	Machinery and equipment, n.e.c.	Basic metals and fabricated metal products	

(Source: (OECD, 2011)**)**

Table 4.4 Firm size of the respondent companies

Number of employees (Firm size)	Number of companies
0-200	98
201-500	57
501-1000	21
1001+	35
Total	**211**

In order to have access to the names and contact details of the relevant companies of the sample of this study, a database was purchased from Dun and Bradstreet (D&B) (UK), a highly reliable company that provides firms' contact details. With more than 170 years of experience and higher than 235 million business records, Dun & Bradstreet is known for its Data Universal Numbering System (DUNS numbers), which creates business information reports for more

than 100 million firms worldwide. The dataset purchased for this research included all necessary information and contact details of around 10,813 managers. Such information particularly consisted of the company name, Standard Industrial Classification (SIC) code, and manager's position, name, surname, e-mail and telephone number.

4.6.2 Sample size

As per the simplest rule of thumb, the larger the sample size, the better. The sample size needed relies on the size of effect that the researcher is seeking to detect, which means how strong the relationship is that the researcher is trying to measure. It is also linked to how much power the researcher needs to detect these effects (Field, 2013). In multiple regression analysis, power represents the probability of identifying as statistically significant a particular level of R square or a regression coefficient at an identified significance level for a particular sample size. Sustaining power at 0.80 in multiple regression necessitates a minimum sample size of 50. Yet what is more preferable is 100 observations for the majority of the research situations (Hair *et al.*, 2014).

A very large sample size tends to result in ineffectiveness and a waste of resources. At the same time, a small sample size can generate information that may not be valid for adequate interpretation of the results (Peterson, 1988). Based on that, the researcher in this study balanced expenses and sample size rationally for adequate generalisations. The researcher in this study followed the recommendations of Kline (2011) for the sample size based on the ratio to estimated parameters in structural equation modelling (SEM). Both SEM and multiple regression are based on the analysis of different variables, whereby SEM mixes factor analysis and multiple regression analysis. Kline (2011) suggests that a sample size of 100 is viewed as "small," 100 to 200 is "medium," and more than 200 is "large." In this study, 211 completed survey responses were obtained and were considered suitable for the data analysis, representing a sufficient sample size.

4.6.3 Key respondents

The main respondents to the survey of this study were R&D, innovation, engineering, new product development, technical and design managers. They also included CEOs, managing directors and general managers. In a study conducted by Bahemia *et al.* (2017) on managing open innovation in NPD, participants were innovation, R&D and engineering managers (or

equivalent). This is because the primary interviews in their study showed that these managers are knowledgeable about new product development, and hence innovation and open innovation. Moreover, participants that are very familiar with open innovation are mostly R&D managers (Lakemond *et al.*, 2016). Based on the pilot interviews conducted by the researcher in this study prior to sending out the survey, it was found that managing directors and technical directors are also highly knowledgeable about the open innovation strategy in their firm. As companies in this study were called over the phone before sending them the survey, an overview on the topic of this research was briefed to the main respondents of the questionnaire. Accordingly, those that agreed to complete the survey clearly showed their familiarity with and knowledge about open innovation and showed an interest in participating in this research. Thus, calling the respondents in this study prior to sending them the survey also ensured they were the relevant ones to complete the questionnaire. All managers that revealed they were not the appropriate people for this research suggested that another appropriate manager in the firm be contacted.

In some companies, it was difficult to have a specific manager with a job title of "R&D" or "innovation manager". However, general managers and managing directors or any other people in high managerial positions, e.g., top executives, can be very helpful as such people are mainly in charge of different tasks within firms. They are well aware and engaged in all processes and strategies implemented within the firm. In fact, top executives are real representatives of the company and their opinions can be relied on, as effective representatives of the process being studied (Venkatraman and Grant, 1986). Therefore, all key respondents in this study were highly relevant and appropriate to answer the survey adequately and accurately.

4.6.4 Encouraging responses using a web-based survey

In order to increase the survey response rate in this study, the following approaches were adopted, as suggested by Dillman *et al.* (2009a). First, before sending any e-mail with the survey, a phone call was conducted with each respondent. As managers receive several e-mails daily requesting them to fill in online questionnaires, they are more than likely to ignore these e-mails. This is due to them being busy and the lack of accurate and reliable information about the source and purpose of these surveys. The researcher in this study called every respondent prior to sending any survey. Through this call, the researcher introduced herself and the institution she was calling from (Newcastle University Business School). In addition, the

researcher gave an overview about the study's topic and purpose, and kindly asked the respondent whether it would be possible to complete this online survey as part of this research. Also, to encourage participants' participation, the researcher assured them that the survey did not contain any question related to financial or any other sensitive information about their company. The survey e-mail was only sent to the managers that agreed to participate. Specifically, a personalised e-mail with a subject line as "Open innovation – Newcastle University", was sent to them following the call. Beside this approach, used as a way to stimulate the response rate, this study also followed the recommendations of Cobanoglu and Cobanoglu (2003) stating that researchers can use incentives in online questionnaires to obtain higher response rates. Based on that, the researcher included in the e-mail sent to respondents the promise that respondents would be entered into a prize draw for a 100 GBP Amazon voucher. In all, such strategies worked well and helped in collecting a satisfactory response rate, as will be shown below. Adding to that, the researcher sent reminders to participants one week after the initial e-mail was sent to increase the response rate (Kanuk and Berenson, 1975; Cobanoglu and Cobanoglu, 2003; Evans and Mathur, 2005). (See Appendix 5, which includes the survey e-mail sent to the respondents that agreed to complete the survey and Appendix 6 for the survey of this study).

4.6.5 Response rate

Calling the respondents prior to sending them the survey was an effective strategy in general. Some respondents completed the survey immediately after the call, some did it later and some agreed but did not complete it. Researchers have to obtain a high response rate so that their sample is representative, and in turn, accurate results can be obtained from the data analysis. A perfect representative sample is a sample that accurately illustrates the population from which it is taken (Saunders *et al.*, 2011). Although the dataset used to collect data for this study included the contact details of around 10,813 managers, 1,000 managers agreed to complete the survey, and hence 1,000 e-mails with the survey link were sent out. The researcher phoned much more than 1,000 managers to have their consent before sending them the survey as will be explained in the following sections in this chapter. However, only 1,000 managers agreed to complete the survey. Other managers in this dataset refused to participate, whereas some others were not reachable. The researcher decided to stop calling respondents when 1,000 managers were reached simply by considering "1,000" as a round figure with which it can be

guaranteed that at least a 20% satisfactory response rate can be obtained (Hair *et al.*, 2014). Out of the 1,000 surveys sent to those that accepted, 336 responses were obtained, from which 211 questionnaires were fully completed and appropriate to be used in the data analysis of this study. Through the following equation, the researcher obtained a response rate of 21.1%.

Response rate= (number of usable questionnaires / total sample) x 100

Based on the target sample of this study, including the specific category of managers required (in charge of open innovation) and their busy schedule, the response rate obtained was considered satisfactory and acceptable (Hair *et al.*, 2014). In addition, the researcher ensured that the 1,000 managers to whom the survey was sent met the sample criteria that are relevant to this study. This means that the 1,000 managers were all in positions where they deal with open innovation and in companies that are in the high value manufacturing sector. Specifically, and as will be explained below, the 1,000 managers contacted occupied positions such as "technical directors/managers, vice president business development, managing directors, product managers, engineering directors/managers, general managers, CEOs, design managers, R&D directors/managers, head of innovation, business development managers". Moreover, these 1,000 managers contacted were employed in firms in the high value manufacturing sector that are for instance manufacturers of semi-conductors, marine-based equipment, aerospace, components for hybrid and electric powertrains, pumps, large steel components, electric motors, generators and transformers, ventilation systems, other special-purpose machinery n.e.c.", as explained previously in the sampling frame section (OECD, 2011). In contrast, managers from the database used in this study that were not contacted work at companies that are not related to the high value manufacturing sector having a SIC code such as "manufacturers of prepared animal feeds", "other articles of paper and paperboard", "processing and preserving of meat", "manufacturers of cosmetics", "metal coating", "process food", "manufacturers essential oils", "butter and cheese production", "aluminum production", "manufacturers of carpets and rugs". Nor where operations managers contacted as they do not tend to be relevant or well engaged in open innovation. Consequently, as the sector that companies relate to differs between the companies contacted and those not contacted for this study, there should not be any issue in terms of self-selection bias. The non-response bias is discussed in the next section.

4.6.6 Non-response bias

After collecting the data, the researcher evaluated whether there is a non-response bias. For instance, an extrapolation approach can be used to assess non-response bias based on the notion that late respondents are more similar to non-respondents than they are to early respondents (Armstrong and Overton, 1977). With the purpose of checking for non-response bias in this study, the researcher relied on the following process. In the first instance, the researcher compared the non-respondent firms to the overall sample involved in the questionnaire as per the key characteristics of the firms provided in the dataset, such as the industry type and position of the manager. Then, the researcher compared the respondents with the information available on companies that explicitly refused to participate in the survey. In addition, the researcher checked for early/late response bias by looking for different patterns of responses among companies that completed the survey early on versus those at a later stage. The following sub-sections will discuss non-respondents, explicit refusals and early/late response bias.

4.6.6.1 Non-respondents

As reported above, 1000 e-mails with the survey link were sent to the managers, out of which 336 responses were obtained. Thus, 664 firms did not complete the survey, representing 66.4% of the survey sample (1000 firms). Based on this high percentage of non-respondents, there were no differences between the entire survey sample and the non-respondents in terms of key characteristics such as the industry that firms relate to and the manager's position in each firm.

4.6.6.2 Explicit refusals

Through the phone calls conducted prior to sending the surveys, there were not too many managers that explicitly refused to complete the survey. Managers either accepted and completed the survey, or accepted but did not complete it. Some others were simply unreachable. However, the main firm characteristics of the managers that refused to participate in the study are very similar to those that completed the survey. For instance, similar to those that completed the survey, refusals were also related to high-value manufacturing sectors, such as "manufacturing of power driven hand tools", "manufacture of other special purpose

machinery", "manufacturing of furniture components", "manufacturing of architectural hardware", "manufacturing of injection moulding". Also, the positions of the managers in those companies that refused to participate were the same as the ones in the respondent companies. They included "general managers", "product managers", "managing directors", "technical directors", and "design managers". These 2 criteria are key demographic characteristics in this study as the researcher was targeting firms that are high-value manufacturers and managers in charge of open innovation.

4.6.6.3 Early/late response bias

The data collection stage took a long time between November 2018 and May 2019 due to the target respondents' roles, with constantly busy and unavailable managers. However, despite this long period, no significant changes were found in the responses between those that completed the survey at an early stage and those that completed it later on.

4.6.7 Unit of analysis

The "firm level" represents the most dominant unit of analysis in the open innovation literature. However, beside this level, there are also other levels that are much less investigated such as the project (discussed before), individual (Chatenier *et al.*, 2010; Salter *et al.*, 2015), and network level (Rampersad *et al.*, 2010). In addition, considering the Chesbrough and Bogers (2014) categorisation of open innovation studies at different levels of analysis, it includes the intra-organisational, organisational, extra-organisational, inter-organisational and industry, regional innovation systems and society. Nevertheless, this particular research focuses on the firm level of analysis of open innovation. In fact, there are still many capabilities at this level (organisational capabilities) that need to be investigated to show their effect on the breadth of open innovation activities and in turn firm innovativeness. This is a key gap in the open innovation at the firm level literature that this study seeks to address. Moreover, taking the firm level in this research makes it possible to compare the results of this study with previous research at the firm level and hence show its contributions to the open innovation implementation literature at the firm level.

4.7 Variables and measures

Analysing data includes identifying and measuring variation in different variables, either among themselves or between a dependent variable and one or more independent variables. The main word in this process is "measurement", as the researcher is not able to find variation unless it can be measured. The measurement is vital in precisely illustrating the concept of interest, and is instrumental in the choice of the suitable multivariate method of analysis (Hair *et al.*, 2014). The measurement stream is related to the relationships between the results obtained from the operationalisations and the main theoretical concepts (Schwab, 1980). Operationalisation represents the way in which a construct may be illustrated. This specific section will show how each of the independent, dependent and control variables constituting the model of this study was operationalised, i.e., by which items or indicators it was measured. Defined, an independent variable is a presumed reason for any change in the dependent variable, whereas a dependent variable is a presumed effect of, or reaction to, a change in the independent variable(s) (Hair *et al.*, 2014).

All items to measure the different variables in this study were multi-item scales. In fact, using multi-item scales makes it possible to average out errors and specificities that are innate to single items. This results in a higher reliability and construct validity (DeVellis, 2003). Items to operationalise all the variables in this study were taken from existing measures in previous studies published in highly-ranked academic journals. Among the advantages of using existing measures in the literature is the ability of the researcher to compare the results obtained with research that relied on similar operationalisations (Walsh, 1990; Hair, 2015). Also, a high reliability and validity can be guaranteed by relying on existing measures. Table 4.5 below shows the indicators measuring the scale variables of the conceptual model of this study, along with the sources of these measures. Some of these measures were somewhat adapted to meet the objectives of this research. The operationalisation of other types of variables in the model of this study, such as the firm size and binary variables which are the breadth of open innovation activities, external search breadth and open innovation team, is discussed in the section that follows Table 4.5.

Table 4.5 Measurements of constructs

Construct	Items	Source
Dependent variable		
1. Firm innovativeness	a- We invent new products and services	(Adopted from Abernathy and Clark (1985); Love and Roper (2001); Danneels (2002); Benner and Tushman (2003); Jansen et al. (2006))
	b-We experiment with new products and services in our local market	
	c- We commercialise products and services that are completely new to our organisation	
	d- We frequently utilise new opportunities in new markets	
Independent variables		
2. Open innovation training	a-Open innovation-related training is given to employees throughout our organisation	(Adapted from Dean Jr and Bowen (1994); Hackman and Wageman (1995); Powell (1995))
	b- Open innovation-related training is given to managers and supervisors throughout our organisation	
	c-Training is given in the "open innovation strategy" (i.e., what open innovation signifies for the firm, individual and task) throughout our organisation	
	d-Training is given in statistical tools and techniques in the organisation as a whole to collect and analyse information (i.e. market, technology, patents) quickly	
	e-Our organisation's top management is committed to employee training for open innovation	
	f-Resources are provided for employee training in open innovation	
3. Social information systems capabilities	a- Social information systems capabilities assist in searching for relevant external information	(Adapted from Limaj et al. (2016) based on Wade and Hulland (2004); Lu and Ramamurthy (2011); Kane et al. (2014))
	b- Social information systems capabilities assist in identifying and considering different types of external partners	
	c- Social information systems capabilities assist in acquiring relevant external information	

		d- Social information systems capabilities assist in analysing and sharing ideas and concepts	
		e- Social information systems capabilities assist in interpreting and understanding external information	
		f-Social information systems capabilities assist in quickly exchanging information between business units	
		g- Social information systems capabilities assist in discussing new insights	
		h- Social information systems capabilities assist in structuring and using newly collected information	
		i- Social information systems capabilities assist in preparing newly collected information for further purposes and making it available	
		j- Social information systems capabilities assist our employees in integrating new information into their work	
		k- Social information systems capabilities assist in accessing stored information, e.g., about new or changed guidelines or instructions	
		l- Social information systems capabilities assist in developing prototypes or new concepts	
		m- Social information systems capabilities assist in applying new knowledge in the workplace to respond quickly to environment changes	
4.	**Anticipation of new technologies**	a-We pursue long-range programs, in order to acquire manufacturing capabilities in advance of our needs	(Adopted from (Hayes and Wheelwright, 1984))
		b- We make an effort to anticipate the potential of new manufacturing practices and technologies	
		c-Our plant stays on the leading edge of new technology in our industry	
		d- We are constantly thinking of the next generation of manufacturing technology	
5.	**Relational capability**	a-To identify potential types of external partners and initiate relationships with them	(Adapted from Lorenzoni and Lipparini (1999); Morgan et al. (2009))
		b- To design effective governance mechanism for managing your relationship with key types of external partners	
		c-To develop and manage mutually beneficial relationships with key types of external partners	
		d- To establish effective working relationship with different types of external partners through both formal and informal channels	

Control variables			
6.	**Innovation climate**	a- Our company provides time and resources for employees to generate, share, exchange, experiment with innovative ideas and solutions	(Adopted from Oke et al. (2013))
		b- Our employees are working in diversely skilled work groups where there is free and open communication among the group members	
		c- Our employees frequently encounter non-routine and challenging work that stimulates creativity	
		d- Our employees are recognised and rewarded for their creativity and innovative ideas	
7.	**Innovation protection**	a-Our organisation has implemented firm-specific mechanisms to protect innovations	(Adopted from Becker and Dietz (2004)
		b-Our organisation has implemented mechanisms to protect innovations by law	
8.	**Organisational slack**	a-Our firm has uncommitted resources that can quickly be used to fund new strategic initiatives	(Adopted from Atuahene-Gima (2005)
		b- Our firm has few resources available in the short run to fund initiatives	
		c- We are able to obtain resources at short notice to support new strategic initiatives	
		d- We have substantial resources at the discretion of management for funding new strategic initiatives	
9.	**Internal R&D**	a- Our R&D department has high quality and quick feedback from manufacturing to design and engineering	(Adopted from Yam et al. (2011))
		b- Our R&D department has good mechanisms for transferring technology from research to product development	
		c- Our R&D department has great extent of market and customer feedback into technological innovation process	
10.	**Market volatility**	a-Customers' preferences for our products change constantly	(Adopted from Heide and John (1990) and other similar scales).
		b-Our customers demand the very latest technologies	
		c-Our competitors rapidly advance their product technologies	
		d-Nothing stays the same for long in our industry	
11.	**Innovation incentives**	a-In terms of promotion and salary rises, our firm gives priority to employees who actively engage in innovation activities	(Adopted from Wang *et al.* (2018))

b-Our firm recognises and rewards employees for their knowledge-sharing initiatives

c-Our firm gives commendation and praise to employees for their knowledge exchange and improvement

---

4.7.1 The breadth of open innovation activities and firm innovativeness

Respondents in the survey of this study were asked to indicate which of the 9 inbound open innovation activities they had been conducting in their firm in the last three years. As mentioned before, these activities were adopted by each of Podmetina *et al.* (2018) and Teplov *et al.* (2019), based on Chesbrough and Brunswicker (2014). These activities included IP in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing, collaborative innovation with external partners, and scanning for external ideas. Each of these activities was coded with 1 if the respondent firm reported using this activity and 0 if it reported not using the activity. Each firm's scores on these 9 open innovation activities were subsequently added up in such a way that they received a score of 0 when no open innovation activity was used and of 9 when all open innovation activities were used (Laursen and Salter, 2006). Table 4.6 below summarises the number of respondent companies that reported the usage of each open innovation activity in the questionnaire of this study. The results of this study showed that a large number of companies uses each activity, except for the "crowdsourcing" open innovation activity, adopted by a lower number of companies in comparison to the other activities in the survey. This can be simply related to the fact that crowdsourcing was among the inbound open innovation activities that were rated lowest in importance in the study by Chesbrough and Brunswicker (2014). Firm innovativeness, which relates to the outcomes of the innovation process, was represented by scale items to measure the extent to which firms invented new products and services, experimented with them in their local market, commercialised products and services completely new to them, and utilised new

opportunities in new markets.

Table 4.6 Adoption frequencies of the breadth of open innovation activities

Breadth of open innovation activities	IP in-licensing	External technology acquisition	Subcontracting R&D	Using external networks	Idea and start-up competitions	Collaborative innovation with external partners	Crowd-sourcing	Customer co-creation with R&D projects	Scanning for external ideas
Number of companies	180	186	161	172	128	190	63	187	188

4.7.2 The antecedents of the breadth of open innovation activities

As per table 4.5 above, open innovation training was measured using 6 items (Dean Jr and Bowen, 1994; Hackman and Wageman, 1995; Powell, 1995). Social information systems capabilities were measured using 13 items from Limaj *et al.* (2016), which they self-developed based on Wade and Hulland (2004), Lu and Ramamurthy (2011) and Kane *et al.* (2014). As far as the anticipation of new technologies is concerned, it was measured with 4 items. These items assessed the extent to which the firm anticipated and acquired new manufacturing technologies and capabilities essential for them in the future. Relational capability was also measured by 4 items evaluating the extent to which firms identified external partners with whom they developed and managed mutually beneficial relationships through governance mechanisms or channels.

4.7.3 Control variables

The innovation climate, also known as “innovation culture”, was measured through 4 items adapted from Oke *et al.* (2013). The scale of innovation protection comprised 2 items: the extent to which the company had implemented firm and legal mechanisms to protect innovations (Becker and Dietz, 2004). For the external search breadth variable, respondents were asked to indicate with which of the 10 types of external sources of knowledge they had been collaborating in their innovation activities in the last three years. These external sources of knowledge involved customers, universities, suppliers, public research organisations, entrepreneurs and start-ups, contracted R&D service providers, external consultants, competitors, unrestricted communities, and open innovation intermediaries (Chesbrough and

Brunswicker, 2013). As with the breadth of open innovation activities variable, 0 represented "no" and 1 represented "yes", and the 10 types of external sources were added up (Laursen and Salter, 2006).

Firm size was simply measured by the number of employees in each firm. To measure the open innovation team in this study, the researcher used a binary variable as well. This variable took the value of 0 if the participant firm does not have an open innovation team and 1 if it does have such a team. Organisational slack was measured with 4 items developed by Atuahene-Gima (2005), and internal R&D with 3 items adopted from Yam et al. (2011). For market volatility, the researcher used measures developed by Heide and John (1990) and other similar scales. Finally, innovation incentives were measured by three items, as shown in Table 4.5 (Wang *et al.*, 2018).

4.8 Validity and reliability of the research variables

Validity and reliability are key aspects for the quality of measurement (Slater and Atuahene-Gima, 2004; Hair, 2015). The current research has ensured a high validity and reliability for the measures when taken from the current literature and when tested in the data analysis stage, as will be shown in the next chapter.

4.8.1 Reliability

Reliability is an evaluation of the level of consistency between different measurements of a variable. One form of reliability is "test-retest", through which consistency is measured between the responses for an individual at two points in time. The purpose is guaranteeing that responses are not too different across time periods in such a way that a measurement taken at any time is reliable. Another and more regular way to assess reliability is through internal consistency, used in this study. Internal consistency refers to the consistency among the constructs in a summated scale (Hair *et al.*, 2014). To check the internal consistency, there are many measures. The reliability coefficient, which evaluates the consistency of the whole scale, with Cronbach's coefficient alpha, is the most commonly used measure. This coefficient refers to the average correlation between items and the number of items in a scale (Churchill Jr, 1979; Hair, 2015). As this specific method is common in the research methods literature (Tabachnick

et al., 2007; Hair *et al.*, 2014), this particular study used this technique to measure the reliability of the variables in the model of this study, as shown in the next chapter.

As regards the threshold to evaluate the reliability of the measures, Nunnally and Bernstein (1967) initially suggested a minimum acceptable value of 0.6 for Cronbach alpha. Then, it was changed to 0.7 (Nunnally, 1978). Similarly, Hair *et al.* (2014) consider that Cronbach alpha should be higher than 0.70, even though a 0.6 value can be used in exploratory studies. In this particular study, the researcher followed the suggestion of Nunnally (1978) that researchers have to aim for Cronbach alphas of 0.7 or higher.

4.8.2 Validity

After ensuring that a scale corresponds to its conceptual definition, that it is unidimensional and that it complies with the required levels of reliability, the researcher has to finally check the "validity" scale. Validity represents the extent to which a scale or set of measures precisely illustrates the concept studied (Hair *et al.*, 2014). Validity is the degree to which the measure measures what it is assumed to measure (Tharenou *et al.*, 2007).

Scales that have satisfactory levels of internal consistency with a Cronbach alpha higher than 0.7 may still not have content validity because of multidimensionality (Slater and Atuahene-Gima, 2004). A measure is valid only when it is unidimensional, which means the set of items represents a single construct (Anderson and Gerbing, 1988). For instance, confirmatory factor analysis (CFA), which was conducted in this study, as explained in the next chapter, is viewed as a thorough test of unidimensionality (Slater and Atuahene-Gima, 2004).

Validity in this particular study was checked through the following different types of validity and based on what each refers to. For instance, face validity refers to how closely a measure covers the concept it aims to measure (Hair, 2015), whereas content validity is the evaluation of the degree of correspondence between the items chosen to form a summated scale and its conceptual definition (Hair *et al.*, 2014). Both of these two forms of validity were maximised in this study by a comprehensive and careful review of the literature. As was highlighted above, the researcher ensured that all the measurements of the variables used in this study have been well-checked and validated by previous research published in highly-ranked academic

journals, such as *"Academy of Management Journal", International Journal of Operations and Production Management", "Research Policy" and "Journal of Business Research".*

As will be shown in the next chapter, "Analysis and Results", construct validity was tested in the analysis through both convergent and discriminant validity. Construct validity can be defined as the degree to which different measured variables actually illustrate the theoretical latent construct that those variables are intended to measure (Hair *et al.*, 2014). Convergent validity was checked through the CFA, discussed in the next chapter. Convergent validity is the extent to which items of a particular construct converge or share a high proportion of variance in common. As for discriminant validity, this was ensured through comparing the square root of the average variance extracted (AVE) for each variable with the correlations between that variable and all other latent ones (Fornell and Larcker, 1981). Therefore, discriminant validity refers to the degree to which a factor is truly different from other factors in relation to how much it correlates with other factors and how distinctly measured variables represent only this single factor. As for AVE, it is a summary measure of convergence among different items illustrating a latent construct. It is the average percentage of change explained among the indicators of a factor (Hair *et al.*, 2014). Once convergent and discriminant validity are developed, it can be concluded that unidimensionality of measurement variables is supported. The next chapter, on analysis and results, discusses how each of these different types of validity were assessed in CFA, which was conducted to ensure the fitness of the model prior to conducting the multiple regression analysis. CFA is an approach to examining how well the measured variables represent a smaller number of constructs (Schumacker and Lomax, 2012). The CFA conducted in this study will be thoroughly presented in the next chapter.

As for external validity, it represents the extent of the generalisability of the findings across time, settings, and people (Tabachnick *et al.*, 2007). As researchers have to develop the domain to which the findings can be generalised, external validity is viewed as the closest to the concept of generalisability (Sackett and Larson Jr, 1990). According to Scandura and Williams (2000), external validity or generalisability can be better addressed by methods such as formal theory and sample surveys. The researcher in the current study has conducted a critical and thorough review of the literature from which a conceptual model was developed based on theoretical lens. This model has been tested through a sample survey. All the stages followed and adopted in this study allow the researcher to report more generalisable results and improve external validity.

4.9 Data analysis method

4.9.1 Hierarchical multiple regression

The data in this study was analysed using the "hierarchical multiple regression" method including 2 equations. As the multiple regression analysis is a dependence approach, the researcher has to divide the factors into dependent and independent variables when using it (Hair *et al.*, 2014). Accordingly, the conceptual model of this study was divided into two equations. The first equation involves the relationship between the 4 antecedents and the breadth of open innovation activities, whereas the second equation represents the relationship between the breadth of open innovation activities and firm innovativeness. Regression analysis is when a researcher fits a linear model to his data and uses it to predict the values of a dependent variable from one or more independent variables. Unlike simple regression, which includes one independent variable, this study used a multiple regression method as there is more than one independent variable in the conceptual model of this study (Field, 2013). The flexibility and adaptability of multiple regression were among the main incentives for its adoption in this study with almost any dependence relationship. Adaptability and flexibility are two main reasons for multiple regression's common adoption across a broad variety of applications (Hair *et al.*, 2014).

Multiple regression analysis is a general statistical approach adopted to examine the relationship between a single dependent variable and different independent variables. Every independent variable is weighted by the regression analysis process to guarantee maximal prediction from the different independent variables (Hair *et al.*, 2014). Investigating the effect of each of the four antecedents on the breadth of open innovation activities through multiple regression analysis showed how important each of these 4 capabilities is in supporting the implementation of these activities. Moreover, this analysis revealed how important the breadth of open innovation activities is to firm innovativeness. Specifically, to examine these relationships through multiple regression, the researcher in this study relied mainly on the values of each of the standardised coefficients (Beta), p-values, R square, R square change and adjusted R square values. Standardised coefficients Beta (β) with a positive sign shows a positive relationship between each independent variable and dependent variable, whereas a

negative sign shows a negative relationship. The standardised beta values are all measured in standard deviation units and hence are directly comparable. They give a better understanding about the importance of an independent variable in the model. As for p-values, they show the significance of the relationship between each independent variable and dependent variable. R square is a measure of how much of the variability in the dependent variable is accounted for by the independent variables. The adjusted R square provides the researcher with some idea of how well the model generalises. Ideally, the researcher prefers its value to be the same as, or very close to, the value of R square (Field, 2013). These indicators are all key in multiple regression analysis.

4.9.2 Common methods variance

In this research, data were collected for both dependent and independent variables from a single main respondent through an online questionnaire. As a result, this can possibly lead to a common method variance (CMV) (Podsakoff *et al.*, 2003). As CMV may result in false results, there are different approaches by which it can be reduced.

The researcher has followed the suggestions by Nunnally and Bernstein (1994) and Spector and Brannick (1995) to lower the possibility of having a common method variance in this study. Accordingly, the researcher prevented any implication that there is a preferred answer, made responses to all items of identical effort and paid great attention to details of the wording of each item. Also, the researcher chose to include items that are less subject to bias, avoided having a long survey without affecting the research objectives to reduce participant fatigue, and provided clear guidelines. What is more, the ordering of the scale items was randomised, and there was reverse coding for one item so that the same end of a Likert-type answer format was not always the positive end. Moreover, to reduce the common method variance, managers were assured that their participation in this study was voluntary, and that their answers would be confidential and anonymous. This enabled them to answer as honestly as possible (Podsakoff *et al.*, 2003).

As noted above, the survey and cover letter were adequately designed so that the participants identified the relationship between the latent factors. Also, prior to the main data collection, the survey was pilot-tested with different academics and managers, based on which minor revisions and improvements were implemented in the survey. All these strategies guaranteed a lack of ambiguity and ensured that every question in the survey was easy to understand, hence reducing the common method variance in this study.

Then, "Harman's single-factor", as a statistical testing method, was conducted to check for common method variance (Podsakoff *et al.*, 2003). This test is based on conducting a post hoc factor analysis of the items illustrating the variables studied. Through this test, the presence of common method variance is proposed if a single factor accounts for most of the covariance. Accordingly, all scale variables of the conceptual model of this research were entered into an exploratory factor analysis (EFA). Based on the results, it was found that the variance explained by the first factor was 31.759% (< 50%), as shown in Table 4.7 below. This confirmed that common method bias did not represent a problem in this study (Podsakoff *et al.*, 2003). Additionally, common method bias is not possible when correlations are not excessively high (not > 0.9) (Pavlou *et al.*, 2007; Hu *et al.*, 2016). As will be shown in the next chapter in the descriptive statistics and correlations table, common method bias was not a problem in this study as there are no multicollinearity issues.

Table 4.7 Harman's One-Factor test results

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	15.899	33.124	33.124	15.244	31.759	31.759

4.10 Conclusion to the chapter

This chapter has provided a justification for the suitability and appropriateness of each of the methods of data collection and analysis used in this study. Additionally, it showed how this study has complied with the most important issues in research such as reliability, validity and

research ethics. The next chapter will present the results obtained from the data collected in this study while using the hierarchical multiple regression analysis method.

Chapter 5. Data analysis and results

5.1 Introduction to the chapter

This chapter will present the results of the statistical data analysis conducted in this study to test the conceptual model. The chapter will show the different steps of data screening conducted to make the data ready for analysis. Additionally, it will discuss the confirmatory factor analysis undertaken to check the fitness of the model, and the multiple hierarchical regression approach conducted to test the hypotheses and show the results obtained in this study.

5.2 Data screening

Data screening or data examination is an essential, primary stage in any data analysis. In this stage, the researcher examines the effect of missing data and checks for outliers. Additionally, prior to using any multivariate approach for analysis, such as SEM or multiple hierarchical regression, the researcher has to evaluate the fit of the sample data with statistical assumptions that are essential for the multivariate approach (Tabachnick *et al.*, 2007). Data screening in this research started by reviewing all reverse-coded items to make the data ready for further analysis. Only one item had to be reverse-coded, the second item in the organisational slack construct. Then followed the checks for missing data, normality, influential univariate and multivariate outliers, linearity, homoscedasticity, and multicollinearity (Kline, 2011; Hair *et al.*, 2014). All the data screening checks in this study have been conducted on IBM SPSS statistics software version 25.

5.2.1 Missing data

Missing data are mainly generated from errors in data collection or data entry or from the exclusion of answers by participants (Hair *et al.*, 2014). Before starting to analyse the data in this study, the researcher checked for errors in the data entry phase and for the availability of missing data. In fact, this process is essential to obtain important insights into the data's characteristics before conducting the analysis (Tabachnick *et al.*, 2007). Despite the advantage

of online questionnaires in eradicating the need for data entry, the accuracy of the data has to be checked. Thus, all entries for each case in the current study were checked by the researcher. This stage was followed by evaluating descriptive statistics, which consist of frequency distribution, mean and standard deviation, all of which showed the absence of errors in the dataset.

As noted above 336 responses were received in this study, 211 fully completed questionnaires were obtained and had no missing data at all as the researcher selected the option of "force response" for each question. In fact, the aim of "force response" was not to oblige respondents to answer each question, but just to avoid having missing data. For the question(s) or the option(s) that do(es) not apply to respondents, they could simply choose "neither agree nor disagree". In this case, "force response" did not result in any random answer. The remaining 125 questionnaires were started by participants but were not completed. As these incomplete questionnaires had 20% or more out of the full survey not answered, these surveys were simply removed from the analysis as per the suggestions of Tabachnick *et al.* (2007).

Through some follow up calls, it has been shown that some of the reasons behind the incompletion of these surveys were factors such as the length of the survey. Also, some of the participants simply started the survey and thought they would continue it later on and then simply ignored it despite the reminders. Each of the remaining 211 surveys was fully completed and had no missing data at all, except for the "open innovation team" variable in the questionnaire of this study, which includes different questions related to the open innovation team. Every respondent can answer and has answered the first question related to this variable in terms of whether there is or there is not an open innovation team in the firm. However, not every respondent can answer the remaining questions of this variable related to open innovation team characteristics. Accordingly, the questionnaire for this specific variable was designed in a way that companies not having an open innovation team can skip the remaining questions of this variable and move on to the next question related to "open innovation training". Obviously, a firm without an open innovation team is not able to answer the remaining questions about the team, resulting in "missing data" for these specific questions. However, they represent "ignorable missing data". Much more common are missing data resulting from the design of the data collection instrument, for example through "skip patterns", in which participants skip sections of questions that do not apply to them. In this case, the researcher is not responsible for these missing data as they belong to the research design and it would be unsuitable to try to

remedy this (Hair *et al.*, 2014). The 211 fully completed surveys were suitable and used to conduct the different checks below, CFA and multiple hierarchical regression, to test the research hypotheses in this study.

5.2.2 Assessment of outliers and normality

Outliers, also known as extreme responses, can improperly affect the outcome of any multivariate analysis. Outliers represent observations with a distinctive mixture of characteristics identifiable as distinctly different from the other observations. They cannot be categorically considered as either useful or problematic. However, they have to be seen in the context of the analysis and must be assessed by the types of information they can offer (Hair *et al.*, 2014). Many factors could be behind the presence of outliers. They might involve, for instance, observation, data entry, or very extreme values from self-reported data. A researcher has to check both univariate and multivariate outliers. A univariate outlier has an extreme value on only one variable, whereas a multivariate outlier has extreme values on two or more variables (Tabachnick *et al.*, 2007).

To check for univariate outliers in the current study, z-scores that are obtained by converting the data values to standard scores with a mean of 0 and a standard deviation of 1 can be used. Specifically, none of these z-scores should exceed 3.29 (Field, 2013). Accordingly, in this study all z-scores of all variables in the model of this study have been checked and none of them exceeded the cut-off point of 3.29. This shows that there are no univariate outliers in this study.

When considering more than two variables, the researcher needs an approach to objectively assess the multidimensional position of each case in relation to some common point. Therefore, to check for multivariate outliers, the Mahalanobis distance (Mahalanobis D^2) measure is used (Tabachnick *et al.*, 2007). This measure represents a multivariate evaluation of each case across different variables. This approach measures each case's distance in multidimensional space from the mean centre of all cases, giving a single value for each case regardless of how many variables are considered. The Mahalanobis D^2 measure has statistical properties that make it possible to test the significance. Thus, the D^2 measure divided by the number of variables involved (D^2 /degree of freedom) is approximately distributed as a t-value. It is recommended

that conservative levels of significance of 0.001 be used as the threshold value to be identified as an outlier. Thus, any value below 0.001 is considered as an outlier (Hair *et al.*, 2014). All cases in the dataset of this study had a D^2 /degree of freedom or a p-value, exceeding 0.001, which indicates the absence of any multivariate outlier in this study (the degree of freedom is 4 as there are 4 antecedents in this study). Appendix 7 at the end shows the Mahalanobis distance (D^2) and the D^2 /degree of freedom or p-value, which was higher than 0.001 for each of the 211 cases.

Beside outliers, it is also important to assess the normality in the dataset, being the most essential assumption in multivariate analysis. The normality illustrates the shape of the data distribution for an individual metric variable and its equivalence to the normal distribution, which is the benchmark for statistical approaches. The shape of any distribution can be explained by 2 measures, the "kurtosis" and the "skewness". Kurtosis represents the peakedness or flatness of the distribution compared with the normal distribution. While Kurtosis is the height of the distribution, skewness is utilised to explain the balance of the distribution (i.e., unbalanced and shifted to one side (right or left), or centred and symmetrical) (Hair *et al.*, 2014). Specifically, either highly skewed or high kurtotic data signifies non-normality, which can result in random effects on specification or estimation processes (Hall and Wang, 2005). The non-normality can be frequently justified by the presence of outlier cases in the data collected by the researcher.

Based on that, the researcher in this study conducted different tests to assess the normality of the data and to search for outlier cases. Descriptive statistics analysis using the mean score of items of dependent and independent variables was conducted and showed as per Table 5.1 below, where both skewness and kurtosis values range between -2.58 and +2.58, complying with what is recommended by Hair *et al.* (2014). According to Hair *et al.* (2014), if either kurtosis or skewness scores are greater than the critical value of 2.58, then the data distribution is non-normal. As per Table 5.1 below, the data distribution in this study is normal and there are no outliers.

Table 0.1 Descriptive statistics

Variables	Minimum	Maximum	Mean	Standard deviation	Skewness	Kurtosis
Breadth of open innovation activities	0	9	6.92	2.12	-1.314	1.326
Firm innovativeness	1.5	7	4.85	1.25	-0.302	-0.557
Open innovation training	1	6.83	3.11	1.45	0.338	-0.733
Social information systems capabilities	1	7	4.58	1.21	-0.74	0.176
Anticipation of new technologies	1	7	4.74	1.4	-0.779	0.268
Relational capability	1	7	4.87	1.16	-1.021	1.388
Innovation climate	2	7	4.96	1.04	-0.566	0.047
Innovation protection	1	7	4.9	1.61	-0.921	0.075
External search breadth	0	10	4.65	2.04	0.499	-0.237
Open innovation team	0	1	0.25	0.44	1.156	-0.671
Organisational slack	1	6.25	3.86	1.18	0.011	-0.604
Internal R&D	1.33	7	5.05	1.2	-0.764	0.29
Market volatility	1	7	4.16	1.22	-0.097	-0.476
Innovation incentives	1	7	4.49	1.24	-0.403	-0.004

5.2.3 Linearity and homoscedasticity

Linearity indicates the presence of a linear relationship between variables. The most dominant way to evaluate linearity is to check the scatterplots of the variables and to identify any non-linear patterns in the data. As for the homoscedasticity, it is the assumption that dependent variables show equal levels of variance across the independent variable(s) (Hair *et al.*, 2014). In this study, both linearity and homoscedasticity were checked and they both apply in the data collected in this research. In this research, linearity and homoscedasticity were checked through examining bivariate scatter plots in SPSS (Kline, 2011). The evaluation of these scatter plots resulted in an oval-shaped range of points, indicating that the variables are linearly linked and their variances are homogenously distributed.

5.2.4 Multicollinearity

Multicollinearity occurs when there is a strong correlation between 2 or more independent variables (Field, 2013). This indicates that they represent the same underlying construct (Tabachnick *et al.*, 2007). One approach of detecting multicollinearity and which was adopted in this research, was to check a correlation matrix of the independent variables and check if any correlate very highly. "Very highly" relates to correlations greater than 0.80 or 0.90. Another approach to checking for multicollinearity that was used in this study, was to check the "variance inflation factor" (VIF). The VIF shows whether an independent variable has a strong linear relationship with the other independent variable(s) (Field, 2013). The broadly acceptable rule of thumb is that if VIF is higher than 10, then multicollinearity is high (Tabachnick *et al.*, 2007). In this study, inter-correlations between latent constructs did not exceed 0.50, as shown in Table 5.2 below. Table 5.3 below illustrates the results of the VIF test. VIF values were all low, thus less than 10, with acceptable levels of tolerance. Consequently, these results raised no concern about multicollinearity in this research as these values were not higher than the suggested cut-off values of 0.80 or 0.90 for correlation and 10 for VIF.

Table 0.2 Descriptive statistics and correlations

	Mean	Standard deviation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1-Open innovation training	3.11	1.45	1														
2-Social information systems capabilities	4.58	1.21	.437**	1													
3-Anticipation of new technologies	4.74	1.40	.381**	.302**	1												
4-Relational capability	4.87	1.16	.387**	.435**	.450**	1											
5-Breadth of open innovation activities	6.92	2.12	.380**	.263**	.174*	.299**	1										
6-Firm innovativeness	4.85	1.25	.314**	.404**	.535**	.515**	.172*	1									
7-Innovation climate	4.96	1.04	.317**	.392**	.469**	.470**	0.009	.547**	1								
8-Innovation protection	4.90	1.61	.320**	.266**	.443**	.407**	.262**	.422**	.373**	1							
9-External search breadth	4.65	2.04	.292**	0.101	0.122	.216**	.338**	0.106	0.101	.191**	1						
10-Firm size	2957.58	16054.97	0.020	0.057	0.064	0.089	0.128	0.094	-0.013	0.069	.165*	1					
11-Open innovation team	0.25	0.44	.426**	.293**	.216**	.225**	.186**	.273**	.204**	.201**	.240**	.205**	1				
12-Organisational slack	3.86	1.176	.347**	.262**	.417**	.249**	0.061	.337**	.301**	.232**	0.014	-0.031	.205**	1			
13-Internal R&D	5.05	1.20	.343**	.254**	.487**	.376**	0.122	.483**	.557**	.389**	.149*	0.074	.224**	.281**	1		
14-Market volatility	4.16	1.22	.348**	.307**	.312**	.291**	.264**	.362**	.235**	.200**	.227**	.162*	.231**	0.102	.188**	1	
15-Innovation incentives	4.49	1.24	.399**	.397**	.398**	.426**	0.064	.410**	.592**	.375**	.139*	-0.020	.204**	.386**	.405**	0.129	1

N=211. *, **Significant at 0.05 and 0.01 levels respectively (Two-tailed)

Table 0.3 Multicollinearity assessment

Construct	Tolerance	VIF
Open innovation training	0.724	1.382
Social information systems capabilities	0.723	1.382
Anticipation of new technologies	0.745	1.342
Relational capability	0.683	1.464

a. Dependent variable: Firm innovativeness

5.3 Confirmatory factor analysis

The second step in the analysis stage after conducting data screening is running the confirmatory factor analysis (CFA) to evaluate the fitness of the model and delete items that do not contribute to the model fit. This study used the confirmatory factor analysis approach using AMOS 24 to check the fitness of the overall measurement model, which involves all continuous (scale) variables: Open innovation training, social information systems capabilities, anticipation of new technologies, relational capability, firm innovativeness, innovation climate, innovation protection, organisational slack, internal R&D, market volatility and innovation incentives. CFA is essential before conducting any multivariate approach to data analysis (e.g., regression or structural equation modelling). CFA is an approach to examining how well the measured variables represent a smaller number of constructs. With CFA, the researcher has to indicate the number of factors available for a set of variables and which factor each variable will load on before results can be computed. In the CFA, a researcher hypothesises a particular theoretical model, collects data, and then examines whether the data fit the model. The fit signifies that a model is capable of reproducing the data (Schumacker and Lomax, 2012). A well-fitting model is a model that is highly consistent with the data, not essentially necessitating revisions or modifications (Kenny, 2015).

5.3.1 Goodness of fit indices

The output of the CFA involves different goodness of fit indices. Based on these indices, the researcher in this study has identified whether the model needs to be re-specified or not. In this section, the researcher explains the different goodness of fit indices used in this study and their

recommended cut-off points to assess the model fit. When such indices do not meet the recommended cut-off points, then the model has to be re-specified until its fit is ensured (Hair *et al.*, 2014).

Specifically, this study followed the recommendations of Hair *et al.* (2014) and assessed the following fit indices of the Chi-square (X^2), Comparative fit index (CFI), Incremental fit index (IFI), Tucker-Lewis index (TLI), and Root mean square error of approximation (RMSEA). Before showing the values of each of these indices in the next section, a brief overview is provided on each in this section. The first index referred to in this study to assess the model fit is the Chi-square (X^2). This is a traditional measure for examining the overall fit and assessing the level of variation between the sample and fitted covariance matrices (Hu and Bentler, 1999). Researchers have discussed the X^2 limitations through creating goodness-of-fit indices that take a more pragmatic approach to the evaluation process. As the test is very sensitive in regards to the sample size and complexity of the model, complex models tend to produce higher X^2, which can result in the rejection of the specified model (Kenny and McCoach, 2003). In addition, the test necessitates the availability of multivariate normality and, hence, large deviations from normality can lead to the rejection of the correctly specified model (Hu and Bentler, 1999). Consequently, one of the first fit statistics to deal with these limitations was the X^2 /degrees of freedom ratio (Wheaton *et al.*, 1977). This ratio appears as CMIN/DF and was also assessed in the CFA of this study. CMIN is the minimum discrepancy. It is the discrepancy between the unrestricted sample covariance matrix S, and the restricted covariance matrix (Byrne, 2010). When the X^2 /degrees of freedom value is less than 2.0, it is viewed as very good, and if ranging between 2.0 and 5.0, it is considered acceptable (Hair *et al.*, 2014).

Beside Chi-square (X^2) as one of the modification indices, the Normed Fit Index (NFI) has been the practical measure of choice. Nevertheless, in the light of evidence that the NFI has revealed a tendency to underestimate fit in small samples, Bentler (1990) reviewed the NFI to take sample size into consideration and developed the Comparative Fit Index (CFI). Values for both NFI and CFI are from 0 to 1.00 and result from comparing a hypothesised model with the null model. Each gives a measure of complete covariation in the data. Even though a value of >0.90 was initially viewed as representative of a well-fitting model (Bentler, 1992), a revised cut-off value close to 0.95 was later recommended (Hu and Bentler, 1999). As for the

incremental index of Fit (IFI), this was developed to tackle the issues of parsimony and sample size, which were known to be allied with the NFI.

The suitable threshold values for NFI, IFI, CFI are expected to range between 0 and 1; however, a value greater than 0.9 suggests adequate fit and greater than .95 implies a very good fit model (Schumacker and Lomax, 2004; Byrne, 2013). In regard to the Tucker-Lewis Index (TLI), consistent with the other indices highlighted in this section, yield values lying between 0 and 1.00, with values close to 0.95 (in large samples) represent good fit (Hu and Bentler, 1999). Finally, the Root mean square error of approximation (RMSEA) shows how well the model, with unknown but optimally chosen parameter estimates, would fit the populations covariance matrix (Schumacker and Lomax, 2004). Byrne (2013) summarised the previous literature regarding suggestions related to the acceptable values of RMSEA as follows: an RMSEA value lower than 0.08 represents a reasonable fit, a value between 0.08 and 0.1 implies a mediocre fit, and more than 0.1 is a poor fit. Accordingly, X^2/df, IFI, TLI, CFI, and RMSEA were used to assess the model fit in this study, as shown in the following section.

5.3.2 Goodness of fit indices: re-specification of the original measurement model

Based on the above model fit indices and each of their recommended cut-off points, the researcher assessed the original measurement model in this study and revised it accordingly to ensure the fitness of the statistical model. The fit indices obtained in this study for the original overall model are: X^2= 2288.255, X^2/df=1.957, IFI=0.859, TLI=0.844, CFI=0.857, RMSEA= 0.068. Based on the values obtained, X^2/df and RMSEA show a good fit, as their values were less than the cut-off points of 2 and 0.08 respectively, as discussed above. However, the IFI, TLI, and CFI values were less than the cut-off point of 0.90, hence, the model in this research had to be re-specified. This study conducted a model re-specification process, where the original model was modified by deleting low factor loadings' items and freeing paths between items with high modification indices as explained below, until the best fitting model was obtained. Therefore, and as per the guidelines of Hair *et al.* (2014) and Hooper *et al.* (2008), the following process was adopted to re-specify the model:

Step one: Assessment of factor loadings

A factor loading indicates the degree to which an observed variable is related to a corresponding latent construct (Byrne, 2013). Items that are aimed to measure a particular factor should show high factor loadings on that factor, and preferably low loadings for other factors. To develop the validity of a construct, it is generally suggested that factor loadings should be 0.5 or higher, and preferably 0.7 or higher (Hair *et al.*, 2014). Table 5.4 below illustrates the results of the factor loadings for the observed variables in this study. Table 5.4 shows that all values exceeded the acceptable limit except for items OS2, IC3 and MV1, as highlighted in bold in Table 5.4 below. These three items were candidates for deletion from the re-specified measurement model. Beside deleting OS2 with a very low factor loading of 0.285, IC3 and MV1, with acceptable factor loadings of (0.576) and (0.577) respectively, were also deleted to improve the validity of the innovation climate and market volatility factors. In fact, items with outer loading between 0.40 and 0.70 should be considered for deletion from the scale only when removing the item results in an increase in the composite reliability or the average variance extracted (AVE) (Hair Jr *et al.*, 2016). IC3 and MV1 were deleted to improve their AVE.

Table 0.4 Standardised factor estimates

Construct	Label	Factor loading
Open innovation training	OIT 6	0.869
Open innovation training	OIT 5	0.858
Open innovation training	OIT 4	0.658
Open innovation training	OIT 3	0.836
Open innovation training	OIT 2	0.909
Open innovation training	OIT 1	0.918
Social information systems capabilities	SISC 1	0.706
Social information systems capabilities	SISC 2	0.677
Social information systems capabilities	SISC 3	0.704
Social information systems capabilities	SISC 4	0.772
Social information systems capabilities	SISC 5	0.769
Social information systems capabilities	SISC 6	0.769
Social information systems capabilities	SISC 7	0.843
Social information systems capabilities	SISC 8	0.893
Social information systems capabilities	SISC 9	0.868
Social information systems capabilities	SISC 10	0.839
Social information systems capabilities	SISC 11	0.767
Social information systems capabilities	SISC 12	0.777
Social information systems capabilities	SISC 13	0.831

relational capability	RC 4	0.89
relational capability	RC 3	0.918
relational capability	RC 2	0.776
relational capability	RC 1	0.759
Organisational slack	OS 4	0.794
Organisational slack	OS 3	0.669
Organisational slack	OS 2	**0.285**
Organisational slack	OS 1	0.796
Anticipation of new technologies	ANT 4	0.896
Anticipation of new technologies	ANT 3	0.864
Anticipation of new technologies	ANT 2	0.848
Anticipation of new technologies	ANT 1	0.813
Firm innovativeness	FI 4	0.769
Firm innovativeness	FI 3	0.766
Firm innovativeness	FI 2	0.726
Firm innovativeness	FI 1	0.664
Innovation protection	IP 2	0.863
Innovation protection	IP 1	0.899
Innovation climate	IC 4	0.704
Innovation climate	IC 3	**0.576**
Innovation climate	IC 2	0.739
Innovation climate	IC 1	0.781
Innovation incentives	II3	0.777

Innovation incentives	II2	0.885
Innovation incentives	II1	0.714
Internal R&D	R&D3	0.723
Internal R&D	R&D2	0.843
Internal R&D	R&D1	0.835
Market volatility	MV4	0.787
Market volatility	MV3	0.776
Market volatility	MV2	0.742
Market volatility	MV1	**0.577**

Step two: Assessing the residual matrix

The fit of the model in this study was also enhanced by checking the residual matrix or "standardised residuals". The standardised residuals represent the raw residuals divided by the standard error of the residual. Residuals can be either positive or negative, depending on whether the estimated covariance is below or above the corresponding observed covariance. The better the fit, the smaller the residuals (Hair *et al.*, 2014). These residuals' scores should be small and not higher for one observed variable than another (Schumacker and Lomax, 2004). Evaluating the standardised residuals in this study followed the guidelines of Hair *et al.* (2014), suggesting that standardised residuals lower than 2.5 do not constitute a problem, whereas standardised residuals higher than 4 represent a possibly unacceptable degree of error that can lead to the deletion of an item. Therefore, standardised residuals for any pair of items between 2.5 and 4.0 require some attention. However, they may not imply any modifications to the model if no other problems are related to those two items. Structural equation modelling researchers consider residual values greater than 2.58 to be large (Jöreskog and Sörbom, 1993). In the current research, almost all standardised residuals were less than 2.58, which means that residuals do not affect model misspecifications.

Third: Examining modification indices (MI)

As deleting the three items as explained above (OS2, IC3 and MV1) did not fully improve the model fit to meet the recommended cut-off points in regard to the goodness of fit indices, the modification indices were then checked. In particular, the researcher further improved the model fit in this study by freeing the path for items with high modification indices. According to Hair *et al.* (2014), a modification index is calculated for every potential relationship that is not estimated in a model. Modification indices of around 4.0 or higher indicate that the fit can be enhanced drastically through freeing the corresponding path to be estimated. However, conducting model modifications using solely modification indices is not advised. For this reason, factor loadings and standardised residuals were also checked at the beginning. Researchers can attain a good model fit through freeing parameters with large MI (Schumacker and Lomax, 2004). Table 5.5 below shows the high modification indices and the accompanying par change value statistics for the path between each of the following items as per Table 5.5 below. After deleting the three items above, the researcher improved the model fit by freeing the path between these items with high MI. After conducting this process, the researcher obtained a better model fit, which met the recommended cut-off points for each of X^2, X^2/df, IFI, TLI, CFI and RMSEA.

Table 0.5. Modification indices

Error term (item)		Error (item)	M.I	Par change
e8 (SISC2)	<-->	e9 (SISC3)	65.727	0.624
e1 (OIT6)	<-->	e2 (OIT5)	48.62	0.413
e18 (SISC12)	<-->	e19(SISC13)	36.076	0.366
e9 (SISC3)	<-->	e11 (SISC5)	27.766	0.292
e12 (SISC6)	<-->	e13 (SIS7)	26.86	0.335
e7 (SISC1)	<-->	e9 (SISC3)	22.235	0.267
e7 (SISC1)	<-->	e8 (SISC2)	22.177	0.305
e10 (SISC4)	<-->	e11 (SISC5)	20.533	0.272

5.3.3 Results for the re-specified measurement model

The goodness of fit figures for the re-specified model are: X^2 =1763.544, X^2 /df =1.734, IFI=0.903, TLI=0.891, CFI=0.902, RMSEA=0.059. These results show that the re-specified model fits better to the sample data in comparison to the initial model. All the values meet the suggested cut-off points discussed previously. Table 5.6 below compares the fit indices of the original and re-specified measurement models.

The re-specification process of the model has also significantly increased both convergent and discriminant validity as represented by Cronbach Alpha and the AVE results, which will be presented in the next section. Equally important, deleting those three items above has not changed the nature of the construct from which an item was removed, i.e., organisational slack, innovation climate and the nature of market volatility will not change. This is related to the reason that the scales in this study are reflective, which are interchangeable, rather than formative. In construct, in formative items, deleting an item modifies the nature of the construct (Diamantopoulos and Siguaw, 2006).

Table 0.6 Summary of the initial and final measurement model

Fit indices	Initial model	Re-specified (final) model
X2(df)	2288.255 (1169)	1763.544 (1017)
X2/df	1.957	1.734
IFI	0.859	0.903
TLI	0.844	0.891
CFI	0.857	0.902
RMSEA	0.068	0.059

5.4 Constructs' validity and reliability

This section presents the validity and reliability of the variables in the re-specified measurement model in this study.

5.4.1 Construct validity

Construct validity represents the extent to which the measurement tool in fact measures the latent construct that is being studied (Tabachnick *et al.*, 2007; Hair *et al.*, 2014). As highlighted in the methodology chapter above, construct validity is tested in the analysis through both convergent and discriminant validity (Zhu, 2000). Convergent validity is checked through the CFA, whereas discriminant validity is ensured through comparing the square root of the average variance extracted (AVE) for each variable with the correlations between that variable and all other latent ones (Fornell and Larcker, 1981). Once convergent and discriminant validity are developed, it can be concluded that the unidimensionality of measurement variables is supported.

5.4.1.1 Convergent validity

To examine convergent validity, the current research used a CFA approach, conducted above as per the recommendations of Anderson and Gerbing (1988). Convergent validity was examined through factor loadings of indicators, the average variance expected (AVE), and reliability of constructs (Tabachnick *et al.*, 2007; Hair *et al.*, 2014). Factor loadings of all items of the final re-specified measurement model are reported in Table 5.7 below. All retained items had a higher factor loading, indicating that a factor is strongly defined by its items (Tabachnick *et al.*, 2007). In addition, all factor loadings in Table 5.7 were greater than 0.5, considered as significant (Hair *et al.*, 2014), representing an acceptable measurement model. Table 5.7 below shows the final factor loadings of all items in the re-specified measurement model.

Table 0.7 Standardised factor loadings

Construct	Label	Factor loading
Open innovation training	OIT 6	0.828
Open innovation training	OIT 5	.816
Open innovation training	OIT 4	.652
Open innovation training	OIT 3	.832
Open innovation training	OIT 2	.929

Open innovation training	OIT 1	.937
Social information systems capabilities	SISC 1	.672
Social information systems capabilities	SISC 2	.638
Social information systems capabilities	SISC 3	.668
Social information systems capabilities	SISC 4	.751
Social information systems capabilities	SISC 5	.748
Social information systems capabilities	SISC 6	.758
Social information systems capabilities	SISC 7	.843
Social information systems capabilities	SISC 8	.911
Social information systems capabilities	SISC 9	.878
Social information systems capabilities	SISC 10	.851
Social information systems capabilities	SISC 11	.768
Social information systems capabilities	SISC 12	.767
Social information systems capabilities	SISC 13	.826
relational capability	RC 4	.890
relational capability	RC 3	.918
relational capability	RC 2	.776
relational capability	RC 1	.759
Organisational slack	OS 4	.774
Organisational slack	OS 3	.679
Organisational slack	OS 1	.808
Anticipation of new technologies	ANT 4	.896
Anticipation of new technologies	ANT 3	.864

Anticipation of new technologies	ANT 2	.848
Anticipation of new technologies	ANT 1	.813
Firm innovativeness	FI 4	.771
Firm innovativeness	FI 3	.766
Firm innovativeness	FI 2	.725
Firm innovativeness	FI 1	.663
Innovation protection	IP 2	.865
Innovation protection	IP 1	.897
Innovation climate	IC 4	.707
Innovation climate	IC 2	.719
Innovation climate	IC 1	.769
Innovation incentives	II3	.775
Innovation incentives	II2	.887
Innovation incentives	II1	.715
Internal R&D	R&D3	.725
Internal R&D	R&D2	.842
Internal R&D	R&D1	.835
Market volatility	MV4	.770
Market volatility	MV3	.779
Market volatility	MV2	.756

The second way to check for convergent validity was through the average variance extracted (AVE). AVE is calculated by summing up all the squared standardised loading of the items for each factor divided by the number of items of the same factor. Table 5.8 below shows the AVE

results for all constructs in this study. All variables had values greater than 0.5 as recommended for the AVE, indicating appropriate convergence between each construct and its respective items (Hair *et al.*, 2014).

Table 0.8 Validity and reliability

Constructs	Average Variance Extracted (>0.5)
Firm innovativeness	0.536
Open innovation training	0.702
Social information systems capabilities	0.608
Anticipation of new technologies	0.732
Relational capability	0.703
Innovation climate	0.536
Innovation protection	0.776
Organisational slack	0.571
Internal R&D	0.644
Market volatility	0.591
Innovation incentives	0.633

Finally, convergent validity was also checked through construct reliability measured by the Cronbach's Alpha. According to Churchill Jr (1979), Cronbach's Alpha is important to examine convergent validity. As shown in Table 5.9 below, all constructs maintained good values of Cronbach's alpha (α), higher than the threshold of 0.7 (Nunnally, 1978). Table 5.9 provides a comparison of the Cronbach's Alpha between the original measurement model (initial) and the re-specified measurement model. The Cronbach alpha for both innovation climate and market volatility slightly decreased after deleting one item from each but they both maintained good Cronbach alpha values above 0.7. The reliability of organisational slack has improved (increased) after deleting one item from this factor in the re-specification process of the model.

Table 0.9 Constructs' Cronbach's alpha

Constructs	Model 1 (original) Cronbach's Alpha	Model 2 (Modified) Cronbach's Alpha
Firm innovativeness	0.82	0.82
Open innovation training	0.933	0.933
Social information systems capabilities	0.955	0.955
Anticipation of new technologies	0.915	0.915
Relational capability	0.899	0.899
Innovation climate	0.795	0.77
Innovation protection	0.873	0.873
Organisational slack	0.717	0.794
Internal R&D	0.839	0.839
Market volatility	0.81	0.809
Innovation incentives	0.827	0.827

5.4.1.2 Assessing discriminant validity

Discriminant validity is present when the correlation shared between a factor and any other factor in the model is less than the correlation that factor shares with their indicators (Fornell and Bookstein, 1982). In this research, discriminant validity was checked by comparing the square root of the AVE for a specific latent construct with the correlations between that construct and all other latent constructs. As a result, the square root of the AVE for each variable is greater than the highest correlation, complying with Fornell and Larcker (1981) criterion for discriminant validity. This shows the absence of discriminant validity problems in this study. In Table 5.10 below, the diagonal elements in the correlation matrix (highlighted in bold) illustrate the square roots of the AVE. It shows that all constructs in the model diverged strongly from each other, hence there are no discriminant validity problems in this study.

Table 0.10 Discriminant validity

Constructs	1	2	3	4	5	6	7	8	9	10	11
1-Open innovation training	**0.838**										
2-Social information systems capabilities	0.430***	**0.779**									
3-Relational capability	0.328***	0.396***	**0.838**								
4-Organisational slack	0.424***	0.344***	0.308***	**0.755**							
5-Anticipation of new technologies	0.364***	0.305***	0.472***	0.499***	**0.856**						
6-Firm innovativeness	0.325***	0.444***	0.581***	0.418***	0.613***	**0.732**					
7-Innovation protection	0.315***	0.269***	0.442***	0.295***	0.494***	0.485***	**0.881**				
8-Innovation climate	0.387***	0.472***	0.521***	0.456***	0.550***	0.680***	0.472***	**0.732**			
9-Innovation incentives	0.426***	0.458***	0.461***	0.490***	0.449***	0.468***	0.451***	0.718***	**0.795**		
10-Internal R&D	0.340***	0.279***	0.380***	0.334***	0.548***	0.560***	0.438***	0.719***	0.434***	**0.802**	
11- Market volatility	0.332***	0.311***	0.306***	0.155†	0.363***	0.466***	0.261**	0.285**	0.13	0.220*	**0.768**

Bold figures represent the square root of average variance extracted from observed variables (items)

Off-diagonal: correlations between constructs

Significance of Correlations:

† $p < 0.100$

* $p < 0.050$

** $p < 0.010$

*** $p < 0.001$

5.5 Overall results of measurement development

The above section has shown how the CFA ensured the model fit in this study after deleting low factor loading items that were resulting most in the lack of fit during CFA, and by freeing the path between items with high modification indices. An improved model fit was obtained with satisfactory goodness of fit indices, factor loadings for all retained items, satisfactory AVE and reliability for all constructs without identifying any discriminant validity problems (Hair *et al.*, 2014). Accordingly, the re-specified model has been used to conduct the hierarchical multiple regression as a method of multivariate data analysis, as discussed in the next section, to test the research hypotheses and present the results of this study.

5.6 Hierarchical multiple regression

This section reports the empirical results obtained in this study through conducting a multiple hierarchical regression analysis to test the hypothesised model presented in chapter 3. The 2 following sub-sections present the results of the hierarchical multiple regression for the 2 parts of the conceptual model. The first part is related to testing the hypotheses between each of the 4 antecedents and the breadth of open innovation activities. The second part refers to the relationship between the breadth of open innovation activities and firm innovativeness.

5.6.1 Hypothesis testing

5.6.1.2 Effects of the open innovation antecedents on the breadth of open innovation activities

Table 5.11 below presents the multiple hierarchical regression (conducted on IBM SPSS) results for the effects of open innovation training, social information systems capabilities, the anticipation of new technologies, and relational capability on the breadth of open innovation activities, illustrated respectively by hypotheses H1, H2, H3, and H4. This relationship was controlled by the innovation climate, innovation protection and external search breadth factors. As discussed in chapter 3, these three factors (control variables) are fundamental for a firm to have, when implementing an open innovation strategy. Innovation climate, innovation protection and external search breadth specifically are the most essential elements that firms

should have in the first instance when implementing an open innovation strategy. For instance, an innovation climate encourages innovation capability and the creativity of employees (Menzel *et al.*, 2007) and stimulates inbound open innovation (Popa *et al.*, 2017). Innovation protection is also among the key issues that firms should consider in open innovation (Laursen and Salter, 2014; Bahemia *et al.*, 2017). What is more, through the external search breadth, companies will be able to connect with different external partners with whom to perform the open innovation activities (Laursen and Salter, 2006; Chesbrough and Brunswicker, 2013). Surprisingly, the innovation climate factor was found to be negatively significant, whereas innovation protection and external search breadth were both found to be positively significant. A justification of all these results is provided in the "Discussion" chapter below. In terms of the hypotheses, H1 ($\beta = 0.242$; t-value=3.316; $p < 0.001$) and H2 ($\beta = 0.132$; t-value=1.822; $p < 0.05$) were both supported, showing positive significant relationships between the open innovation training (H1) and social information systems capabilities (H2) with the breadth of open innovation activities. H3 was not supported, showing a negative and non-significant relationship between the anticipation of new technologies and the breadth of open innovation activities. Finally, this research has found a positive significant relationship between relational capability and the breadth of open innovation activities ($\beta = 0.156$; t-value=2.062; $p < 0.05$), supporting H4. All these results will be justified in the "Discussion" chapter.

Table 0.11 Dependent variable: The breadth of open innovation activities

	Model 1	Model 2
Control variables		
Innovation climate	-0.073	-0.241***
Innovation protection	0.234***	0.141*
External search breadth	0.299***	0.214***
Independent variables		
Open innovation training		0.242***
Social information systems capabilities		0.132*
Anticipation of new technologies		-0.004
Relational capability		0.156*
R^2	0.159	0.272
Adjusted R^2	0.147	0.247
R^2 change		0.112***

***, **, * indicate a significance level of .001, .01, and .05, respectively

N = 211. Standardised coefficients Beta (β) are reported

5.6.1.3 Effect of the breadth of open innovation activities on firm innovativeness

Table 5.12 below shows the statistical results of the curvilinear relationship between the breadth of open innovation activities and firm innovativeness. This relationship was controlled by firm size, open innovation team, organisational slack, internal R&D, market volatility and innovation incentives. As the sample of this study was high-value manufacturing companies, which constantly invest in open innovation, firm size was not a key criterion in this research as long as the respondent firms were high-value manufacturers. However, the researcher sought to include firm size as a control variable to see whether any differences in the size of the respondent firms in this study might reflect some changes in the results, and hence whether firm size might show any significant effect as a control variable when firms seek to attain firm innovativeness from the breadth of open innovation activities. In addition, as open innovation teams developed themselves as their firm's door to the external world (Mortara and Minshall,

2011), it is worth examining the role of the open innovation team as a control variable when firms undertake different open innovation activities and seek to achieve a better innovation outcome. Also, due to the expenditures associated with "search" (Laursen and Salter, 2006) and potentially with the breadth of open innovation activities, organisational slack is a key factor to consider in this regard. Moreover, due to the complementary relationship between open innovation and innovation outcome (Cassiman and Veugelers, 2006; Berchicci, 2013), internal R&D was also included in this study to check whether this factor has a significant positive effect as a control variable when examining the breadth of open innovation activities and firm innovativeness. Also, due to the continuous changes in market conditions and consumers' preferences (Hung and Chou, 2013), it is important to investigate market volatility as a control variable when studying the innovation outcome of performing open innovation activities. Finally, since incentives are among the factors by which, if used, firms can obtain the full potential of their relationships with customers (Foss *et al.*, 2011), innovation incentives were included as a control variable in the relationship between the breadth of open innovation activities and firm innovativeness.

As for the results of these control variables in this study, both firm size and open innovation team were found to be positive but non-significant. Organisational slack, internal R&D, market volatility and innovation incentives were all found to be positive and significant. The breadth of the open innovation activities variable had a positive significant coefficient (β=0.466; t-value=1.922; $p<0.05$), whereas the breadth of the open innovation activities squared variable had a negative significant coefficient (β= -0.449; t-value= -1.839; $p<0.05$). This has confirmed the inverted U-shape relationship (curvilinear relationship) between the breadth of open innovation activities and firm innovativeness, supporting H5. All these findings will be discussed in the following chapter.

Table 0.12 Dependent variable: Firm innovativeness

Control variables	Model 1	Model 2	Model 3

Firm size	0.028	0.026	0.036
Open innovation team	0.079	0.075	0.088
Organisational slack	0.138*	0.137*	0.153**
Internal R&D	0.293***	0.291***	0.273***
Market volatility	0.257***	0.249***	0.254***
Innovation incentives	0.189**	0.189**	0.200**
Independent variables			
Breadth of open innovation activities		0.033	0.466*
(Breadth of open innovation activities)^2			-0.449*
R^2	0.389	0.39	0.4
Adjusted R^2	0.371	0.369	0.376
R^2 change		0.001	0.010*

***, **, * indicate a significance level of .001, .01, and .05, respectively

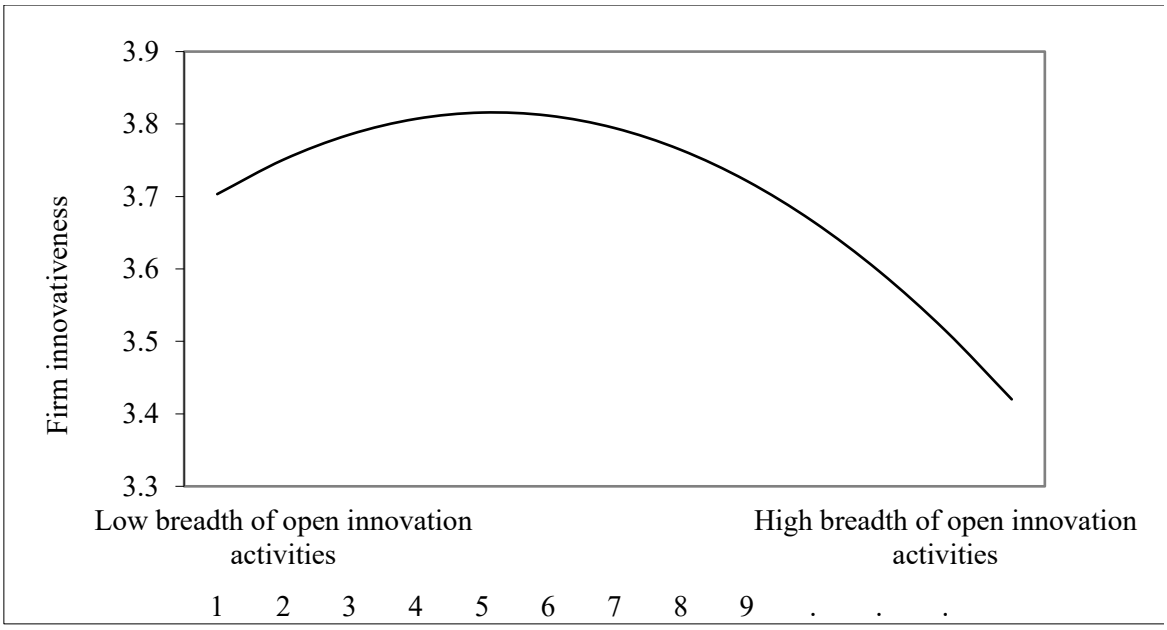
N = 211. Standardised coefficients Beta (β) are reported

Based on the results above (Table 5.12), the statistical significance and coefficient estimates of the squared terms of the breadth of open innovation activities indicate that the marginal effect of undertaking additional open innovation activities on firm innovativeness decreases. Figure 5.1 below graphically reveals the shape and the tipping point of the inverted U-shape relationship between the breadth of open innovation activities and firm innovativeness. This graph was drawn using one of "Jeremy Dawson's" excel plots (http://jeremydawson.co.uk/slopes.htm), related to "Quadratic effects", in particular the "Quadratic regression". The curvilinear relationship obtained as per Figure 5.1 below shows that undertaking different open innovation activities result in a higher level of firm innovativeness up to a certain extent, after which a lower level could be obtained.

An important point to highlight in the analysis and results obtained in this study is that none of the independent variables in the model of this research was mean-centred. In fact, even though some researchers mean-centre all independent variables in a study to lower potential multi-collinearity in the interaction and quadratic terms (Aiken *et al.*, 1991), mean centring in quadratic effects can result in some confusion in the interpretation of the results and hence is not mandatory. In fact, according to Haans *et al.* (2016), there is substantial confusion in relation to whether the independent variable should be mean-centred or standardised to lower

multicollinearity. Studies have explicitly shown that mean-centring is "much ado about nothing" (Kromrey and Foster-Johnson, 1998): the results obtained with centred data and raw data are mathematically alike and mean-centring does not increase the power to identify quadratic or interaction effects (Echambadi and Hess, 2007; Dalal and Zickar, 2012). Similarly, standardisation does very much the same except that all coefficients and standard errors, not just those of the independent variable as in the case of mean-centring, will change predictably and systematically (Aiken *et al.*, 1991). Therefore, such transformations complicate the computation of the turning point and can result in confusion in result interpretation (Haans *et al.*, 2016). Accordingly, to avoid any confusion in the results and their interpretation, the researcher in the current study did not mean-centre the breadth of open innovation activities and the breadth of open innovation activities squared, being 2 independent variables in the model. In addition, to ensure consistency with the first part of the model, the researcher has not mean centred the independent variables, i.e., the antecedents of open innovation.

Figure 5.1 The relationship between the breadth of open innovation activities and firm innovativeness



5.7 Hypothesis testing results

Based on the findings of this study, it has been shown that open innovation training, social information systems capabilities and relational capability are key organisational capabilities that support the breadth of open innovation activities. Therefore, this study's findings have

complied with the research by Mortara *et al.* (2009) and Mortara and Minshall (2011) showing the importance of open innovation training in open innovation. It has also contributed to the work of Limaj *et al.* (2016), which focused on social information systems capabilities in the context of absorptive capacity and innovation, and matched with the findings of Sisodiya *et al.* (2013) and (Wang *et al.*, 2015) in regards to relational capability and open innovation. The anticipation of technologies was not found to be an important capability for open innovation. Finally, in relation to the curvilinear relationship obtained in H5, it justified previous studies' findings on the limitations of open innovation (Laursen and Salter, 2006; Garriga *et al.*, 2013). In the next chapter (Discussion chapter), these findings will be developed much more fully to show and justify the importance of these organisational capabilities as well as the control variables in the breadth of open innovation activities and explain the advantages and limitations of open innovation, specifically in terms of the effect on firm innovativeness along with the control variables used in this study. Table 5.13 below illustrates the results of the hypothesis testing in this research.

Table 0.13 Hypothesis testing results

Hypotheses	Supported	Rejected
H1: Open innovation training is positively related to the breadth of open innovation activities.	✓	
H2: Social information system capabilities are positively related to the breadth of open innovation activities.	✓	
H3: The anticipation of new technologies is positively related to the breadth of open innovation activities.		✓
H4: Relational capability is positively related to the breadth of open innovation activities.	✓	
H5: The relationship between the breadth of open innovation activities and firm innovativeness is curvilinear, such that increasing the number of open innovation activities is associated with higher firm innovativeness up to a point, after which lower firm innovativeness will set in.	✓	

5.8 Conclusion to the chapter

This chapter has shown how the data collected in this study was thoroughly checked and prepared for the hierarchical multiple regression analysis. Then, the results of this study

obtained from this analysis method were presented. The next chapter will discuss these results to show what and how they have added to the open innovation literature and dynamic capabilities theory, and what the prospective justifications behind these findings are.

Chapter 6. Discussion

6.1 Introduction to the chapter

This chapter will first discuss the results obtained in this study in terms of the effect of the breadth of open innovation activities on firm innovativeness. Then, it will discuss the findings of this research in terms of the effects of the different routines and capabilities, including open innovation training, social information systems capabilities, relational capability and the anticipation of new technologies on the breadth of open innovation activities. Based on the findings presented in the previous chapter, the current chapter will discuss the two research questions that were set out at the start of this research in light of previous studies. Equally importantly, it will show how the findings of this study have contributed to the open innovation literature.

6.2 Research question 1: What is the effect of the breadth of open innovation activities on firm innovativeness?

The dominant conceptualisation of open innovation in the literature covers either search or collaboration (Laursen and Salter, 2006; Brunswicker and Vanhaverbeke, 2015; Chen *et al.*, 2016; Zobel, 2017), or one type of activity in isolation such as crowdsourcing (Afuah and

Tucci, 2012; Majchrzak and Malhotra, 2013; Wilson *et al.*, 2018; Cappa *et al.*, 2019; Pollok *et al.*, 2019), customer co-creation (Zwass, 2010; Williams, 2012), outsourcing (Bianchi *et al.*, 2016), interactions with customers (Foss *et al.*, 2011), opportunity exploitation (Foss *et al.*, 2013), external technology sourcing (Van de Vrande *et al.*, 2006) and external technology acquisition (Hung and Chou, 2013). Despite the benefits provided from searching, collaborating, or undertaking only one type of open innovation activity as per the studies referred to above, it is important to go beyond these prevailing conceptualisations of open innovation. Only very few studies have focused on the breadth of open innovation activities (Chesbrough and Brunswicker, 2013; Cheng and Huizingh, 2014; Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2016; Cano-Kollmann *et al.*, 2017; Podmetina *et al.*, 2018; Stephan *et al.*, 2019; Teplov *et al.*, 2019). Nevertheless, some of these studies have simply introduced these activities in terms of their usage and understanding between academic and practical (Chesbrough and Brunswicker, 2014; Teplov *et al.*, 2019). Others have simply discussed in general what may help firms while they undertake these activities (Chesbrough and Brunswicker, 2013; Podmetina *et al.*, 2016; Cano-Kollmann *et al.*, 2017; Podmetina *et al.*, 2018). Nevertheless, none of these studies have shown the effect of these activities on performance except Cheng and Huizingh (2014) and Stephan *et al.* (2019) who studied the effect on innovation performance as noted before. The current research focused on the under-researched conceptualisation of the breadth of open innovation activities, and examined their effect on firm innovativeness.

The motivation to study the breadth of open innovation activities in this research was mainly driven by the research gaps as explained in the literature review chapter. However, it was also related to the importance of examining the breadth of open innovation activities. In fact, academics in the literature illustrated the concept of open innovation by different practices and activities that firms can engage in when doing open innovation. However, they did not give them much attention with regards to the implementation of open innovation. As the purpose of adopting open innovation by companies is to attain competitive advantage, such a strategy necessitates collaborative activities with external partners such as firms, research centres, universities, customers, suppliers, consultants, or the general public through crowdsourcing mechanisms. Companies can increase their permeability to external knowledge in different ways. For instance, companies search for knowledge outside of their own boundaries through different modes, such as acquiring licenses, outsourcing R&D, recruiting workers with specialised knowledge, or directly acquiring other firms (Arora and Gambardella, 1990;

Granstrand *et al.*, 1992; Cockburn and Henderson, 1998). Similarly, companies in different sectors use a range of different organisational modes, such as licensing agreements, alliances, the purchase and supply of technical and scientific services to engage in relationships with several types of external partners to undertake open innovation (Bianchi *et al.*, 2011; Chiaroni *et al.*, 2011; Spithoven *et al.*, 2013; Kortmann and Piller, 2016). Consequently, open innovation is based on doing different types of activities that firms can engage in simultaneously. However, the implementation of different open innovation activities simultaneously has not been given enough attention by scholars.

Seeking to investigate the implementation of open innovation, this study focused on a complementary comprehensive list of inbound open innovation activities, which include: IP in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing, collaborative innovation with external partners, and scanning for external ideas (Chesbrough and Brunswicker, 2013; Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). The findings of this research showed in the first instance that the breadth of open innovation activities resulted in a higher degree of firm innovativeness or competitive advantage. Thus, while this study has extended the conceptualisation of open innovation to the breadth of open innovation activities, it showed their positive effect on firm innovativeness in the first instance. This finding can also be explained from a "complementarity" perspective. Different open innovation activities appear to be mutually complementary: the marginal return of an activity increases to the level of the other activity (Milgrom and Roberts, 1995). For instance, a firm may first use external networks to collaborate with. This will stimulate the possibility of acquiring different types of knowledge, in terms of technology, facilitating the "external technology acquisition" open innovation activity. Also, these activities can increase the chance of developing a "co-creation" between the firm and its external partners, to be able to develop new products together. In turn, it is possible that this co-creation results in the "subcontracting R&D" activity. This is because a successful co-creation helps the start of new product development projects (Fang *et al.*, 2008). Moreover, as companies scan for external ideas, the more they look for them, the higher will be the probability of looking into different modes to achieve it. They can undertake the "idea and start-up competitions" (Nokia, 2017; Unilever, 2017) or "crowdsourcing" activity, through which different external ideas flow into the firm. Therefore, based on the complementarity among these open innovation activities,

each of these activities can benefit firms and stimulate their innovation. Accordingly, a higher competitive advantage can be attained, specifically in terms of firm innovativeness.

The positive effect obtained between the breadth of open innovation activities and firm innovativeness can also be explained via organisational learning theory (Huber, 1991; Crossan *et al.*, 1999). In fact, among the practices related to organisational learning, they include knowledge acquisition and information distribution. Knowledge acquisition involves practices such as searching for information about the firm's environment and performance. Therefore, the different types of open innovation activities conducted by firms can be considered as part of the organisational learning process of the firm. Added to that, as organisational learning leads to the firm's strategic renewal (Crossan *et al.*, 1999), this further explains the positive effect obtained for the breadth of open innovation activities on firm innovativeness. To have a strategic renewal or firm innovativeness as per this study, it should be understood that the firm works in an open system, rather than only making an internal effort (Duncan and Weiss, 1979). Beside firm innovativeness, this strategic renewal can also be viewed in terms of creativity. This is because creativity, which represents the development of a valuable, useful new product, service, idea, or process by individuals working together in a complex social system (Woodman *et al.*, 1993), can be a starting point for the innovation itself (Amabile *et al.*, 1996).

Despite the positive effect, the findings of this research have also shown that the breadth of open innovation activities can result in a negative effect after a certain extent. In other words, it was found that the breadth of open innovation activities is a first-order dynamic capability resulting in competitive advantage or firm innovativeness up to certain limit after which lower firm innovativeness may result. Undertaking too many open innovation activities results in a positive effect on firm innovativeness after which lower firm innovativeness may result. The few studies that exist on the breadth of open innovation activities have not examined the effect on performance (Chesbrough and Brunswicker, 2013; Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2016; Cano-Kollmann *et al.*, 2017; Podmetina *et al.*, 2018; Teplov *et al.*, 2019), excepting Cheng and Huizingh (2014) and Stephan *et al.* (2019) who investigated innovation performance. Therefore, the current study has investigated the effect of the breadth of open innovation activities on firm innovativeness, and has also found a curvilinear (inverted U-shape) relationship between them. Equally important, the curvilinear effect obtained is consistent with prior research that highlighted the limitations of open innovation in terms of either search or collaboration with external partners (Laursen and Salter, 2006; Leiponen and

Helfat, 2010; Garriga *et al.*, 2013), or one open innovation activity (Bianchi *et al.*, 2016).

The curvilinear relationship obtained shows that the choice of open innovation activities has to be judiciously managed, as undertaking too many different types of open innovation activities is likely to exercise pressure on financial, human, cognitive and time resources. A lack of resources can hamper firm innovativeness when a high uncontrollable number of open innovation activities has been pursued, as per the sample of this study. Also, due to the large amount of information and ideas exchanged when different types of open innovation activities are undertaken together, only few of them may be taken seriously or allocated the necessary level of attention to implement them (Koput, 1997). This is because conducting too many open innovation activities may create some confusion due to the large amount of information acquired. For instance, a firm may be collecting knowledge through external technology acquisition. At the same time, it may also be engaged in crowdsourcing or start-up and idea competition activities. It is therefore exposed to several ideas and it may be scanning for more external ideas. In addition, as each activity may be costly, then the costs arising from undertaking several open innovation activities together may indeed result in lower firm innovativeness. In contrast, undertaking up to five activities can still be controllable and manageable by firms, and it exercises less pressure on the range of the aforementioned resources.

Another point that could also explain lower firm innovativeness might be the potential problem of "knowledge leakage" (Ritala *et al.*, 2015). Firms may not be able to control all their internal information and protect it from external partners when engaging in, for instance, "co-creation", "subcontracting" and "collaboration with external partners" activities at the same time. As a result, with several open innovation activities being undertaken, there is a higher risk of exposing a firm's internal information to outsiders, which could consequently result in knowledge leakage.

Some control variables were used while investigating this relationship between the breadth of open innovation activities and firm innovativeness in this study. As presented in the Results chapter of this research, both firm size and open innovation team factors had a positive but non-significant effect. Firm size is not one of the main characteristics of companies when it comes to the effect of the breadth of open innovation activities and firm innovativeness *as long*

as they are high-value manufacturers. As for the open innovation team, the data collected in this study revealed that not all companies have an open innovation team, in fact, only a few of them do. Most of the respondent companies in this study either rely on their R&D department, or simply on general managers and directors to deal with open innovation. In relation to organisational slack, internal R&D, market volatility and innovation incentives control variables, they all showed a positive significant effect while testing the curvilinear relationship, viewing the importance of each of these factors in open innovation as highlighted in previous research (Cassiman and Veugelers, 2006; Laursen and Salter, 2006; Foss *et al.*, 2011; Berchicci, 2013; Hung and Chou, 2013; Salter *et al.*, 2014).

Overall, focusing on the effect of the breadth of open innovation activities on firm innovativeness, this study has demonstrated an inverted U-shape relationship. It has revealed that the breadth of open innovation activities results in a higher degree of firm innovativeness up to a certain extent, after which lower level of firm innovativeness can be obtained. This study showed that doing too much open innovation activities results in diminishing returns. Such a curvilinear relationship is explained by the aforementioned challenges and limitations associated with these activities, as discussed in this section.

6.3 Research question 2: How do different organisational routines and capabilities affect the breadth of open innovation activities at firm level?

The results of this study suggested that the breadth of open innovation activities, being a first-order dynamic capability to some extent, is facilitated by specific second-order dynamic competences and capabilities (Collis, 1994; Ambrosini *et al.*, 2009; Schilke, 2014). In particular, the breadth of open innovation activities, was found to depend on the proactive creation of open innovation training, social information systems capabilities and relational capability as per the results of this study. In addition, these second-order dynamic competences and capabilities do not only support the implementation of open innovation, but also act as effective information-processing mechanisms that decrease the possible risks and the environmental uncertainty arising when companies conduct any of these open innovation activities (Zaltman *et al.*, 1973; Tushman and Nadler, 1978; Bensaou and Venkatraman, 1995). The uncertainties that firms face when undertaking these open innovation activities can involve

geographical distance between partners, potential opportunistic behaviour of external partners, misappropriation of knowledge, challenges associated with searching for information, a lack of open innovation skills among internal employees, and resistance by internal employees to open innovation, as will be further elaborated on below (Chesbrough, 2003; Phene *et al.*, 2006; Faems *et al.*, 2008; Mortara *et al.*, 2009; Ritala *et al.*, 2015).

Open innovation training, social information systems capabilities and relational capability are part of the deliberate and proactive organisational learning mechanisms and routines that enable companies to better manage the breadth of open innovation activities simultaneously (Argote, 1999; Cepeda and Vera, 2007). In this way, firms become better open innovators. The only capability that showed a negative non-significant effect on the breadth of open innovation activities in this study, was the anticipation of new technologies.

This section will explain and justify the results obtained regarding the effects of these capabilities on the breadth of open innovation activities. Accordingly, it will elaborate on their contribution to the implementation of the open innovation literature, specifically from a dynamic capability perspective.

The direct effect of each of these four open innovation capabilities is discussed in sections 6.3.1, 6.3.2, 6.3.3 and 6.3.4 below.

6.3.1 The effect of open innovation training on the breadth of open innovation activities

Examining the effects of different key capabilities and competences on the breadth of open innovation activities, this research studied the effect of open innovation training as a potential second-order dynamic competence that facilitate the implementation of different types of open innovation activities. The results obtained in this study showed that open innovation training is a second-order dynamic competence enabling the implementation of different types of open innovation activities. As in any other new process or strategy implemented in a firm, one of the fundamentals of human resource practices is to carry out training for employees in the new strategy. Accordingly, training is well established and investigated in other contexts such as "total quality management" (Powell, 1995; Douglas and Judge Jr, 2001; Kaynak, 2003) and "knowledge management capacity" (Chen and Huang, 2009). However, it is not yet well investigated in the context of open innovation, and particularly regarding the breadth of open innovation activities. Mortara and Minshall (2011) and Salter *et al.* (2014) showed the

importance of training in open innovation, but their studies were qualitative, based on interviews and case studies, from which it was not possible to generalise more from the results. Also, they could not examine the overall effect on innovation outcomes due to their qualitative research design. Nor did they focus on a specific conceptualisation of open innovation, but simply "open innovation" in general.

An important point that could explain the importance of open innovation training in facilitating the breadth of open innovation activities is that open innovation training can involve educating people about what each open innovation activity is based on. It can also be based on how to conduct and how to manage these different types of open innovation activities more effectively. This is because training is part of an organisational culture that stimulates employees to act and behave in a specific way (Alavi *et al.*, 2005). For instance, taking the "Innovation Academy" as an example, it works with clients (companies) finding it difficult to organise or monetise their innovation practices. The "Innovation Academy" aims to develop a consistent culture of innovation in their firms. As part of its objectives, it provides firms with an open innovation workshop that teaches open innovation techniques that have been successfully implemented in different industries, offering firms the required competencies to start or enhance their current collaborative efforts. This training incorporates areas related to, for instance, how the team currently collaborates. It also involves a collaboration test. Equally significant, among the topics covered in the open innovation workshop of this academy, they include key partners and activities and business models for collaborations, for instance. They also involve open innovation methods, in terms of collaborative open innovation, cooperative open innovation, and co-creative open innovation. For the open innovation tools, they incorporate tools for collaborating online and offline, crowdsourcing and creativity techniques (Academy, 2019). The nature and content of training provided by this academy in practice focuses on different types of activities such as collaboration, crowdsourcing and co-creation. This in turn greatly justifies the supporting role of open innovation training in the wide range of open innovation activities as per the results of this study.

Another point that shows how training can help different open innovation activities relates to the different types of skills provided through open innovation training as per Mortara *et al.* (2009). Taking the introspective skills, they enable the firm's evaluation of the value of each gap or opportunity generated from inside the firm itself. As for the extrospective skills, they facilitate the evaluation of the value of each interaction from the viewpoint of the other party.

They also assess competences and opportunities generated from outside. Interactive skills represent communication skills that send the value of any interaction with the external context both internally and externally. Finally, the technical skills involve all the technological, marketing, financial, commercial, management and business proficiencies and techniques required to stimulate the other three skills discussed. Offering these types of skills, open innovation training can help firms identify the best external opportunities through each open innovation activity they conduct, boosting the implementation of the breadth of open innovation activities. For instance, the different skills provided by Unilever for its employees when moving to open innovation have scouting as the core one. They also encompass mentoring and forming employees into communities and collaborative networks, which in turn enhances and maintains learning (Unilever, 2011).

Training not only facilitates open innovation activities, but also reduces the challenges and risks that can arise when conducting these activities. This further explains the supporting role of open innovation training for these activities. Through open innovation training, employees in the focal firm can understand both the benefits of open innovation activities and their limitations after a certain point. In this way, they can avoid the problems related to a large amount of information being acquired and the expenses of undertaking several activities. Beside the tipping point issue, knowledge leakage, discussed in the first research question, is also highly likely to occur where different open innovation activities are taking place, at any time during the process. However, this challenge can also be mitigated through open innovation training. This is because open innovation training stimulates employees to perceive themselves operating a social exchange relationship of mutual trust, respect and support (Piening *et al.*, 2013). When such traits are available, firms can prevent knowledge leakage and the opportunism that can arise with these different types of open innovation activities. Thus, the possibility of mitigating the negative attitudes arising with open innovation activities justifies why "professional training" and "training for innovation and creativity" limit the impact of the not-invented-here syndrome (NIH) on inbound open innovation (de Araújo Burcharth *et al.*, 2014).

Relying on the creativity literature, training is an approach that stimulates employees to generate more ideas and to stay open-minded, resulting in positive enhancements in attitudes (Birdi, 2007). In particular, it reduces employees' negatively biased attitudes toward external

sources (Kraiger *et al.*, 1993) and manages the Not-Invented-Here and Not-Shared-Here limitations (Katz and Allen, 1982; Chesbrough, 2003). Building on these assumptions, the positive relationship between open innovation training and the breadth of open innovation activities has also contributed to the creativity literature. Moreover, as the breadth of open innovation activities has been shown to represent an organisational learning process as in the previous section, this study has confirmed that training is one of the most important human resource practices for the organisational learning process (Ulrich *et al.*, 1993; Nonaka and Takeuchi, 1995). It should be directed towards creating a culture of commitment to learning (Kamoche and Mueller, 1998). It boosts the breadth of open innovation activities, which is a source of learning for the organisation. Equally importantly, this training represents a learning routine and a second-order dynamic capability or a regenerative dynamic capability because it supports the way firms conduct their open innovation activities, a first-order dynamic competence (Ambrosini *et al.*, 2009).

6.3.2 The effect of social information systems capabilities on the breadth of open innovation activities

The open innovation literature clearly acknowledges the significance of technology in open innovation, but not the related "capabilities" that firms should develop for open innovation. Moreover, the role of technology has been underlined since the emergence of the 5th generation model. For example, Rothwell (1992) focused on the importance of more external emphasis through the use of information technologies. Thus, open innovation was found to be more suitable in environments characterised by factors such as technology intensity and technology fusion (Gassmann, 2006). For instance, "social media", which is used to connect, interact and collaborate with consumers, has increased considerably recently (Mount and Martinez, 2014). As an example, online communities allow firms to draw insights from a deep, varied knowledge pool that can be used in organisational innovation (Füller *et al.*, 2007). Also, knowledge management systems facilitate the creation of an open and collaborative ecosystem (Santoro *et al.*, 2018). There are no studies yet that have examined the capabilities related to these technologies in order that they can be effectively adopted when implementing open innovation. Therefore, to close the gap in the open innovation implementation literature, this

study has also investigated social information systems capabilities as a potential second-order dynamic capability to investigate their effect on implementing the breadth of open innovation activities.

This study found that social information systems capabilities have a significant positive effect on the breadth of open innovation activities. This finding supported the view that social information systems capabilities are also a significant second-order dynamic capability that boosts the breadth of open innovation activities (Ambrosini *et al.*, 2009; Schilke, 2014). As social information systems capabilities facilitate the process of searching, interacting and acquiring external knowledge from external partners (Limaj *et al.*, 2016), such practices are related to the different types of open innovation activities that firms can engage in. Based on that, social information systems capabilities can also boost the process of doing different types of open innovation activities together, such as IP in-licensing, using external networks, collaborative innovation with external partners, co-creation and scanning for external ideas (Chesbrough and Brunswicker, 2013; Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2018; Teplov *et al.*, 2019).

Social information systems capabilities have not yet been investigated in the context of open innovation. They have been studied with exploratory and exploitative innovation outcomes (Limaj *et al.*, 2016). The dynamic effects generated from mixing social information systems capabilities with absorptive capacity have a positive effect on both exploratory and exploitative innovation outcomes (Limaj *et al.*, 2016). As both of these innovation types necessitate looking beyond firm boundaries for ideas in innovation and conducting different open innovation activities, this clearly explains why these capabilities stimulate the breadth of open innovation activities as well as per the results of this research. Therefore, the findings of this study are consistent with Limaj *et al.* (2016). When SMEs for instance rely on external knowledge, using social information systems and creating outside-in social information systems capabilities helps them to be well connected and to efficiently acquire external knowledge (Limaj *et al.*, 2016). Other than resonating with Limaj *et al.* (2016), the findings of this research also allied with how Wang *et al.* (2015) describe the information capability. They describe it as the firm using technology to collect, process, and transfer information to help decision-making, make improved business operations, and enable communication, coordination and successful collaboration with external sources. In essence, social information systems capabilities are an information capability which, as with all these practices of

collection, processing, and transmission of knowledge and collaboration, can stimulate the breadth of open innovation activities as well.

Like open innovation training, social information systems capabilities also seek to manage the different challenges that may be faced when implementing several open innovation activities. Therefore, it is for this reason also that they can support the breadth of open innovation activities. These challenges could include an over-search of the external environment (Laursen and Salter, 2006), inappropriate place and time of the development of ideas, a lack of the necessary level of attention allocated for the implementation of ideas (Koput, 1997) and the firm's geographical distance from its collaborators and external partners (Phene *et al.*, 2006; Sidhu *et al.*, 2007). In fact, outside-in social information systems capabilities simplify and speed up the process of accessing and looking for relevant external information (Boyd and Ellison, 2007). In addition, "spanning interpretation social information systems capabilities", one form of the social information systems capabilities, support the clarification and the communication of significant information. Another form, "spanning integration social information systems" capabilities enable the effective mixture of various sources of knowledge while recombining current ideas into new ones (Leonardi, 2014). With these capability functions, firms will be better able to manage the large amount of knowledge acquired and the potential challenges that could arise with these different forms of open innovation activities. Similarly, the attention problem will be reduced using these capabilities because they will appropriately structure the process. Also, as face to face meetings will no longer be required due to these capabilities, geographical distance and timing problems will be solved. Social information systems capabilities can reduce the time and expenses that may be linked to the breadth of open innovation activities.

Overall, social information systems capabilities are effective information-processing mechanisms that stimulate open innovation activities and mitigate the challenges associated with their implementation. Revealing the positive impact of social information systems capabilities on the breadth of open innovation activities in this research has shed light on the importance of "technology-related capabilities" in the breadth of open innovation activities.

6.3.3 The effect of relational capability on the breadth of open innovation activities

The facilitating role of relational capability has been studied with regards to knowledge acquisition and exploitation (Yli-Renko *et al.*, 2001), and strategic alliances (Kale *et al.*, 2000).

Relational capability was also investigated in establishing and nurturing relationships with external partners (Morgan *et al.*, 2009). However, the role of this capability in supporting the breadth of open innovation activities was still not yet investigated in the literature. A few studies have shown the importance of this capability in external collaboration (Wang *et al.*, 2015), inbound open innovation (Sisodiya *et al.*, 2013), knowledge acquisition and co-creation with universities (De Silva and Rossi, 2018), and external knowledge sourcing (Dyer and Singh, 1998; Carmeli and Azeroual, 2009). However, it is still not clear what the effect of relational capability on the breadth of open innovation activities is. Driven by this research gap, as well as by the potential supporting effect of this capability on the breadth of open innovation activities as explained in Chapter 3 of this thesis, this study examined whether relational capability is a second-order dynamic capability for the implementation of the breadth of open innovation activities.

This study found a positive significant relationship between this second-order dynamic capability (relational capability) and the breadth of open innovation activities, a first-order dynamic capability. This indicates that when undertaking different types of open innovation activities together, it is highly beneficial to have such a capability to help firms manage these different activities with their external partners. Relational capability does not only refer to the ability to find suitable partners. It also helps with developing and fostering relationships with them (Morgan *et al.*, 2009), and planning means of governance for effective collaboration (Faems *et al.*, 2008). Therefore, this conceptualisation of relational capability can be illustrated by many open innovation activities considered in this study such as IP in-licensing, using external networks, collaborative innovation with external partners, co-creation and scanning for external ideas (Chesbrough and Brunswicker, 2013; Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). Also, when firms focus on many types of open innovation activities at the same time, the process of implementation of open innovation becomes more difficult and complicated, hence a relational capability may be required to manage and control these activities. Therefore, the current research has extended the scope of studying relational capability to the breadth of open innovation activities instead of only one activity. For instance, relational capability helps firms identify which networks are really important for their innovation needs and hence they can effectively structure the process of collaborating with them, and co-create products with them. Furthermore, companies enhance

their interactional competencies in terms of negotiation, collaboration and problem solving with the external partners during these open innovation activities, all of which are part of the relational capability (Sisodiya *et al.*, 2013).

Another way of interpreting how relational capability supports the breadth of open innovation activities is its potential in mitigating the risks associated with the breadth of open innovation activities. In addition to the major importance of relational capability in helping firms to create and manage their relationships with external partners (Day, 2000), this second-order dynamic capability can help firms manage one common challenge perceived in open innovation, namely knowledge leakage (Ritala *et al.*, 2015). In fact, as is the case with open innovation, there is always a risk of knowledge leakage when different types of open innovation activities are performed together. The literature demonstrates that firms have to protect their own knowledge from rivals' imitation when engaging in open innovation (Laursen and Salter, 2014). However, the literature has also revealed that placing a strong emphasis on appropriability can result in lowering of effort to rely on knowledge from several external partners in formal collaborations (Laursen and Salter, 2014). Moreover, the use of secrecy negatively moderates the relationship between openness to external knowledge and innovation performance (Monteiro *et al.*, 2017). Thus, as secrecy and other appropriability forms have both positive and negative effects when it comes to protecting knowledge in open innovation, a relational capability may be an adequate competence in this regard. A high relational capability makes collaborators confident that problems that might occur in relationships can be avoided and reduced (Fang *et al.*, 2008). It enables firms to differentiate between transactional and collaborative relationships. This capability also applies the appropriate governance mechanisms to manage these inter-firm relationships and reduces the potential risks of opportunistic behaviour and the misappropriation of knowledge (Day, 2000; Faems *et al.*, 2008). For instance, firms can create the "structuring capability", one of the facets of relational capability. This capability represents the ability of companies to create up-front contractual agreements and relationship management frameworks (Ariño *et al.*, 2014) – called "learning to contract" (Mayer and Argyres, 2004). Overall, as relational capability manages the potential risks associated with the breadth of open innovation activities, this capability is a second-order dynamic capability that supports these activities.

6.3.4 The effect of the anticipation of new technologies on the breadth of open innovation activities

Open innovation is not only based on acquiring knowledge, but also technologies. In open innovation, companies can and should use external and internal ideas as they seek to advance their technology (Chesbrough, 2006b). Based on that, and according to other arguments as will be shown in this section, it can be expected that a firm with an anticipation of new technologies capability is highly likely to conduct open innovation activities. This is because different open innovation activities can be conducted with different types of external partners, all of which can generate the latest updates, innovative ideas and knowledge regarding manufacturing technologies. Driven by these arguments as well as by the lack of studies on the anticipation of new technologies capability in the open innovation context, this study examined the effect of this capability on the breadth of open innovation activities. Nevertheless, the findings of this study have not supported the hypothesis developed regarding this relationship. They showed that the anticipation of new technologies has a negative and non-significant effect on the breadth of open innovation activities. Although there is a strong association between the anticipation of new technologies and looking beyond firm boundaries (Beheregarai Finger *et al.*, 2014), this particular study revealed that the anticipation of new technologies does not support the breadth of open innovation activities. The findings of this study did not echo Beheregarai Finger *et al.* (2014), who state that focusing on technologies that could be important in the future incentivises environmental scanning to accelerate the process of acquiring knowledge. A potential explanation might be the absence of coherent digital strategies and the inability of companies to understand the practical applications of some of the transformational digital technologies of smart factories (Peters, 2019). These are holding firms in the UK back from digital investment in the manufacturing process. Building on the situation of UK manufacturing firms in relation to the inability to acquire and deal with the latest manufacturing firms, this could be among the reasons for firms' lack of investment in the breadth of open innovation activities to obtain these technologies. Firms that are not yet looking for the latest manufacturing digital trends would not invest in the breadth of open innovation activities to acquire the relevant knowledge in this area. Although the UK has a remarkable platform to capitalise on these technologies, the adoption has to be accelerated (Peters, 2019). Accordingly, such technologies are still not yet fully adopted and this could be behind the reason why firms are not engaging in open innovation activities.

In the present day, firms are increasingly relying on technologically advanced approaches in their manufacturing process associated with different terms such as “Industry 4.0”, “Big Data”, and the “Internet of things”. Based on this, it was also initially expected that firms that are interested in acquiring learning about such new manufacturing technologies would undertake the breadth of open innovation activities needed to acquire them. However, a negative non-significant relationship was obtained. A possible justification for this relationship could be related to the situation of UK manufacturing firms in relation to Industry 4.0, which is still not yet fully developed. Industry 4.0 is a concept that arose for the first time in 2011 with the aim of characterising highly digitised manufacturing processes where information flows amongst machines in a controlled environment so that human involvement is mitigated to a minimum (Qin *et al.*, 2016). Despite its potential, Industry 4.0 is only fully used or incorporated in internal and external processes by a relatively small number of firms in the UK. This is because of a mixture of workforce capabilities and a lack of maturity of some technologies, whereby Industry 4.0 technologies necessitate investment for adopting industries to attain their full potential (Allinson, 2019).

In addition, the lack of sufficient investment in manufacturing technologies aspect, which might mainly be behind this non-significant relationship, does not only exist in the UK, but in other countries as well globally. In fact, developing countries’ comparative advantage in low-skill, low-labor-cost production is at risk since routine low-skill tasks are progressively automated. New technologies require higher-level skills, raising the capital intensity of production, increasing the importance of innovation ecosystems, and necessitating strong digital infrastructure and readiness for manufacturers to become competitive. Consequently, countries that currently have or are investing dynamically in the skills, capital, and infrastructure of the future are those that will control global manufacturing in the future. Accordingly, and across these changing criteria for success, today's global manufacturing hubs in North America, Europe, and East Asia are in the lead, and low-income countries in Africa and elsewhere are lagging behind, especially when it comes to Internet access and digital readiness (Coulibaly and Foda, 2020).

Moreover, the need for a tech-savvy workforce is all the more vital as industrial manufacturing leaders aim to move to digitised operations and migrate to more resilient, agile and innovative business models. Specifically, industrial manufacturing firms have been discussing and

piloting new solutions for the past few years. However, they have not largely implemented them at scale. Government incentives in the majority of countries allow tax credits or other types of subsidies for such investment. In the Global CEO Survey of PwC, industrial manufacturing CEOs focused on the increased usage of artificial intelligence (34%) and other digital innovation such as predictive maintenance (37%). Thus, although these CEO's around the world show an adequate percentage of interest in such manufacturing technologies, the rate could still be even higher. These indicators hence, show that there is still a low interest for companies in these manufacturing technologies around the world. Among the reasons why companies might still be reluctant in referring to these manufacturing technologies is related to the "Cybersecurity" threats. These threats present another dimension of uncertainty and could lead to an increased government regulation, which might reduce the pace of the fourth industrial revolution. Among the industrial manufacturing CEO's surveyed, 69% showed that the increasing complexity of cyber threats has the highest effect in determining their cybersecurity strategy, whereas 55% stated that cybersecurity and data privacy regulations have the highest effect.

Consequently, even though several firms have at least launched pilot programmes, wide adoption of digital is still limited. Too many firms still have not made bold commitments to embrace and scale digital innovation across their organisation. As a result, the non-significant effect obtained of the anticipation of new technologies on the breadth of open innovation activities can be primarily explained by the lack of sufficient investment of firms in such manufacturing technologies, not only in the UK, but also worldwide (PwC, 2020).

This negative and non-significant effect can also be interpreted from two other perspectives: On one hand, as the anticipation of new technologies is mainly related to an interest in and anticipation of new manufacturing technologies, it may not be worth firms undertaking the breadth of open innovation activities. This is because firms may think it may be time consuming. Moreover, viewing the expenses and the large amount of information associated with open innovation and the different types of external partners (Laursen and Salter, 2006), a firm that is only interested in acquiring technology from external partners may not be engaged in all these types of activities. Also, the anticipation of new technologies can be expensive. It includes the creation and acquisition of technologies that may or may not actually be important in the future, whereby considerable capital, time and other resources are needed. In this situation, companies may be inclined to only connect with the suppliers (Beheregarai Finger *et*

al., 2014) they are used to, and from whom they receive all manufacturing technologies without the need to conduct any other open innovation activity. Alternatively, a firm may only undertake the "external technology acquisition" as the most relevant open innovation activity (Pisano, 1990; Lane and Lubatkin, 1998; Veugelers and Cassiman, 1999; Chesbrough, 2006c; Van de Vrande *et al.*, 2006; Hung and Chou, 2013). This is in line with the fact that searching for new technologies relates to the external acquisition of technologies (Peng *et al.*, 2008). Firms can use external technology acquisition, which illustrates the apprehension of external technologies via in-licensing agreements or strategic alliances (Van de Vrande *et al.*, 2006). In this case, the breadth of open innovation activities may not be required.

Despite the negative non-significant effect obtained for this relationship, this insight is also important. The anticipation of new technologies was not found to be a second-order dynamic capability as it does not boost and help develop the first-order dynamic capability namely, the breadth of open innovation activities (Ambrosini *et al.*, 2009). This study provided new and interesting insights regarding UK manufacturing firms, specifically that they are either not using these manufacturing technologies much, or are not undertaking the breadth of open innovation activities to acquire these technologies.

In terms of the control variables used in this research to study the effect of each of these four antecedents on the breadth of open innovation activities, the researcher found a negative significant effect for innovation climate. A straightforward reason could simply be that conducting different open innovation activities together may not require an innovation climate to be present within the firm. In contrast, firms may be more likely to conduct open innovation activities when the level of innovation climate is not particularly greatly stimulated internally. Another reason could be that the development of an innovation climate has to incorporate the development of an entrepreneurial culture (Enkel *et al.*, 2011), an aspect not covered by the items measuring innovation climate in this study. As for the other two control variables, innovation protection and external search breadth, they both showed a positive, significant effect, consistent with the importance of these factors in open innovation (Laursen and Salter, 2006; Laursen and Salter, 2014; Brunswicker and Vanhaverbeke, 2015; Bahemia *et al.*, 2017).

6.4 Overall discussion

Drawing on the theory of dynamic capabilities, the results of this study showed the effect of

undertaking the breadth of open innovation activities on firm innovativeness. Additionally, this research indicated how a routine and different capabilities affect the breadth of open innovation activities.

When referring to open innovation, it does not necessarily only illustrate how knowledge flows across the firm's boundaries and the search for external partners. As noted above, companies search for knowledge outside of their own boundaries through different ways when doing inbound open innovation (Arora and Gambardella, 1990; Granstrand *et al.*, 1992; Cockburn and Henderson, 1998; Bianchi *et al.*, 2011; Kortmann and Piller, 2016). Accordingly, this research sheds light on a complementary set of open innovation activities that the literature has not yet well developed. The current research clarified that doing open innovation is also related to a set of activities that firms get involved in, that potentially benefit them, and for which they develop routine/capabilities for their effective implementation. There should be specific competencies supporting the breadth of open innovation activities from which to attain higher firm innovativeness as long as not too many activities are undertaken together. Consequently, this study has contributed to both theory and practice, as will be explained in the next chapter.

Chapter 7. Conclusion and Future Areas of Research

7.1 Introduction to the chapter

This study has examined the antecedents and effects of implementing the breadth of inbound open innovation activities. The context of this study was high value manufacturing companies in the UK. Based on the results obtained in this research, the current chapter shows the theoretical and managerial contributions of this study. It also highlights the limitations of this research, based on which further areas of study are suggested and presented in this chapter.

7.2 Overview of the thesis

Many academics have investigated several research areas in open innovation and have focused on this new type of innovation since the development of the concept in the work of Chesbrough (2003). Nevertheless, in addition to the importance of examining the benefits and limitations of open innovation (Laursen and Salter, 2006; de Araújo Burcharth *et al.*, 2014; Love *et al.*, 2014; Bianchi *et al.*, 2016), it is also important to understand the implementation process of open innovation. There are key "learning routines" and "capabilities" that should be investigated when it comes to facilitating the breadth of open innovation activities. Moreover, in addition to conceptualising open innovation in terms of the breadth of the search for or collaboration with external partners, one type of open innovation activity in isolation or just inbound and/or outbound open innovation as shown before, it is worth defining open innovation in terms of the breadth of activities undertaken with external partners. While there are a few studies which have introduced the breadth of open innovation activities (Chesbrough and Brunswicker, 2013; Cheng and Huizingh, 2014; Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2016; Cano-Kollmann *et al.*, 2017; Podmetina *et al.*, 2018; Stephan *et al.*, 2019; Teplov *et al.*, 2019), they have not provided an understanding regarding the advantages and/or limitations of these activities. Research which focuses on these activities is still very limited in the literature. These aforementioned studies have presented these activities and have only offered insights in terms of, for instance, their usage, popularity and firms' familiarity with them. Some of them have shown how these activities can be supported. None of these studies investigated the effect of the breadth of open innovation activities on performance except Cheng and Huizingh (2014) who included some moderating effects and Stephan *et al.* (2019) who considered the effects of goals on innovation performance through only two open innovation activities. Therefore, the current research has not only conceptualised open innovation in terms of the breadth of open innovation activities but has also examined their effect on firm innovativeness. In addition, this research has considered how antecedents affect the breadth of open innovation activities.

This study examined also the effect of second-order dynamic routines and capabilities including open innovation training, social information systems capabilities, the anticipation of new technologies and relational capability on the breadth of open innovation activities, representing a first-order dynamic capability. In turn, the effect of the breadth of open innovation activities on firm innovativeness was investigated.

Using a quantitative method of data collection, online surveys were distributed to high value manufacturing companies in the UK with the target respondents being mainly innovation and R&D managers and other managers in charge of open innovation in the firm. The findings of this research revealed that the breadth of open innovation activities is a first-order dynamic capability resulting in a high firm innovativeness up to a certain extent after which diminishing returns occur (Laursen and Salter, 2006; Garriga *et al.*, 2013; Bianchi *et al.*, 2016). Moreover, this study revealed that open innovation training is a key second-order learning routine and social information systems capabilities and relational capability are key second-order dynamic capabilities that support the breadth of open innovation activities.

7.3 Contributions

The current research is the first quantitative study that provides a granular application and testing of the dynamic capabilities theory in the context of open innovation, differentiating between first and second order learning routines and dynamic capabilities (Collis, 1994; Schilke, 2014). This study contributes to the open innovation literature by providing a clearer view into the implementation of inbound open innovation at two distinct levels. These two distinct levels will be discussed in the following section as part of the theoretical contributions of this study. Thereafter follows the managerial contributions of this research.

7.3.1 Theoretical contributions

At the first level, the main theoretical contribution of this study relates to the definition of the breadth of openness in terms of open innovation activities and its effect on firm innovativeness. This research has shifted away from the dominant definition of open innovation in terms of the breadth of the search for external partners (Laursen and Salter, 2006; Brunswicker and Vanhaverbeke, 2015; Chen *et al.*, 2016), and one type of activity in isolation such as crowdsourcing (Afuah and Tucci, 2012; Majchrzak and Malhotra, 2013), customer co-creation (Zwass, 2010; Williams, 2012) or outsourcing (Bianchi *et al.*, 2016). It used a wider definition of inbound open innovation in terms of the breadth of openness to a diverse range of open innovation activities that firms can undertake (Chesbrough and Brunswicker, 2013; Podmetina *et al.*, 2016; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). As discussed before, the few studies that addressed the breadth of open innovation activities have not examined their effect on

innovation outcomes. The current research revealed that the breadth of open innovation activities does not only result in higher firm innovativeness; it has a curvilinear effect on it. It was found that the breadth of open innovation activities results in higher firm innovativeness up to five activities as per the sample of this study, after which lower firm innovativeness results. Moreover, and as per the next section, this study showed which second-order learning routines and capabilities support the breadth of open innovation activities.

At the second level, this study has also provided a better understanding of the implementation process of open innovation by shedding light on key routines and capabilities. It showed that there are second-order dynamic routines and capabilities supporting the process of undertaking different open innovation activities together. They include open innovation training as a second-order learning routine, and social information systems capabilities and relational capability, as second-order dynamic capabilities. None of these antecedents was previously investigated within the breadth of open innovation activities. This study went beyond focusing only on what can help open innovation or on one type of open innovation activity in isolation (Foss *et al.*, 2011; Mortara and Minshall, 2011; Foss *et al.*, 2013; Bianchi *et al.*, 2016). It showed which key routines and capabilities can support the breadth of open innovation activities.

7.3.1.1 The effect of the breadth of open innovation activities on firm innovativeness

The first theoretical contribution of this study refers to conceptualising open innovation in terms of the breadth of its activities and showing its effect on firm innovativeness. Few previous studies have examined the breadth of open innovation activities (Chesbrough and Brunswicker, 2013; Cheng and Huizingh, 2014; Chesbrough and Brunswicker, 2014; Podmetina *et al.*, 2016; Cano-Kollmann *et al.*, 2017; Podmetina *et al.*, 2018; Stephan *et al.*, 2019; Teplov *et al.*, 2019), but without understanding what effects these activities have on performance, and specifically on firm innovativeness. These previous studies were more about introducing the open innovation activities and their usage, but not their outcomes. As firms undertake several open innovation activities, there should be clear insights regarding their benefits and limitations so that firms can be aware of the outcomes of these activities. The current study revealed that conducting several open innovation activities such as IP in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing,

customer co-creation in R&D projects and scanning for external ideas (Chesbrough and Brunswicker, 2013; Podmetina *et al.*, 2016; Podmetina *et al.*, 2018; Teplov *et al.*, 2019), is a first-order dynamic capability resulting in a higher degree of firm innovativeness or competitive advantage up to a certain limit, after which diminishing returns occur. Thus, it did not only contribute to these few studies on the breadth of open innovation activities by examining their effect, but also by showing a curvilinear effect on firm innovativeness. This finding provided evidence that not only does searching or collaborating with different types of external partners have advantages and limitations (Laursen and Salter, 2006; Leiponen and Helfat, 2010; Garriga *et al.*, 2013), but so too does undertaking different open innovation activities.

As demonstrated earlier, firms can engage in many types of open innovation activities, and each open innovation activity tends to benefit the company in a certain way, hence the breadth of open innovation activities represents organisational learning resulting in strategic renewal in terms of firm innovativeness (Crossan *et al.*, 1999). Additionally, viewing the complementarity (Milgrom and Roberts, 1995) of the different open innovation activities, they present advantages in terms of firm innovativeness in the first instance. However, viewing the different challenges that may arise with the breadth of open innovation activities such as geographical distance between partners, expenses, opportunism, knowledge leakage, the NIH challenge, and the level of attention to the different external ideas (Koput, 1997; Chesbrough, 2003; Phene *et al.*, 2006; Faems *et al.*, 2008; Mortara *et al.*, 2009; de Araújo Burcharth *et al.*, 2014; Ritala *et al.*, 2015; Bianchi *et al.*, 2016), firms should be aware of these problems to maintain a high level of firm innovativeness and avoid the associated negative effects.

7.3.1.2 The antecedents of the breadth of open innovation activities

This study showed that the implementation of the first-order dynamic capability, the breadth of open innovation activities, tends to rely on developing a second-order learning routine, namely open innovation training, and second-order dynamic capabilities which are social information systems capabilities and relational capability. This study has shown how these three antecedents are essential for open innovation, and how they are among the most fundamental competences that firms should have for open innovation. These three antecedents have not yet been well investigated in the context of open innovation and have not yet been studied within the breadth of open innovation activities. For instance, the literature showed the

importance of training within the sphere of open innovation, but through qualitative studies (Mortara and Minshall, 2011; Salter *et al.*, 2014). Moreover, social information systems capabilities have been studied with absorptive capacity, exploratory and exploitative innovation, but not yet with open innovation (Limaj *et al.*, 2016). Finally, relational capability was studied in open innovation (Sisodiya *et al.*, 2013), external collaboration (Wang *et al.*, 2015), and knowledge acquisition and co-creation with universities (De Silva and Rossi, 2018). Thus, this study was able to extend the importance of these three antecedents to the breadth of open innovation activities.

What is also important about the facilitating role of these capabilities is not only their support regarding the breadth of open innovation activities, but also their management and mitigating roles regarding the challenges that may be faced when undertaking this breadth of open innovation activities as highlighted before (Chesbrough, 2003; Mortara *et al.*, 2009; de Araújo Burcharth *et al.*, 2014; Ritala *et al.*, 2015). Yet to be studied within the breadth of open innovation activities, this study has shown that these three types of capabilities greatly help firms manage and effectively undertake the breadth of open innovation activities, which requires more effort and resources in comparison to only one type of open innovation activity. The only capability considered within this study that was not found to have a facilitating role, was the anticipation of new technologies.

7.3.1.3 Second-order dynamic capabilities, first-order dynamic capabilities and open innovation

The two main theoretical contributions of this study have filled the main research gaps in the open innovation literature, in particular from a dynamic capabilities theory perspective – first order and second order learning routines and dynamic capabilities. Bogers *et al.* (2019) created a dynamic capabilities context as an approach to better understanding the strategic management of open innovation, which in turn helps to better justify both success and failure in open innovation. As the main research gap identified by this study is the implementation of the breadth of open innovation activities in terms of antecedents and outcomes, second-order and first-order dynamic capabilities represented a relevant and appropriate theoretical lens for this research. This is because second-order dynamic capabilities help to develop the first-order dynamic capabilities (Collis, 1994; Zollo and Winter, 2002; Ambrosini *et al.*, 2009). As the

current study examined the antecedents that help in undertaking the breadth of open innovation activities, it has contributed to the open innovation literature by showing that the second-order learning routine is open innovation and that second-order dynamic capabilities are social information systems capabilities and relational capability facilitating the development of the first-order dynamic capability or the breadth of open innovation activities. Consequently, supported by these second-order dynamic capabilities, the breadth of open innovation activities results in firm innovativeness or competitive advantage, up to a certain point, as explained before (Schilke, 2014).

This study contributed to the open innovation literature and dynamic capabilities theory by showing the importance of differentiating between two levels of capabilities in the context of open innovation. Therefore, the contributions of this study to the open innovation literature are related to the investigation of the open innovation strategy from a dynamic capabilities theory perspective. In this context, the antecedents and outcomes of the breadth of open innovation activities illustrated the relationship between each of the, first and second-order dynamic capabilities and competitive advantage (Schilke, 2014). The current study is the first empirical research to examine first and second-order dynamic capabilities in the context of open innovation.

Beside the theoretical contributions that this study has provided, it has also offered managerial contributions, which will be discussed in the following section.

7.3.2 Managerial contributions

The findings of this study suggest that firms can benefit from investing in different open innovation activities, rather than in only one type. Managers will understand that open innovation is not only about searching for different external sources of information. There is a much wider breadth of open innovation activities they can choose from such as scanning for external ideas, crowdsourcing, ideas and start-up competitions, using external networks, collaborative innovation with different types of external partners, customer co-creation in R&D projects, external technology acquisition, subcontracting R&D, and IP in-licensing (Podmetina *et al.*, 2018; Teplov *et al.*, 2019). Specifically, firms will be able to understand the importance of these activities in stimulating their innovativeness. However, and equally important, they

will all understand that doing too many of these activities is not beneficial: it results in a lower level of firm innovativeness. Consequently, firms will become aware of the benefits of the breadth of open innovation activities while avoiding the negative effect of these activities.

This study can also guide managers on how to pro-actively improve the implementation of their open innovation activities. In fact, top management in firms are provided with evidence about the importance to develop open innovation training, social information systems capabilities and relational capability to support their breadth of open innovation activities. They will understand the importance of these factors in not only facilitating these activities, but also in reducing the potential risks and challenges that may arise when undertaking them.

7.4 Limitations

This research has identified key research gaps in the open innovation literature, based on which a strong and relevant theoretical lens was chosen to develop the research hypotheses of this study. Using a suitable research design of quantitative data collection and analysis, this study contributed significantly to the open innovation literature and to practice. However, like any other research, it involves some limitations that could not be addressed by this study due to resource constraints. Therefore, this study offers opportunities for future research.

First, the common limitations of cross-sectional data and its restricted potential to develop a reverse causality apply in this research. Due to time constraints, it was not possible to conduct a longitudinal study to consider reverse causality or to observe any change in the effect on firm innovativeness over time. In terms of reverse causality, a longitudinal study could address the question of whether undertaking the breadth of open innovation activities, facilitated by the open innovation capabilities (antecedents), can in turn help in further developing the open innovation capabilities longer term. However, this requires much more time and resources, and these were limited in the current study. In addition, as the research objectives of this study focused on studying the key antecedents and outcomes of the breadth of open innovation activities, reverse causality was not relevant as the interest was in identifying enabling capabilities to undertake the breadth of activities and assessing its effect on firm innovativeness. Also, through a longitudinal study, examining the evolution of the development and requirements for capabilities at different stages of open innovation would also be possible.

Second, even though "firm innovativeness" represents an essential and important innovation outcome resulting in competitive advantage, further research could consider other performance indicators, such as innovation performance or financial performance outcomes. The only reason that this study did not consider these indicators is that most of the studies on open innovation effects investigated innovation performance. In addition, due to the sensitivity of the questions related to financial performance, the researcher promised respondents that no financial information would be provided about the company in the study's questionnaires.

Third, this study only involved a single respondent from each company, due to constraints related to time, cost, busy schedules, and the unavailability of managers. Other research could involve multiple participants in each respondent firm to reduce any bias and detect any differences in the responses of managers from the same company.

Fourth, and in terms of sampling, as this study was based on a sample of UK manufacturing firms, the results are contextually limited and it may not be possible to generalise regarding other countries and sectors. Therefore, future studies could examine the ecological validity of these findings through collecting data from other countries such as in Europe or the US or other sectors, such as the services sector. Moreover, even though the researcher in this study focused on high value manufacturing sector to ensure that insightful results were obtained, it would have been interesting to include low value manufacturing companies to examine the implementation of open innovation in this context.

Fifth, as this study was only based on quantitative work, case studies and/or interviews complement the quantitative research design by refining the results and identifying other potential open innovation capabilities and/or activities. Since this research focused on these four antecedents, there are many other potential capabilities and open innovation activities (inbound/outbound) that can be considered.

Sixth, with a more varied sample of usage combinations of open innovation activities in comparison to the combinations obtained from the sample of this study, it might be possible to look at the effect of complementarity between these activities via an ad hoc analysis to understand which open innovation activities specifically among the nine (considered in this study) tend to be performing better.

Finally, the items used to measure "open innovation training" in the current research were taken from a study examining training in "total quality management" due to the lack of quantitative

studies on training in open innovation. A measure of training from a study on open innovation would have been stronger.

7.5 Future areas of research

Based on the aforementioned limitations of this study, several areas of research can be suggested for future studies.

First, future longitudinal data sets could capture how firm innovativeness or any other innovation outcome changes over time. In this way, high and low innovation outcomes can be assessed not only in terms of the number of open innovation activities, but also in terms of short-term and long-term. Moreover, through a longitudinal research design, firms can also consider the reverse causality, where the effect of the breadth of open innovation activities on the creation of facilitating capabilities can also be studied. Moreover, how the creation and requirements for capabilities evolve at different stages of open innovation such as "being in the early stages of implementing open innovation activities", or "in the process of refining open innovation activities and shaping programs to help establish best practices in open innovation" (Podmetina *et al.*, 2016; Teplov *et al.*, 2019) can also be examined. Moreover, the reverse causality could be studied when undertaking the ad hoc analysis discussed earlier. This can be through considering open innovation capabilities' association with only the best performing open innovation activities.

Second, and as mentioned before, other types of innovation outcomes beside firm innovativeness could also be examined within the breadth of open innovation activities such as innovation performance, financial performance and even product innovation performance or competitive advantage in product innovation for instance in relation to improvement in product quality/functionality, overall development costs, overall efficiencies of new product development processes (Pavlou and El Sawy, 2005).

Third, future research might involve more than one manager from the same company in order to gain insights from different managers within the company. In addition, conducting studies in countries other than the UK or comparative studies between the UK and any other country would identify any potential differences between countries when it comes to the process of implementing the breadth of open innovation activities. Future research could include other industries, such as the services sector. Similarly, a comparative study between the

manufacturing and service sectors could also help highlighting differences regarding the capabilities and the effects of open innovation between these two sectors. In terms of level of analysis, the project level of analysis could also be a potential level by which to identify project level-related capabilities in open innovation.

Fourth, a mixed method of data collection and analysis could also be used, where the researcher can identify other capabilities and open innovation activities. In addition, some moderating factors can be considered with a different and relevant theory to open innovation, where it would be possible to involve a moderator such as with the information processing theory (Tushman and Nadler, 1978). Also, an example of poor implementation could be undertaking too many activities where each activity requires considerable resources, so a qualitative research design in future studies could identify the different types of "resources" required when undertaking the breadth of open innovation activities. In turn, a quantitative research design can complement the qualitative one and investigates the overall effect on innovation outcomes.

Finally, in relation to the open innovation dimensions, a comparative study could be conducted between specific capabilities that affect the implementation of the breadth of inbound open innovation activities and others that affect the implementation of the breadth of outbound open innovation activities (Chesbrough and Brunswicker, 2013; Podmetina *et al.*, 2016; Podmetina *et al.*, 2018; Teplov *et al.*, 2019). The coupled mode of open innovation could also be a potential area of research (Gassmann and Enkel, 2004; Cheng and Huizingh, 2014).

Despite the limitations of this study, based on which further areas of research have been identified, the current research has filled one of the key research gaps in the inbound open innovation literature. It has presented important findings and made contributions to the implementation of the breadth of open innovation activities in terms of facilitators and effects, and represents a good starting point for future research in the field.

References

Abernathy, W.J. and Clark, K.B. (1985) 'Innovation: Mapping the winds of creative destruction', *Research policy*, 14(1), pp. 3-22.

Academy, I. (2019) *Open Innovation Workshop*. Available at: https://www.innovation-academy.co.uk/courses/open-innovation-workshop/ (Accessed: December 2020).

Afuah, A. and Tucci, C.L. (2012) 'Crowdsourcing as a solution to distant search', *Academy of Management Review*, 37(3), pp. 355-375.

Ahuja, G. (2000) 'Collaboration networks, structural holes, and innovation: A longitudinal study', *Administrative science quarterly*, 45(3), pp. 425-455.

Aiken, L.S., West, S.G. and Reno, R.R. (1991) *Multiple regression: Testing and interpreting interactions*. sage.

Ajmal, M.M. and Koskinen, K.U. (2008) 'Knowledge transfer in project-based organizations: an organizational culture perspective', *Project Management Journal*, 39(1), pp. 7-15.

Alavi, M., Kayworth, T.R. and Leidner, D.E. (2005) 'An empirical examination of the influence of organizational culture on knowledge management practices', *Journal of management information systems*, 22(3), pp. 191-224.

Alderson, P. (2013) *An Introduction to Critical Realism and Childhood Studies*. Routledge.

Alexiev, A.S., Volberda, H.W. and Van den Bosch, F.A. (2016) 'Interorganizational collaboration and firm innovativeness: Unpacking the role of the organizational environment', *Journal of Business Research*, 69(2), pp. 974-984.

Allen, T.J. (1977) 'Managing the flow of technology'. Cambridge, MA: MIT Press.
Allen, T.J. and Cohen, S.I. (1969) 'Information flow in research and development laboratories', *Administrative science quarterly*, pp. 12-19.
Allinson, Y. (2019) 'Industry 4.0 and the UK', https://www.ibisworld.com/industry-insider/analyst-insights/industry-40-and-the-uk/ [Online].
Amabile, T.M., Conti, R., Coon, H., Lazenby, J. and Herron, M. (1996) 'Assessing the work environment for creativity', *Academy of management journal*, 39(5), pp. 1154-1184.
Ambrosini, V. and Bowman, C. (2009) 'What are dynamic capabilities and are they a useful construct in strategic management?', *International journal of management reviews*, 11(1), pp. 29-49.
Ambrosini, V., Bowman, C. and Collier, N. (2009) 'Dynamic capabilities: An exploration of how firms renew their resource base', *British Journal of Management*, 20, pp. S9-S24.
Anderson, J.C. and Gerbing, D.W. (1988) 'Structural equation modeling in practice: A review and recommended two-step approach', *Psychological bulletin*, 103(3), p. 411.
Andriole, S.J. (2010) 'Business impact of Web 2.0 technologies', *Communications of the ACM*, 53(12), pp. 67-79.
Argote, L. (1999) 'Organizational Learning: Creating, retaining, and transferring knowledge. np Kluwer', *Norwell, MA*.
Argote, L., McEvily, B. and Reagans, R. (2003) 'Managing knowledge in organizations: An integrative framework and review of emerging themes', *Management science*, 49(4), pp. 571-582.
Ariño, A., Reuer, J.J., Mayer, K.J. and Jané, J. (2014) 'Contracts, negotiation, and learning: An examination of termination provisions', *Journal of Management Studies*, 51(3), pp. 379-405.
Armstrong, J.S. and Overton, T.S. (1977) 'Estimating nonresponse bias in mail surveys', *Journal of marketing research*, 14(3), pp. 396-402.
Arora, A. and Gambardella, A. (1990) 'Complementarity and external linkages: the strategies of the large firms in biotechnology', *The journal of industrial economics*, pp. 361-379.
Arrow, K. (1962) 'Economic Welfare and the Allocation of Resources to Invention. The Rate and Direction of Economic Activity: Economic and Social Factors. U.-NBC f. ER a. C. o. EG ot SSR Council'. Princeton, Princeton University Press.
Athaide, G.A., Stump, R.L. and Joshi, A.W. (2003) 'Understanding new product co-development relationships in technology-based, industrial markets', *Journal of marketing theory and practice*, 11(3), pp. 46-58.
Atuahene-Gima, K. (2005) 'Resolving the capability—rigidity paradox in new product innovation', *Journal of marketing*, 69(4), pp. 61-83.
Atuahene-Gima, K. (1995) 'An exploratory analysis of the impact of market orientation on new product performance: a contingency approach', *Journal of Product Innovation Management: an International Publication of the Product Development & Management Association*, 12(4), pp. 275-293.
Babbie, E. (2012) 'The Practice of Social Research, 13, illustrated, revised ed', *Belmont, Cengage Learning*.
Bae, Y. and Chang, H. (2012) 'Efficiency and effectiveness between open and closed innovation: empirical evidence in South Korean manufacturers', *Technology Analysis & Strategic Management*, 24(10), pp. 967-980.
Bagherzadeh, M., Markovic, S., Cheng, J. and Vanhaverbeke, W. (2019) 'How does outside-in open innovation influence innovation performance? Analyzing the mediating roles of

knowledge sharing and innovation strategy', *IEEE Transactions on Engineering Management*.
Bahemia, H., Sillince, J. and Vanhaverbeke, W. (2018) 'The timing of openness in a radical innovation project, a temporal and loose coupling perspective', *Research Policy*, 47(10), pp. 2066-2076.
Bahemia, H. and Squire, B. (2010) 'A contingent perspective of open innovation in new product development projects', *International Journal of Innovation Management*, 14(04), pp. 603-627.
Bahemia, H., Squire, B. and Cousins, P. (2017) 'A multi-dimensional approach for managing open innovation in NPD', *International Journal of Operations & Production Management*, 37(10), pp. 1366-1385.
Bassey, M. (1995) *Creating education through research: a global perspective of educational research for the 21st century*. Kirklington Moor Press in conjunction with the British Educational Research ….
Baum, J.A.C., Calabrese, T. and Silverman, B.S. (2000) 'Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology', *Strategic management journal*, pp. 267-294.
Becker, W. and Dietz, J. (2004) 'R&D cooperation and innovation activities of firms—evidence for the German manufacturing industry', *Research policy*, 33(2), pp. 209-223.
Beheregarai Finger, A., B. Flynn, B. and Laureanos Paiva, E. (2014) 'Anticipation of new technologies: supply chain antecedents and competitive performance', *International Journal of Operations & Production Management*, 34(6), pp. 807-828.
Beneito, P. (2006) 'The innovative performance of in-house and contracted R&D in terms of patents and utility models', *Research Policy*, 35(4), pp. 502-517.
Benner, M.J. and Tushman, M.L. (2003) 'Exploitation, exploration, and process management: The productivity dilemma revisited', *Academy of management review*, 28(2), pp. 238-256.
Bennett, R.J. and Robson, P.J. (2005) 'The advisor-SMF client relationship: Impact, satisfaction and commitment', *Small Business Economics*, 25(3), pp. 255-271.
Bensaou, M. and Venkatraman, N. (1995) 'Configurations of interorganizational relationships: A comparison between US and Japanese automakers', *Management science*, 41(9), pp. 1471-1492.
Bentler, P.M. (1990) 'Comparative fit indexes in structural models', *Psychological bulletin*, 107(2), p. 238.
Bentler, P.M. (1992) 'On the fit of models to covariances and methodology to the Bulletin', *Psychological bulletin*, 112(3), p. 400.
Berchicci, L. (2013) 'Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance', *Research Policy*, 42(1), pp. 117-127.
Berg, B. (2009) 'Qualitative research methods for the social sciences/Bruce L. Berg'. Boston: Allyn & Bacon, c2009.
Bessant, J. and Rush, H. (1995) 'Building bridges for innovation: the role of consultants in technology transfer', *Research policy*, 24(1), pp. 97-114.
Bianchi, M., Cavaliere, A., Chiaroni, D., Frattini, F. and Chiesa, V. (2011) 'Organisational modes for Open Innovation in the bio-pharmaceutical industry: An exploratory analysis', *Technovation*, 31(1), pp. 22-33.
Bianchi, M., Croce, A., Dell'Era, C., Di Benedetto, C.A. and Frattini, F. (2016) 'Organizing for inbound open innovation: How external consultants and a dedicated R&D unit influence

product innovation performance', *Journal of Product Innovation Management*, 33(4), pp. 492-510.
Bingham, A. and Spradlin, D. (2011) *The open innovation marketplace: creating value in the challenge driven enterprise*. Ft press.
Birdi, K. (2007) 'A lighthouse in the desert? Evaluating the effects of creativity training on employee innovation', *The Journal of Creative Behavior*, 41(4), pp. 249-270.
Bloodgood, J. (2013) 'Crowdsourcing: Useful for problem solving, but what about value capture?', *Academy of Management Review*, 38(3), pp. 455-457.
Bogers, M., Chesbrough, H., Heaton, S. and Teece, D.J. (2019) 'Strategic Management of Open Innovation: A Dynamic Capabilities Perspective', *California Management Review*, 62(1), pp. 77-94.
Bogers, M., Foss, N.J. and Lyngsie, J. (2018) 'The "human side" of open innovation: The role of employee diversity in firm-level openness', *Research Policy*, 47(1), pp. 218-231.
Bogers, M. and West, J. (2012) 'Managing distributed innovation: Strategic utilization of open and user innovation', *Creativity and innovation management*, 21(1), pp. 61-75.
Boyd, D.M. and Ellison, N.B. (2007) 'Social network sites: Definition, history, and scholarship', *Journal of computer-mediated Communication*, 13(1), pp. 210-230.
Bradley, F., Meyer, R. and Gao, Y. (2006) 'Use of supplier-customer relationships by SMEs to enter foreign markets', *Industrial marketing management*, 35(6), pp. 652-665.
Brandon-Jones, A. and Knoppen, D. (2018) 'The role of strategic purchasing in dynamic capability development and deployment', *International Journal of Operations & Production Management*.
Brunswicker, S. and 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(4), pp. 1241-1263.
Bryman, A. and Bell, E. (2011) 'Business Research Methods (3rdedn): Oxford University Press'.
Bughin, J., Chui, M. and Manyika, J. (2013) 'Ten IT-enabled business trends for the decade ahead', *McKinsey Quarterly*, 13(May).
Bureau, A.F. (2020) *Real World Examples of Open Innovation by Global Organizations*. Available at: https://alcorfund.com/insight/real-world-examples-of-open-innovation-by-global-organizations/ (Accessed: April 2021).
Burton, D. (2000) *Research training for social scientists: a handbook for postgraduate researchers*. Sage.
Byrne, B.M. (2010) 'Structural equation modeling with AMOS Basic concepts, applications, and programming (Multivariate Applications Series)'. New York: Routledge.
Byrne, B.M. (2013) 'Structural Equation Modeling With AMOS: Basic Concepts, Applications, and Programming: Hoboken'. Taylor and Francis, c2013.
Cano-Kollmann, M., Hamilton III, R.D. and Mudambi, R. (2017) 'Public support for innovation and the openness of firms' innovation activities', *Industrial and Corporate Change*, 26(3), pp. 421-442.
Cappa, F., Oriani, R., Pinelli, M. and De Massis, A. (2019) 'When does crowdsourcing benefit firm stock market performance?', *Research Policy*, 48(9), p. 103825.
Carmeli, A. and Azeroual, B. (2009) 'How relational capital and knowledge combination capability enhance the performance of work units in a high technology industry', *Strategic entrepreneurship journal*, 3(1), pp. 85-103.

Carter, C.F. and Williams, B.R. (1957) 'Industry and technical progress: Factors governing the speed of application of science'.
Carter, C.F. and Williams, B.R. (1959) 'The characteristics of technically progressive firms', *The Journal of Industrial Economics*, pp. 87-104.
Cassiman, B., Di Guardo, M.C. and Valentini, G. (2010) 'Organizing links with science: Cooperate or contract?: A project-level analysis', *Research Policy*, 39(7), pp. 882-892.
Cassiman, B. and Veugelers, R. (2006) 'In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition', *Management science*, 52(1), pp. 68-82.
Cepeda, G. and Vera, D. (2007) 'Dynamic capabilities and operational capabilities: A knowledge management perspective', *Journal of business research*, 60(5), pp. 426-437.
Chatenier, E.d., Verstegen, J.A., Biemans, H.J., Mulder, M. and Omta, O.S.F. (2010) 'Identification of competencies for professionals in open innovation teams', *R&d Management*, 40(3), pp. 271-280.
Chen, C.-J. and Huang, J.-W. (2009) 'Strategic human resource practices and innovation performance—The mediating role of knowledge management capacity', *Journal of business research*, 62(1), pp. 104-114.
Chen, C.W., Chang, M.L., Tseng, C.P., Chen, B.C. and Chang, Y.Y.C. (2013) 'Retracted: Critical Human Factor Evaluation of Knowledge Sharing Intention in Taiwanese Enterprises', *Human Factors and Ergonomics in Manufacturing & Service Industries*, 23(2), pp. 95-106.
Chen, Y., Vanhaverbeke, W. and Du, J. (2016) 'The interaction between internal R&D and different types of external knowledge sourcing: an empirical study of Chinese innovative firms', *R&D Management*, 46(S3), pp. 1006-1023.
Cheng, C.C. and Huizingh, E.K. (2014) 'When is open innovation beneficial? The role of strategic orientation', *Journal of product innovation management*, 31(6), pp. 1235-1253.
Chesbrough, H. (2003) *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business School Press: Cambridge: MA.
Chesbrough, H. (2004) 'Managing open innovation', *Research-Technology Management*, 47(1), pp. 23-26.
Chesbrough, H. (2006a) *Open business models: How to thrive in the new innovation landscape*. Harvard Business Press.
Chesbrough, H. (2006b) 'Open innovation: a new paradigm for understanding industrial innovation', *Open innovation: Researching a new paradigm*, 400, pp. 0-19.
Chesbrough, H. (2012) 'Open innovation: Where we've been and where we're going', *Research-Technology Management*, 55(4), pp. 20-27.
Chesbrough, H. and Bogers, M. (2014) 'Explicating open innovation: Clarifying an emerging paradigm for understanding innovation', *New Frontiers in Open Innovation. Oxford: Oxford University Press, Forthcoming*, pp. 3-28.
Chesbrough, H. and Brunswicker, S. (2013) 'Managing open innovation in large firms', *Stuttgart: Fraunhofer Institute for Industrial Engineering*.
Chesbrough, H. and Brunswicker, S. (2014) 'A fad or a phenomenon?: The adoption of open innovation practices in large firms', *Research-Technology Management*, 57(2), pp. 16-25.
Chesbrough, H. and Crowther, A.K. (2006) 'Beyond high tech: early adopters of open innovation in other industries', *R&d Management*, 36(3), pp. 229-236.
Chesbrough, H. and Prencipe, A. (2008) 'Networks of innovation and modularity: a dynamic perspective', *International Journal of Technology Management*, 42(4), pp. 414-425.
Chesbrough, H., Vanhaverbeke, W. and West, J. (2006) *Open innovation: Researching a new paradigm*. Oxford University Press on Demand.

Chesbrough, H., Vanhaverbeke, W. and West, J. (2014) *New frontiers in open innovation*. OUP Oxford.
Chesbrough, H.W. (2006c) 'The era of open innovation', *Managing innovation and change*, 127(3), pp. 34-41.
Chiang, Y.H. and Hung, K.P. (2010) 'Exploring open search strategies and perceived innovation performance from the perspective of inter-organizational knowledge flows', *R&d Management*, 40(3), pp. 292-299.
Chiaroni, D., Chiesa, V. and Frattini, F. (2010) 'Unravelling the process from Closed to Open Innovation: evidence from mature, asset-intensive industries', *R&d Management*, 40(3), pp. 222-245.
Chiaroni, D., Chiesa, V. and Frattini, F. (2011) 'The Open Innovation Journey: How firms dynamically implement the emerging innovation management paradigm', *Technovation*, 31(1), pp. 34-43.
Chowhan, J. (2016) 'Unpacking the black box: understanding the relationship between strategy, HRM practices, innovation and organizational performance', *Human Resource Management Journal*, 26(2), pp. 112-133.
Christensen, J.F., Olesen, M.H. and Kjær, J.S. (2005) 'The industrial dynamics of Open Innovation—Evidence from the transformation of consumer electronics', *Research policy*, 34(10), pp. 1533-1549.
Christidis, K., Mentzas, G. and Apostolou, D. (2012) 'Using latent topics to enhance search and recommendation in Enterprise Social Software', *Expert Systems with Applications*, 39(10), pp. 9297-9307.
Chui, M., Manyika, J., Bughin, J., Dobbs, R., Roxburgh, C., Sarrazin, H., Sands, G. and Westergren, M. (2012) 'The social economy: Unlocking value and productivity through social technologies', *McKinsey Global Institute*, 4, pp. 35-58.
Churchill Jr, G.A. (1979) 'A paradigm for developing better measures of marketing constructs', *Journal of marketing research*, 16(1), pp. 64-73.
Cobanoglu, C. and Cobanoglu, N. (2003) 'The effect of incentives in web surveys: application and ethical considerations', *International Journal of Market Research*, 45(4), pp. 1-13.
Cockburn, I.M. and Henderson, R.M. (1998) 'Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery', *The journal of industrial Economics*, 46(2), pp. 157-182.
Cohen, L., Manion, L. and Morrison, K. (2000) 'Research methods in education [5 th edn] London: Routledge Falmer', *Teaching in higher education*, 41, p. 21.
Cohen, W.M. and Levinthal, D.A. (1990) 'Absorptive capacity: A new perspective on learning and innovation', *Administrative science quarterly*, pp. 128-152.
Cohen, W.M. and Malerba, F. (2001) 'Is the tendency to variation a chief cause of progress?', *Industrial and Corporate Change*, 10(3), pp. 587-608.
Collis, D.J. (1994) 'Research note: how valuable are organizational capabilities?', *Strategic management journal*, 15(S1), pp. 143-152.
Coulibaly, B.S. and Foda, K. (2020) *The future of global manufacturing*. Available at: https://www.brookings.edu/blog/up-front/2020/03/04/the-future-of-global-manufacturing/ (Accessed: April 2021).
Crescenzi, R., Nathan, M. and Rodríguez-Pose, A. (2016) 'Do inventors talk to strangers? On proximity and collaborative knowledge creation', *Research Policy*, 45(1), pp. 177-194.
Creswell, J.W. and Creswell, J.D. (2017) *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Crossan, M.M., Lane, H.W. and White, R.E. (1999) 'An organizational learning framework: From intuition to institution', *Academy of management review*, 24(3), pp. 522-537.
Crotty, M. (1998) *The foundations of social research: Meaning and perspective in the research process*. Sage.
Cui, T., Ye, H.J., Teo, H.H. and Li, J. (2015) 'Information technology and open innovation: A strategic alignment perspective', *Information & Management*, 52(3), pp. 348-358.
Dąbrowska, J., Lopez-Vega, H. and Ritala, P. (2019) 'Waking the sleeping beauty: Swarovski's open innovation journey', *R&D Management*, 49(5), pp. 775-788.
Dahlander, L. and Gann, D.M. (2010) 'How open is innovation?', *Research policy*, 39(6), pp. 699-709.
Dahlander, L., O'Mahony, S. and Gann, D.M. (2016) 'One foot in, one foot out: how does individuals' external search breadth affect innovation outcomes?', *Strategic Management Journal*, 37(2), pp. 280-302.
Dalal, D.K. and Zickar, M.J. (2012) 'Some common myths about centering predictor variables in moderated multiple regression and polynomial regression', *Organizational Research Methods*, 15(3), pp. 339-362.
Danneels, E. (2002) 'The dynamics of product innovation and firm competences', *Strategic management journal*, 23(12), pp. 1095-1121.
Day, G.S. (2000) 'Managing market relationships', *Journal of the academy of marketing science*, 28(1), pp. 24-30.
de Araújo Burcharth, A.L., Knudsen, M.P. and Søndergaard, H.A. (2014) 'Neither invented nor shared here: The impact and management of attitudes for the adoption of open innovation practices', *Technovation*, 34(3), pp. 149-161.
De Silva, M. and Rossi, F. (2018) 'The effect of firms' relational capabilities on knowledge acquisition and co-creation with universities', *Technological Forecasting and Social Change*, 133, pp. 72-84.
De Vaus, D. (2001) *Research design in social research*. Sage.
De Winne, S. and Sels, L. (2010) 'Interrelationships between human capital, HRM and innovation in Belgian start-ups aiming at an innovation strategy', *The International Journal of Human Resource Management*, 21(11), pp. 1863-1883.
Dean Jr, J.W. and Bowen, D.E. (1994) 'Management theory and total quality: improving research and practice through theory development', *Academy of management review*, 19(3), pp. 392-418.
DeVellis, R. (2003) 'Scale Development: Theory and Applications.,(Sage Publications, Inc.: Thousand Oaks, CA, USA)'.
Di Minin, A., Frattini, F. and Piccaluga, A. (2010) 'Fiat: open innovation in a downturn (1993–2003)', *California Management Review*, 52(3), pp. 132-159.
Diamantopoulos, A. and Siguaw, J.A. (2006) 'Formative versus reflective indicators in organizational measure development: A comparison and empirical illustration', *British journal of management*, 17(4), pp. 263-282.
Dillman, D., Smyth, J. and Christian, L. (2009a) 'Internet, mail, and mixed-mode surveys: the total design method. Hoboken', *NJ: John Wiley & Sons. DiMaggio, PJ, & Powell, WW (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. American Sociological Review*, 48(2), pp. 147-160.
Dillman, D.A., Smyth, J.D. and Christian, L.M. (2009b) 'Internet, mail, and mixed-mode surveys: The tailored design approach', *Hoboken: Wiley*, pp. 65-68.

Dodgson, M., Gann, D. and Salter, A. (2006) 'The role of technology in the shift towards open innovation: the case of Procter & Gamble', *R&D Management*, 36(3), pp. 333-346.
Douglas, T.J. and Judge Jr, W.Q. (2001) 'Total quality management implementation and competitive advantage: the role of structural control and exploration', *Academy of Management journal*, 44(1), pp. 158-169.
Du, J., Leten, B. and Vanhaverbeke, W. (2014) 'Managing open innovation projects with science-based and market-based partners', *Research Policy*, 43(5), pp. 828-840.
Du Plessis, M. (2007) 'The role of knowledge management in innovation', *Journal of knowledge management*, 11(4), pp. 20-29.
Duncan, R. and Weiss, A. (1979) 'Organizational learning: Implications for organizational design.(J. Press, Hrsg.) Research in Organizational Behavior 1'. S.
Dyer, J.H. and Nobeoka, K. (2000) 'Creating and managing a high-performance knowledge-sharing network: the Toyota case', *Strategic management journal*, pp. 345-367.
Dyer, J.H. and Singh, H. (1998) 'The relational view: Cooperative strategy and sources of interorganizational competitive advantage', *Academy of management review*, 23(4), pp. 660-679.
Easton, G. (2010) 'Critical realism in case study research', *Industrial marketing management*, 39(1), pp. 118-128.
Echambadi, R. and Hess, J.D. (2007) 'Mean-centering does not alleviate collinearity problems in moderated multiple regression models', *Marketing Science*, 26(3), pp. 438-445.
Edler, J., Meyer-Krahmer, F. and Reger, G. (2002) 'Changes in the strategic management of technology: results of a global benchmarking study', *R&D Management*, 32(2), pp. 149-164.
Edwards, P.K., O'Mahoney, J. and Vincent, S. (2014) *Studying organizations using critical realism: A practical guide*. OUP Oxford.
Eisenhardt, K.M. and Martin, J.A. (2000) 'Dynamic capabilities: what are they?', *Strategic management journal*, pp. 1105-1121.
Enkel, E., Bell, J. and Hogenkamp, H. (2011) 'Open innovation maturity framework', *International Journal of Innovation Management*, 15(06), pp. 1161-1189.
Enkel, E., Gassmann, O. and Chesbrough, H. (2009) 'Open R&D and open innovation: exploring the phenomenon', *R&d Management*, 39(4), pp. 311-316.
Evans, J.R. and Mathur, A. (2005) 'The value of online surveys', *Internet research*.
Fabrizio, K.R. (2009) 'Absorptive capacity and the search for innovation', *Research Policy*, 38(2), pp. 255-267.
Faems, D., Janssens, M., Madhok, A. and Van Looy, B. (2008) 'Toward an integrative perspective on alliance governance: Connecting contract design, trust dynamics, and contract application', *Academy of management journal*, 51(6), pp. 1053-1078.
Faems, D., Van Looy, B. and Debackere, K. (2005) 'Interorganizational collaboration and innovation: Toward a portfolio approach', *Journal of product innovation management*, 22(3), pp. 238-250.
Fang, E., Palmatier, R.W. and Evans, K.R. (2008) 'Influence of customer participation on creating and sharing of new product value', *Journal of the Academy of Marketing Science*, 36(3), pp. 322-336.
Field, A. (2013) *Discovering statistics using IBM SPSS statistics*. sage.
Fisher, W. (2001) 'Theories of intellectual property', *New essays in the legal and political theory of property*, 168(1).
Fletcher, A.J. (2017) 'Applying critical realism in qualitative research: methodology meets method', *International journal of social research methodology*, 20(2), pp. 181-194.

Fornell, C. and Bookstein, F.L. (1982) 'Two structural equation models: LISREL and PLS applied to consumer exit-voice theory', *Journal of Marketing research*, 19(4), pp. 440-452.
Fornell, C. and Larcker, D.F. (1981) 'Evaluating structural equation models with unobservable variables and measurement error', *Journal of marketing research*, 18(1), pp. 39-50.
Foss, N.J., Laursen, K. and Pedersen, T. (2011) 'Linking customer interaction and innovation: The mediating role of new organizational practices', *Organization Science*, 22(4), pp. 980-999.
Foss, N.J., Lyngsie, J. and Zahra, S.A. (2013) 'The role of external knowledge sources and organizational design in the process of opportunity exploitation', *Strategic Management Journal*, 34(12), pp. 1453-1471.
Freel, M. (2006) 'Patterns of technological innovation in knowledge-intensive business services', *Industry and Innovation*, 13(3), pp. 335-358.
Frishammar, J. and Åke Hörte, S. (2005) 'Managing external information in manufacturing firms: The impact on innovation performance', *Journal of Product innovation management*, 22(3), pp. 251-266.
Füller, J., Jawecki, G. and Mühlbacher, H. (2007) 'Innovation creation by online basketball communities', *Journal of business research*, 60(1), pp. 60-71.
Garriga, H., Von Krogh, G. and Spaeth, S. (2013) 'How constraints and knowledge impact open innovation', *Strategic Management Journal*, 34(9), pp. 1134-1144.
Gassmann, O. (2006) 'Opening up the innovation process: towards an agenda', *R&d Management*, 36(3), pp. 223-228.
Gassmann, O. and Enkel, E. (2004) 'Towards a theory of open innovation: three core process archetypes'.
Gassmann, O., Enkel, E. and Chesbrough, H. (2010) 'The future of open innovation', *R&d Management*, 40(3), pp. 213-221.
Gassmann, O., Sandmeier, P. and Wecht, C.H. (2005) 'Extreme customer innovation in the front-end: learning from a new software paradigm', *International Journal of Technology Management*, 33(1), pp. 46-66.
Giannopoulou, E., Yström, A., Ollila, S., Fredberg, T. and Elmquist, M. (2010) 'Implications of openness: A study into (all) the growing literature on open innovation', *Journal of technology management & innovation*, 5(3), pp. 162-180.
Gold, A.H., Malhotra, A. and Segars, A.H. (2001) 'Knowledge management: An organizational capabilities perspective', *Journal of management information systems*, 18(1), pp. 185-214.
Granstrand, O., Bohlin, E., Oskarsson, C. and Sjöberg, N. (1992) 'External technology acquisition in large multi-technology corporations', *R&D Management*, 22(2), pp. 111-134.
Greer, C.R. and Stevens, C.D. (2015) 'HR in collaborative innovation with customers: role, alignment and challenges', *The International Journal of Human Resource Management*, 26(20), pp. 2569-2593.
Grimpe, C. and Sofka, W. (2009) 'Search patterns and absorptive capacity: Low-and high-technology sectors in European countries', *Research Policy*, 38(3), pp. 495-506.
Gulati, R. (1998) 'Alliances and networks', *Strategic management journal*, 19(4), pp. 293-317.
Haans, R.F., Pieters, C. and He, Z.L. (2016) 'Thinking about U: Theorizing and testing U-and inverted U-shaped relationships in strategy research', *Strategic Management Journal*, 37(7), pp. 1177-1195.

Hackman, J.R. and Wageman, R. (1995) 'Total quality management: Empirical, conceptual, and practical issues', *Administrative science quarterly*, pp. 309-342.
Hagedoorn, J. (1993) 'Understanding the rationale of strategic technology partnering: Nterorganizational modes of cooperation and sectoral differences', *Strategic management journal*, 14(5), pp. 371-385.
Hair, J.F. (2015) *Essentials of business research methods*. ME Sharpe.
Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2014) 'Multivariate data analysis: Pearson new international edition', *Essex: Pearson Education Limited*.
Hair Jr, J.F., Hult, G.T.M., Ringle, C. and Sarstedt, M. (2016) *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage publications.
Hakansson, H. and Eriksson, A.K. (1993) 'Getting innovations out of the supplier networks', *Journal of business-to-business marketing*, 1(3), pp. 3-34.
Hall, D.B. and Wang, L. (2005) 'Two-component mixtures of generalized linear mixed effects models for cluster correlated data', *Statistical Modelling*, 5(1), pp. 21-37.
Hamel, G. (1991) 'Competition for competence and interpartner learning within international strategic alliances', *Strategic management journal*, 12(S1), pp. 83-103.
Handfield, R.B. and Lawson, B. (2007) 'Integrating suppliers into new product development', *Research-Technology Management*, 50(5), pp. 44-51.
Harison, E. and Koski, H. (2010) 'Applying open innovation in business strategies: Evidence from Finnish software firms', *Research Policy*, 39(3), pp. 351-359.
Hayes, R.B. and Jaikumar, R. (1988) 'New technologies, obsolete organizations', *Harvard Business Review*, 66(5), pp. 77-85.
Hayes, R.H. and Wheelwright, S.C. (1984) 'Restoring our competitive edge: competing through manufacturing'.
He, J. and Wang, H.C. (2009) 'Innovative knowledge assets and economic performance: The asymmetric roles of incentives and monitoring', *Academy of Management Journal*, 52(5), pp. 919-938.
Heide, J.B. and John, G. (1990) 'Alliances in industrial purchasing: The determinants of joint action in buyer-supplier relationships', *Journal of marketing Research*, 27(1), pp. 24-36.
Heidegger, M. (1993) 'SuZ), Sein und Zeit. Tübingen'. Max Niemeyer Verlag.
Hooper, D., Coughlan, J. and Mullen, M. (2008) 'Structural equation modelling: guidelines for determining model fit. Electron J Bus Res Methods 6: 53–60'.
Howe, J. (2006) 'The rise of crowdsourcing', *Wired magazine*, 14(6), pp. 1-4.
Howe, J. (2008) *Crowdsourcing: How the power of the crowd is driving the future of business*. Random House.
Howells, J., Gagliardi, D. and Malik, K. (2008) 'The growth and management of R&D outsourcing: evidence from UK pharmaceuticals', *R&d Management*, 38(2), pp. 205-219.
Hu, L.t. and Bentler, P.M. (1999) 'Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives', *Structural equation modeling: a multidisciplinary journal*, 6(1), pp. 1-55.
Hu, X., Huang, Q., Zhong, X., Davison, R.M. and Zhao, D. (2016) 'The influence of peer characteristics and technical features of a social shopping website on a consumer's purchase intention', *International Journal of Information Management*, 36(6), pp. 1218-1230.
Huang, T., Wang, W.-C., Ken, Y., Tseng, C.-Y. and Lee, C.-L. (2010a) 'Managing technology transfer in open innovation: the case study in Taiwan', *Modern Applied Science*, 4(10), p. 2.
Huang, T., Wang, W.C., Ken, Y., Tseng, C.-Y. and Lee, C.-L. (2010b) 'Managing technology transfer in open innovation: the case study in Taiwan', *Modern Applied Science*, 4(10), p. 2.

Huber, G.P. (1991) 'Organizational learning: The contributing processes and the literatures', *Organization science*, 2(1), pp. 88-115.
Huizingh, E.K.R.E. (2011) 'Open innovation: State of the art and future perspectives', *Technovation*, 31(1), pp. 2-9.
Hung, K.-P. and Chou, C. (2013) 'The impact of open innovation on firm performance: The moderating effects of internal R&D and environmental turbulence', *Technovation*, 33(10-11), pp. 368-380.
Hurley, R.F. and Hult, G.T.M. (1998) 'Innovation, market orientation, and organizational learning: an integration and empirical examination', *Journal of marketing*, 62(3), pp. 42-54.
Jansen, J.J., Van Den Bosch, F.A. and Volberda, H.W. (2006) 'Exploratory innovation, exploitative innovation, and performance: Effects of organizational antecedents and environmental moderators', *Management science*, 52(11), pp. 1661-1674.
Jap, S.D. (2001) '"Pie sharing" in complex collaboration contexts', *Journal of Marketing Research*, 38(1), pp. 86-99.
Jaw, B.S. and Liu, W. (2003) 'Promoting organizational learning and self-renewal in Taiwanese companies: The role of HRM', *Human Resource Management: Published in Cooperation with the School of Business Administration, The University of Michigan and in alliance with the Society of Human Resources Management*, 42(3), pp. 223-241.
Jeppesen, L.B. and Lakhani, K.R. (2010) 'Marginality and problem-solving effectiveness in broadcast search', *Organization science*, 21(5), pp. 1016-1033.
Johnson, J.L., Sohi, R.S. and Grewal, R. (2004) 'The role of relational knowledge stores in interfirm partnering', *Journal of Marketing*, 68(3), pp. 21-36.
Jones, G.K., Lanctot, A. and Teegen, H.J. (2001) 'Determinants and performance impacts of external technology acquisition', *Journal of Business venturing*, 16(3), pp. 255-283.
Jöreskog, K.G. and Sörbom, D. (1993) *LISREL 8: Structural equation modeling with the SIMPLIS command language*. Scientific Software International.
Joshi, A. and Jackson, S.E. (2003) 'Managing workforce diversity to enhance cooperation in organizations', *International handbook of organizational teamwork and cooperative working*, pp. 277-296.
Kale, P., Singh, H. and Perlmutter, H. (2000) 'Learning and protection of proprietary assets in strategic alliances: Building relational capital', *Strategic management journal*, 21(3), pp. 217-237.
Kamoche, K. and Mueller, F. (1998) 'Human resource management and the appropriation learning perspective', *Human Relations*, 51(8), pp. 1033-1060.
Kane, G.C., Alavi, M., Labianca, G. and Borgatti, S.P. (2014) 'What's different about social media networks? A framework and research agenda', *MIS quarterly*, 38(1), pp. 275-304.
Kanuk, L. and Berenson, C. (1975) 'Mail surveys and response rates: A literature review', *Journal of marketing research*, 12(4), pp. 440-453.
Kaplan, A.M. and Haenlein, M. (2010) 'Users of the world, unite! The challenges and opportunities of Social Media', *Business horizons*, 53(1), pp. 59-68.
Katila, R. and Ahuja, G. (2002) 'Something old, something new: A longitudinal study of search behavior and new product introduction', *Academy of management journal*, 45(6), pp. 1183-1194.
Katila, R. and Mang, P.Y. (2003) 'Exploiting technological opportunities: the timing of collaborations', *Research policy*, 32(2), pp. 317-332.

Katz, R. and 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', *R&D Management*, 12(1), pp. 7-20.
Kaynak, H. (2003) 'The relationship between total quality management practices and their effects on firm performance', *Journal of operations management*, 21(4), pp. 405-435.
Kenny, D.A. (2015) 'Measuring model fit'.
Kenny, D.A. and McCoach, D.B. (2003) 'Effect of the number of variables on measures of fit in structural equation modeling', *Structural equation modeling*, 10(3), pp. 333-351.
Kilian, T., Hass, B.H. and Walsh, G. (2008) 'Grundlagen des Web 2.0', in *Web 2.0*. Springer, pp. 3-21.
Kirschbaum, R. (2005) 'Open innovation in practice', *Research-Technology Management*, 48(4), pp. 24-28.
Kline, R. (2011) 'Principles and practice of structural equation modeling/Rex B. Kline'. New York, The Guilford Press A Division of Guilford Publications, Inc.
Koput, K.W. (1997) 'A chaotic model of innovative search: some answers, many questions', *Organization science*, 8(5), pp. 528-542.
Kortmann, S. and Piller, F. (2016) 'Open business models and closed-loop value chains: Redefining the firm-consumer relationship', *California Management Review*, 58(3), pp. 88-108.
Kraiger, K., Ford, J.K. and Salas, E. (1993) 'Application of cognitive, skill-based, and affective theories of learning outcomes to new methods of training evaluation', *Journal of applied psychology*, 78(2), p. 311.
Kromrey, J.D. and Foster-Johnson, L. (1998) 'Mean centering in moderated multiple regression: Much ado about nothing', *Educational and Psychological Measurement*, 58(1), pp. 42-67.
Kurokawa, S. (1997) 'Make-or-buy decisions in R&D: small technology based firms in the United States and Japan', *IEEE Transactions on Engineering Management*, 44(2), pp. 124-134.
Lakemond, N., Bengtsson, L., Laursen, K. and Tell, F. (2016) 'Match and manage: the use of knowledge matching and project management to integrate knowledge in collaborative inbound open innovation', *Industrial and Corporate Change*, 25(2), pp. 333-352.
Lane, P.J. and Lubatkin, M. (1998) 'Relative absorptive capacity and interorganizational learning', *Strategic management journal*, pp. 461-477.
Laursen, K. (2012) 'Keep searching and you'll find: what do we know about variety creation through firms' search activities for innovation?', *Industrial and Corporate Change*, 21(5), pp. 1181-1220.
Laursen, K. and Salter, A. (2006) 'Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms', *Strategic management journal*, 27(2), pp. 131-150.
Laursen, K. and Salter, A.J. (2014) 'The paradox of openness: Appropriability, external search and collaboration', *Research Policy*, 43(5), pp. 867-878.
Lee, S., Park, G., Yoon, B. and Park, J. (2010) 'Open innovation in SMEs—An intermediated network model', *Research policy*, 39(2), pp. 290-300.
Leiponen, A. (2012) 'The benefits of R&D and breadth in innovation strategies: a comparison of Finnish service and manufacturing firms', *Industrial and Corporate Change*, 21(5), pp. 1255-1281.

Leiponen, A. and Helfat, C.E. (2010) 'Innovation objectives, knowledge sources, and the benefits of breadth', *Strategic management journal*, 31(2), pp. 224-236.
Lenihan, H., McGuirk, H. and Murphy, K.R. (2019) 'Driving innovation: Public policy and human capital', *Research Policy*, p. 103791.
Leonard-Barton, D. (1992) 'Core capabilities and core rigidities: A paradox in managing new product development', *Strategic management journal*, 13(S1), pp. 111-125.
Leonardi, P.M. (2014) 'Social media, knowledge sharing, and innovation: Toward a theory of communication visibility', *Information systems research*, 25(4), pp. 796-816.
Leonardi, P.M., Huysman, M. and Steinfield, C. (2013) 'Enterprise social media: Definition, history, and prospects for the study of social technologies in organizations', *Journal of Computer-Mediated Communication*, 19(1), pp. 1-19.
Leten, B., Vanhaverbeke, W., Roijakkers, N., Clerix, A. and Vanhelleputte, J. (2013) 'Managing innovation ecosystems through IP-based orchestration models: IMEC, a public research institute in nano-electronics', *California Management Review*, 55(4), pp. 51-64.
Li, Y. and Vanhaverbeke, W. (2009) 'The effects of inter-industry and country difference in supplier relationships on pioneering innovations', *Technovation*, 29(12), pp. 843-858.
Lifshitz-Assaf, H. (2018) 'Dismantling knowledge boundaries at NASA: The critical role of professional identity in open innovation', *Administrative science quarterly*, 63(4), pp. 746-782.
Lim, K., Chesbrough, H. and Ruan, Y. (2010) 'Open innovation and patterns of R&D competition', *International Journal of Technology Management*, 52(3/4), pp. 295-321.
Limaj, E., Bernroider, E.W. and Choudrie, J. (2016) 'The impact of social information system governance, utilization, and capabilities on absorptive capacity and innovation: A case of Austrian SMEs', *Information & Management*, 53(3), pp. 380-397.
Lorenzoni, G. and Lipparini, A. (1999) 'The leveraging of interfirm relationships as a distinctive organizational capability: a longitudinal study', *Strategic Management Journal*, pp. 317-338.
Love, J.H. and Roper, S. (2001) 'Location and network effects on innovation success: evidence for UK, German and Irish manufacturing plants', *Research policy*, 30(4), pp. 643-661.
Love, J.H. and Roper, S. (2004) 'The organisation of innovation: collaboration, cooperation and multifunctional groups in UK and German manufacturing', *Cambridge Journal of Economics*, 28(3), pp. 379-395.
Love, J.H., Roper, S. and Vahter, P. (2014) 'Learning from openness: The dynamics of breadth in external innovation linkages', *Strategic management journal*, 35(11), pp. 1703-1716.
Lu, Y. and Ramamurthy, K. (2011) 'Understanding the link between information technology capability and organizational agility: An empirical examination', *MIS quarterly*, pp. 931-954.
Luft, J. and Shields, M.D. (2014) 'Subjectivity in developing and validating causal explanations in positivist accounting research', *Accounting, Organizations and Society*, 39(7), pp. 550-558.
Majchrzak, A. and Malhotra, A. (2013) 'Towards an information systems perspective and research agenda on crowdsourcing for innovation', *The Journal of Strategic Information Systems*, 22(4), pp. 257-268.
Mangematin, V. and Nesta, L. (1999) 'What kind of knowledge can a firm absorb?', *International Journal of Technology Management*, 18(3-4), pp. 149-172.

Marczyk, G. and DeMatteo, D. (2005) *Essentials of research design and methodology*. John Wiley & Sons.
Markus, M.L. and Silver, M.S. (2008) 'A foundation for the study of IT effects: A new look at DeSanctis and Poole's concepts of structural features and spirit', *Journal of the Association for Information systems*, 9(10), p. 5.
Marques, J.P. (2014a) 'Closed versus open innovation: evolution or combination?', *International Journal of Business and Management*, 9(3), p. 196.
Marques, J.P.C. (2014b) 'Closed versus open innovation: evolution or combination?', *International Journal of Business and Management*, 9(3), p. 196.
Martín-de Castro, G., Delgado-Verde, M., Navas-López, J.E. and Cruz-González, J. (2013) 'The moderating role of innovation culture in the relationship between knowledge assets and product innovation', *Technological Forecasting and Social Change*, 80(2), pp. 351-363.
May, B. (2015) *What is High Value Manufacturing ?* Available at: https://highvaluemanufacturingconsulting.com/what-is-high-value-manufacturing/ (Accessed: October 29, 2020).
Mayer, K.J. and Argyres, N.S. (2004) 'Learning to contract: Evidence from the personal computer industry', *Organization science*, 15(4), pp. 394-410.
Mazzola, E., Bruccoleri, M. and Perrone, G. (2012) 'The effect of inbound, outbound and coupled innovation on performance', *International Journal of Innovation Management*, 16(06), p. 1240008.
McAfee, A. (2006) 'Mastering the three worlds of information technology', *Harvard business review*, 84(11), p. 141.
McAfee, A. (2009) *Enterprise 2.0: New collaborative tools for your organization's toughest challenges*. Harvard Business Press.
Meek, W.R., Davis-Sramek, B., Baucus, M.S. and Germain, R.N. (2011) 'Commitment in franchising: The role of collaborative communication and a franchisee's propensity to leave', *Entrepreneurship Theory and Practice*, 35(3), pp. 559-581.
Menzel, H.C., Aaltio, I. and Ulijn, J.M. (2007) 'On the way to creativity: Engineers as intrapreneurs in organizations', *Technovation*, 27(12), pp. 732-743.
Meulman, F., Reymen, I.M., Podoynitsyna, K.S. and L. Romme, A.G. (2018) 'Searching for partners in open innovation settings: How to overcome the constraints of local search', *California Management Review*, 60(2), pp. 71-97.
Meyers, P.W. and Athaide, G.A. (1991) 'Strategic mutual learning between producing and buying firms during product innovation', *Journal of Product Innovation Management*, 8(3), pp. 155-169.
Michailova, S. and Husted, K. (2003) 'Knowledge-sharing hostility in Russian firms', *California management review*, 45(3), pp. 59-77.
Milgrom, P. and Roberts, J. (1995) 'Complementarities and fit strategy, structure, and organizational change in manufacturing', *Journal of accounting and economics*, 19(2-3), pp. 179-208.
Mitrega, M., Forkmann, S., Zaefarian, G. and Henneberg, S.C. (2017) 'Networking capability in supplier relationships and its impact on product innovation and firm performance', *International Journal of Operations & Production Management*.
Monteiro, F., Mol, M. and Birkinshaw, J. (2017) 'Ready to be open? Explaining the firm level barriers to benefiting from openness to external knowledge', *Long Range Planning*, 50(2), pp. 282-295.

Morgan, N.A., Slotegraaf, R.J. and Vorhies, D.W. (2009) 'Linking marketing capabilities with profit growth', *International Journal of Research in Marketing*, 26(4), pp. 284-293.
Mortara, L. and Minshall, T. (2011) 'How do large multinational companies implement open innovation?', *Technovation*, 31(10), pp. 586-597.
Mortara, L., Napp, J.J., Slacik, I. and Minshall, T. (2009) 'How to implement open innovation: Lessons from studying large multinational companies', *University of Cambridge, IFM*.
Mount, M. and Martinez, M.G. (2014) 'Social media: A tool for open innovation', *California Management Review*, 56(4), pp. 124-143.
Myers, S. and Marquis, D.G. (1969) *Successful Industrial Innovations: A Study of Factoring Undelying Innovation in Selected Firms*. National Science Foundation.
Naqshbandi, M.M. and Tabche, I. (2018) 'The interplay of leadership, absorptive capacity, and organizational learning culture in open innovation: Testing a moderated mediation model', *Technological Forecasting and Social Change*, 133, pp. 156-167.
Narin, F., Hamilton, K.S. and Olivastro, D. (1997) 'The increasing linkage between US technology and public science', *Research policy*, 26(3), pp. 317-330.
Nelson Richard, R. and Winter Sidney, G. (1982) 'An evolutionary theory of economic change', *Harvard Business School Press, Cambridge*.
Neuman, W.L. and Kreuger, L. (2003) *Social work research methods: Qualitative and quantitative approaches*. Allyn and Bacon.
Nieto, M.J. and Santamaría, L. (2007) 'The importance of diverse collaborative networks for the novelty of product innovation', *Technovation*, 27(6-7), pp. 367-377.
Nohria, N. and Gulati, R. (1997) 'What is the optimum amount of organizational slack?: A study of the relationship between slack and innovation in multinational firms', *European Management Journal*, 15(6), pp. 603-611.
Nokia (2017) *Open innovation challenge 2017*. Available at: https://www.nokia.com/en_int/about-us/news-events/open-innovation-challenge. (Accessed: June 2017).
Nonaka, I. and Takeuchi, H. (1995) *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford university press.
Nunnally, J. and Bernstein, I. (1967) 'Psychometric Theory, McGraw-Hill Inc', *New York*.
Nunnally, J.C. (1978) *Psychometric Theory: 2d Ed*. McGraw-Hill.
Nunnally, J.C. and Bernstein, I.H. (1994) 'Psychological theory'. New York: McGraw-Hill.
O'Riordan, S., Feller, J. and Nagle, T. (2012) *ECIS 2012: 20th European Conference on Information Systems*. (AIS Electronic Library (AISeL).
OECD (2011) *ISIC REV. 3 TECHNOLOGY INTENSITY DEFINITION*. Available at: https://www.oecd.org/sti/ind/48350231.pdf.
Oke, A., Prajogo, D.I. and Jayaram, J. (2013) 'Strengthening the innovation chain: The role of internal innovation climate and strategic relationships with supply chain partners', *Journal of Supply Chain Management*, 49(4), pp. 43-58.
Parida, V., Westerberg, M. and Frishammar, J. (2012) 'Inbound open innovation activities in high-tech SMEs: the impact on innovation performance', *Journal of small business management*, 50(2), pp. 283-309.
Pavlou, P. and El Sawy, O. (2005) 'Understanding the 'Black Box'of Dynamic Capabilities, March 2005', *Under 3rd round of Review in Management Science, URL:* http://www/*. agsm. ucr. edu/faculty/pages/pavlou/MS_PAVLOU_ELSAWY_ REV3. pdf, Abruf*, 5, p. 2005.
Pavlou, P.A., Liang, H. and Xue, Y. (2007) 'Understanding and mitigating uncertainty in online exchange relationships: A principal-agent perspective', *MIS quarterly*, pp. 105-136.

Peng, D.X., Schroeder, R.G. and Shah, R. (2008) 'Linking routines to operations capabilities: A new perspective', *Journal of operations management*, 26(6), pp. 730-748.
Perkmann, M. and Salter, A. (2012) 'How to create productive partnerships with universities', *MIT Sloan Management Review*, 53(4), pp. 79-88.
Perkmann, M. and Walsh, K. (2007) 'University–industry relationships and open innovation: Towards a research agenda', *International Journal of Management Reviews*, 9(4), pp. 259-280.
Peters, N. (2019) *Annual Manufacturing Report Gauging the mood of UK manufacturing*. Research, H.
Petersen, K.J., Handfield, R.B. and Ragatz, G.L. (2003) 'A model of supplier integration into new product development', *Journal of product innovation management*, 20(4), pp. 284-299.
Peterson, R.A. (1988) *Marketing research*. Business Publications, Incorporated.
Phene, A., Fladmoe-Lindquist, K. and Marsh, L. (2006) 'Breakthrough innovations in the US biotechnology industry: the effects of technological space and geographic origin', *Strategic management journal*, 27(4), pp. 369-388.
Piening, E.P., Baluch, A.M. and Salge, T.O. (2013) 'The relationship between employees' perceptions of human resource systems and organizational performance: Examining mediating mechanisms and temporal dynamics', *Journal of Applied Psychology*, 98(6), p. 926.
Piening, E.P. and Salge, T.O. (2015) 'Understanding the antecedents, contingencies, and performance implications of process innovation: A dynamic capabilities perspective', *Journal of Product Innovation Management*, 32(1), pp. 80-97.
Piller, F. and West, J. (2014) 'Firms, users, and innovation', *New frontiers in open innovation*, 29.
Pisano, G.P. (1990) 'The R&D boundaries of the firm: an empirical analysis', *Administrative science quarterly*, pp. 153-176.
Pittaway, L., Robertson, M., Munir, K., Denyer, D. and Neely, A. (2004) 'Networking and innovation: a systematic review of the evidence', *International journal of management reviews*, 5(3-4), pp. 137-168.
Podmetina, D., Lopez Vega, H., Dabrowska, J., Albats, E., Teplov, R., Equey Balzli, C., Petraite, M., Soderquist, E., Rethi, G. and Cunningham, J. (2016) *Open Innovation in European Industries*. Open Innovation Network.
Podmetina, D., Soderquist, K.E., Petraite, M. and Teplov, R. (2018) 'Developing a competency model for open innovation', *Management Decision*.
Podsakoff, P.M., MacKenzie, S.B., Lee, J.-Y. and Podsakoff, N.P. (2003) 'Common method biases in behavioral research: a critical review of the literature and recommended remedies', *Journal of applied psychology*, 88(5), p. 879.
Pollok, P., Lüttgens, D. and Piller, F.T. (2019) 'How firms develop capabilities for crowdsourcing to increase open innovation performance: The interplay between organizational roles and knowledge processes', *Journal of Product Innovation Management*, 36(4), pp. 412-441.
Popa, S., Soto-Acosta, P. and Martinez-Conesa, I. (2017) 'Antecedents, moderators, and outcomes of innovation climate and open innovation: An empirical study in SMEs', *Technological Forecasting and Social Change*, 118, pp. 134-142.
Powell, T.C. (1995) 'Total quality management as competitive advantage: a review and empirical study', *Strategic management journal*, 16(1), pp. 15-37.

Prahalad, C.K. and Hamel, G. (1994) *Competing for the Future*. Harvard Business School Press Boston.
Prahalad, C.K. and Ramaswamy, V. (2004) 'Co-creating unique value with customers', *Strategy & leadership*, 32(3), pp. 4-9.
Prahelad, C.K. and Hamel, G. (1990) 'The Core competence of the corpo-ration', *Harvard Business Review*, 5(6).
PwC (2020) *Industrial manufacturing trends 2020: Succeeding in uncertainty through agility and innovation*. [Online]. Available at: https://www.pwc.com/industrial-manufacturing-trends-2020 (Accessed: April 2021).
Qin, J., Liu, Y. and Grosvenor, R. (2016) 'A categorical framework of manufacturing for industry 4.0 and beyond', *Procedia cirp*, 52, pp. 173-178.
Ragatz, G.L., Handfield, R.B. and Petersen, K.J. (2002) 'Benefits associated with supplier integration into new product development under conditions of technology uncertainty', *Journal of business research*, 55(5), pp. 389-400.
Ramaswamy, V. and Gouillart, F. (2010) 'The power of co-creation', *New York et al*.
Rampersad, G., Quester, P. and Troshani, I. (2010) 'Managing innovation networks: Exploratory evidence from ICT, biotechnology and nanotechnology networks', *Industrial marketing management*, 39(5), pp. 793-805.
Randhawa, K., Wilden, R. and Gudergan, S. (2018) 'Open service innovation: the role of intermediary capabilities', *Journal of Product Innovation Management*, 35(5), pp. 808-838.
Randhawa, K., Wilden, R. and Hohberger, J. (2016) 'A bibliometric review of open innovation: Setting a research agenda', *Journal of Product Innovation Management*, 33(6), pp. 750-772.
Reitzig, M.G. and Sorenson, O. (2010) 'Intra-organizational provincialism'.
Ritala, P., Olander, H., Michailova, S. and Husted, K. (2015) 'Knowledge sharing, knowledge leaking and relative innovation performance: An empirical study', *Technovation*, 35, pp. 22-31.
Ritter, L.A. and Sue, V.M. (2007) 'Introduction to using online surveys', *New Directions for Evaluation*, 2007(115), pp. 5-14.
Rohrbeck, R. (2010) 'Harnessing a network of experts for competitive advantage: technology scouting in the ICT industry', *R&d Management*, 40(2), pp. 169-180.
Roper, S. and Arvanitis, S. (2012) 'From knowledge to added value: A comparative, panel-data analysis of the innovation value chain in Irish and Swiss manufacturing firms', *Research Policy*, 41(6), pp. 1093-1106.
Rothwell, G., Rothwell, R. and Zegveld, W. (1985) *Reindustrialization and technology*. ME Sharpe.
Rothwell, R. (1992) 'Successful industrial innovation: critical factors for the 1990s', *R&d Management*, 22(3), pp. 221-240.
Rothwell, R. (1994) 'Towards the fifth-generation innovation process', *International marketing review*.
Rubera, G., Chandrasekaran, D. and Ordanini, A. (2016) 'Open innovation, product portfolio innovativeness and firm performance: the dual role of new product development capabilities', *Journal of the Academy of Marketing Science*, 44(2), pp. 166-184.
Ryan, F., Coughlan, M. and Cronin, P. (2009) 'Interviewing in qualitative research: The one-to-one interview', *International Journal of Therapy and Rehabilitation*, 16(6), pp. 309-314.
Sackett, P.R. and Larson Jr, J.R. (1990) 'Research strategies and tactics in industrial and organizational psychology'.

Sakkab, N.Y. (2002) 'Connect & develop complements research & develop at P&G', *Research-Technology Management*, 45(2), pp. 38-45.
Salge, T.O., Farchi, T., Barrett, M.I. and Dopson, S. (2013) 'When does search openness really matter? A contingency study of health-care innovation projects', *Journal of Product Innovation Management*, 30(4), pp. 659-676.
Salter, A., Criscuolo, P. and Ter Wal, A.L. (2014) 'Coping with open innovation: responding to the challenges of external engagement in R&D', *California Management Review*, 56(2), pp. 77-94.
Salter, A., Wal, A.L.J., Criscuolo, P. and Alexy, O. (2015) 'Open for Ideation: Individual-Level Openness and Idea Generation in R&D', *Journal of Product Innovation Management*, 32(4), pp. 488-504.
Santamaría, L., Nieto, M.J. and Barge-Gil, A. (2009) 'Beyond formal R&D: Taking advantage of other sources of innovation in low-and medium-technology industries', *Research Policy*, 38(3), pp. 507-517.
Santoro, G., Vrontis, D., Thrassou, A. and Dezi, L. (2018) 'The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity', *Technological Forecasting and Social Change*, 136, pp. 347-354.
Santoro, M.D. (2000) 'Success breeds success: The linkage between relationship intensity and tangible outcomes in industry–university collaborative ventures', *The journal of high technology management research*, 11(2), pp. 255-273.
Sarantakos, S. (2005) 'Social research: Macmillan South Melbourne'.
Saunders, M., Lewis, P. and Thornhill, A. (2011) 'Research methods for business students. India'. Pearson Education.
Sayer, A. (2000) '2000: Realism and social science. London: Sage'.
Scandura, T.A. and Williams, E.A. (2000) 'Research methodology in management: Current practices, trends, and implications for future research', *Academy of Management journal*, 43(6), pp. 1248-1264.
Schiele, H. (2010) 'Early supplier integration: the dual role of purchasing in new product development', *R&d Management*, 40(2), pp. 138-153.
Schilke, O. (2014) 'Second-order dynamic capabilities: How do they matter?', *Academy of Management Perspectives*, 28(4), pp. 368-380.
Schlagwein, D., Schoder, D. and Fischbach, K. (2011) 'Social information systems: Review, framework, and research agenda'.
Schumacker, R.E. and Lomax, R. (2012) 'A Beginner's Guide to Structural Equation Modeling: New York'. Taylor & Francis.
Schumacker, R.E. and Lomax, R.G. (2004) *A beginner's guide to structural equation modeling*. psychology press.
Schwab, D.P. (1980) 'Construct validity in organizational behavior', *Res Organ Behav*, 2, pp. 3-43.
Sheehan, K.B. and McMillan, S.J. (1999) 'Response variation in e-mail surveys: An exploration', *Journal of advertising research*, 39(4), pp. 45-54.
Sidhu, J.S., Commandeur, H.R. and Volberda, H.W. (2007) 'The multifaceted nature of exploration and exploitation: Value of supply, demand, and spatial search for innovation', *Organization Science*, 18(1), pp. 20-38.
Sidhu, J.S., Volberda, H.W. and Commandeur, H.R. (2004) 'Exploring exploration orientation and its determinants: Some empirical evidence', *Journal of Management Studies*, 41(6), pp. 913-932.

Sieg, J.H., Wallin, M.W. and Von Krogh, G. (2010) 'Managerial challenges in open innovation: a study of innovation intermediation in the chemical industry', *R&d Management*, 40(3), pp. 281-291.
Simonin, B.L. (2004) 'An empirical investigation of the process of knowledge transfer in international strategic alliances', *Journal of international business studies*, 35(5), pp. 407-427.
Sirmon, D.G. and Hitt, M.A. (2003) 'Managing resources: Linking unique resources, management, and wealth creation in family firms', *Entrepreneurship theory and practice*, 27(4), pp. 339-358.
Sisodiya, S.R., Johnson, J.L. and Grégoire, Y. (2013) 'Inbound open innovation for enhanced performance: Enablers and opportunities', *Industrial Marketing Management*, 42(5), pp. 836-849.
Slater, S.F. and Atuahene-Gima, K. (2004) 'Conducting survey research in strategic management', *Research methodology in strategy and management*, 1(1), pp. 227-249.
Sloane, P. (2011) *A guide to open innovation and crowdsourcing: Advice from leading experts in the field*. Kogan Page Publishers.
Slowinski, G. and Sagal, M.W. (2010) 'Good practices in open innovation', *Research-Technology Management*, 53(5), pp. 38-45.
Song, C.H., Elvers, D. and Leker, J. (2017) 'Anticipation of converging technology areas—A refined approach for the identification of attractive fields of innovation', *Technological Forecasting and Social Change*, 116, pp. 98-115.
Spector, P.E. and Brannick, M.T. (1995) 'The nature and effects of method variance in organizational research'.
Spithoven, A., Vanhaverbeke, W. and Roijakkers, N. (2013) 'Open innovation practices in SMEs and large enterprises', *Small Business Economics*, 41(3), pp. 537-562.
Stahl, B.C. (2007) 'Positivism or non-positivism—tertium non datur', in *Ontologies*. Springer, pp. 115-142.
Stephan, U., Andries, P. and Daou, A. (2019) 'Goal multiplicity and innovation: how social and economic goals affect open innovation and innovation performance', *Journal of Product Innovation Management*, 36(6), pp. 721-743.
Tabachnick, B.G., Fidell, L.S. and Ullman, J.B. (2007) *Using multivariate statistics*. Pearson Boston, MA.
Teece, D.J. (2007) 'Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance', *Strategic management journal*, 28(13), pp. 1319-1350.
Teece, D.J., Pisano, G. and Shuen, A. (1997) 'Dynamic capabilities and strategic management', *Strategic management journal*, pp. 509-533.
Teirlinck, P. and Spithoven, A. (2013) 'Research collaboration and R&D outsourcing: Different R&D personnel requirements in SMEs', *Technovation*, 33(4-5), pp. 142-153.
Teplov, R., Albats, E. and Podmetina, D. (2019) 'What does open innovation mean? Business versus academic perceptions', *International Journal of Innovation Management*, 23(01), p. 1950002.
Terwiesch, C. and Ulrich, K.T. (2009) *Innovation tournaments: Creating and selecting exceptional opportunities*. Harvard Business Press.
Tharenou, P., Donohue, R. and Cooper, B. (2007) *Management research methods*. Cambridge University Press.

Thompson, V.A. (1965) 'Bureaucracy and innovation', *Administrative science quarterly*, pp. 1-20.
Tidd, J. (1995) 'Development of novel products through intraorganizational and interorganizational networks the case of home automation', *Journal of product innovation management*, 12(4), pp. 307-322.
Treem, J.W. and Leonardi, P.M. (2013) 'Social media use in organizations: Exploring the affordances of visibility, editability, persistence, and association', *Annals of the International Communication Association*, 36(1), pp. 143-189.
Trott, P. and Hartmann, D. (2009) 'Why'open innovation'is old wine in new bottles', *International Journal of Innovation Management*, 13(04), pp. 715-736.
Tsang, E.W. and Kwan, K.-M. (1999) 'Replication and theory development in organizational science: A critical realist perspective', *Academy of Management review*, 24(4), pp. 759-780.
Tucci, C.L., Chesbrough, H., Piller, F. and West, J. (2016) 'When do firms undertake open, collaborative activities? Introduction to the special section on open innovation and open business models', *Industrial and Corporate Change*, 25(2), pp. 283-288.
Tuli, F. (2010) 'The basis of distinction between qualitative and quantitative research in social science: Reflection on ontological, epistemological and methodological perspectives', *Ethiopian Journal of Education and Sciences*, 6(1).
Tushman, M.L. and Nadler, D.A. (1978) 'Information processing as an integrating concept in organizational design', *Academy of management review*, 3(3), pp. 613-624.
Udwadia, F.E. and Kumar, K.R. (1991) 'Impact of customer coconstruction in product/service markets', *Technological Forecasting and Social Change*, 40(3), pp. 261-272.
Ulin, P.R., Robinson, E.T. and Tolley, E.E. (2005) 'Qualitative methods in public health: a field guide for applied research', *Medicine & Science in Sports & Exercise*, 37(7), p. 1249.
Ulrich, D., Jick, T. and Von Glinow, M.A. (1993) 'High-impact learning: Building and diffusing learning capability', *Organizational dynamics*, 22(2), pp. 52-66.
Ulset, S. (1996) 'R&D outsourcing and contractual governance: An empirical study of commercial R&D projects', *Journal of Economic Behavior & Organization*, 30(1), pp. 63-82.
Unilever (2011) *Access is the new ownership: a case study of Unilever's approach to open innovation*. Available at: https://www.academia.edu/6133963/Access_is_the_new_ownership_a_case_study_of_Unilevers_approach_to_open_innovation (Accessed: December 2020).
Unilever (2017) *Open innovation*. Available at: https://www/. unilever.co.uk/about/innovation/open-innovation/. (Accessed: June 2017).
Van de Vrande, V., De Jong, J.P.J., Vanhaverbeke, W. and De Rochemont, M. (2009) 'Open innovation in SMEs: Trends, motives and management challenges', *Technovation*, 29(6), pp. 423-437.
Van de Vrande, V., Lemmens, C. and Vanhaverbeke, W. (2006) 'Choosing governance modes for external technology sourcing', *R&d Management*, 36(3), pp. 347-363.
Van de Vrande, V., Vanhaverbeke, W. and Gassmann, O. (2010) 'Broadening the scope of open innovation: past research, current state and future directions', *International Journal of Technology Management*, 52(3/4), pp. 221-235.
Van der Meer, H. (2007) 'Open innovation–the Dutch treat: challenges in thinking in business models', *Creativity and innovation management*, 16(2), pp. 192-202.
van Wyk, R. (1997) 'Strategic Technology Scanning, Technology Forecasting and Social Change, 55, p21-38', *Grupp, H. and HA Linstone (2000), National Foresight Activities Around the Globe, Technology Forecasting and Social Change*, 60(1).

Vanhaverbeke, W. (2006) 'The interorganizational context of open innovation', *Open innovation: Researching a new paradigm*, pp. 205-219.
Vanhaverbeke, W., Du, J., Leten, B. and Aalders, F. (2014) 'Exploring open innovation at the level of R&D projects', *New frontiers in open innovation*, pp. 115-31.
Vega-Jurado, J., Gutiérrez-Gracia, A., Fernández-de-Lucio, I. and Manjarrés-Henríquez, L. (2008) 'The effect of external and internal factors on firms' product innovation', *Research policy*, 37(4), pp. 616-632.
Vehovar, V. and Manfreda, K.L. (2008) 'Overview: online surveys', *The SAGE handbook of online research methods*, 1.
Venkatraman, N. and Grant, J.H. (1986) 'Construct measurement in organizational strategy research: A critique and proposal', *Academy of management review*, 11(1), pp. 71-87.
Verona, G., Prandelli, E. and Sawhney, M. (2006) 'Innovation and virtual environments: Towards virtual knowledge brokers', *Organization Studies*, 27(6), pp. 765-788.
Veugelers, R. and Cassiman, B. (1999) 'Make and buy in innovation strategies: evidence from Belgian manufacturing firms', *Research policy*, 28(1), pp. 63-80.
Von Hippel, E. (1978) 'Successful Industrial Products from Customer Ideas: Presentation of a new customer-active paradigm with evidence and implications', *Journal of marketing*, 42(1), pp. 39-49.
Von Hippel, E. (2005) 'Democratizing innovation: The evolving phenomenon of user innovation', *Journal für Betriebswirtschaft*, 55(1), pp. 63-78.
Von Hippel, E. (2007) 'Horizontal innovation networks—by and for users', *Industrial and corporate change*, 16(2), pp. 293-315.
Wade, M. and Hulland, J. (2004) 'The resource-based view and information systems research: Review, extension, and suggestions for future research', *MIS quarterly*, 28(1), pp. 107-142.
Walsh, A. (1990) *Statistics for the social sciences: with computer applications*. Harper & Row.
Wang, G., Dou, W., Zhu, W. and Zhou, N. (2015) 'The effects of firm capabilities on external collaboration and performance: The moderating role of market turbulence', *Journal of Business Research*, 68(9), pp. 1928-1936.
Wang, L., Zhao, J.Z. and Zhou, K.Z. (2018) 'How do incentives motivate absorptive capacity development? The mediating role of employee learning and relational contingencies', *Journal of Business Research*, 85, pp. 226-237.
Wei, Y.S. and Atuahene-Gima, K. (2009) 'The moderating role of reward systems in the relationship between market orientation and new product performance in China', *International Journal of Research in Marketing*, 26(2), pp. 89-96.
Weisberg, R.W. (2006) 'Expertise and Reason in Creative Thinking: Evidence from Case Studies and the Laboratory'.
West, J. and Bogers, M. (2014) 'Leveraging external sources of innovation: a review of research on open innovation', *Journal of Product Innovation Management*, 31(4), pp. 814-831.
West, J. and Gallagher, S. (2006) 'Challenges of open innovation: the paradox of firm investment in open-source software', *R&d Management*, 36(3), pp. 319-331.
West, J. and Lakhani, K.R. (2008) 'Getting clear about communities in open innovation', *Industry and Innovation*, 15(2), pp. 223-231.
West, J., Salter, A., Vanhaverbeke, W. and Chesbrough, H. (2014) 'Open innovation: The next decade'. Elsevier.

Wheaton, B., Muthen, B., Alwin, D.F. and Summers, G.F. (1977) 'Assessing reliability and stability in panel models', *Sociological methodology*, 8, pp. 84-136.
Williams, D. (2012) 'Navigate the co-creation vendor landscape', *Forrester Report, June*, 22.
Williams, K.Y. and Charles, A. (1998) ''Reilly. 1998. Demography and diversity in organizations: A review of 40 years of research', *Research in organizational behavior*, 20(20), pp. 77-140.
Wilson, K.B., Bhakoo, V. and Samson, D. (2018) 'Crowdsourcing: A contemporary form of project management with linkages to open innovation and novel operations', *International Journal of Operations & Production Management*, 38(6), pp. 1467-1494.
Winter, S.G. (2003) 'Understanding dynamic capabilities', *Strategic management journal*, 24(10), pp. 991-995.
Wong, C.Y., Boon-Itt, S. and Wong, C.W. (2011) 'The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance', *Journal of Operations management*, 29(6), pp. 604-615.
Woodman, R.W., Sawyer, J.E. and Griffin, R.W. (1993) 'Toward a theory of organizational creativity', *Academy of management review*, 18(2), pp. 293-321.
Yam, R.C., Lo, W., Tang, E.P. and Lau, A.K. (2011) 'Analysis of sources of innovation, technological innovation capabilities, and performance: An empirical study of Hong Kong manufacturing industries', *Research policy*, 40(3), pp. 391-402.
Yli-Renko, H., Autio, E. and Sapienza, H.J. (2001) 'Social capital, knowledge acquisition, and knowledge exploitation in young technology-based firms', *Strategic management journal*, 22(6-7), pp. 587-613.
Yu, Y., Dong, X.-Y., Shen, K.N., Khalifa, M. and Hao, J.-X. (2013) 'Strategies, technologies, and organizational learning for developing organizational innovativeness in emerging economies', *Journal of business research*, 66(12), pp. 2507-2514.
Zahra, S.A. and George, G. (2002) 'Absorptive capacity: A review, reconceptualization, and extension', *Academy of management review*, 27(2), pp. 185-203.
Zahra, S.A., Sapienza, H.J. and Davidsson, P. (2006) 'Entrepreneurship and dynamic capabilities: A review, model and research agenda', *Journal of Management studies*, 43(4), pp. 917-955.
Zaltman, G., Duncan, R. and Holbek, J. (1973) *Innovations and organizations*. John Wiley & Sons.
Zeng, S.X., Xie, X.M. and Tam, C.M. (2010) 'Relationship between cooperation networks and innovation performance of SMEs', *Technovation*, 30(3), pp. 181-194.
Zhou, L., Wu, W.-p. and Luo, X. (2007) 'Internationalization and the performance of born-global SMEs: the mediating role of social networks', *Journal of international business studies*, 38(4), pp. 673-690.
Zhu, W. (2000) 'Which should it be called: Convergent validity or discriminant validity?', *Research quarterly for exercise and sport*, 71(2), pp. 190-194.
Zobel, A.-K., Balsmeier, B. and Chesbrough, H. (2016) 'Does patenting help or hinder open innovation? Evidence from new entrants in the solar industry', *Industrial and Corporate Change*, 25(2), pp. 307-331.
Zobel, A.K. (2017) 'Benefiting from open innovation: A multidimensional model of absorptive capacity', *Journal of Product Innovation Management*, 34(3), pp. 269-288.
Zollo, M. and Winter, S.G. (2002) 'Deliberate learning and the evolution of dynamic capabilities', *Organization science*, 13(3), pp. 339-351.

Zwass, V. (2010) 'Co-creation: Toward a taxonomy and an integrated research perspective', *International journal of electronic commerce*, 15(1), pp. 11-48.

Appendices

Appendix 1: Pilot test questions

The purpose of this interview is to understand the innovation strategy in your firm as well as the strategy you have to help and support open innovation.

1) How much engaged your is firm in research and development (R&D)?
2) How many people does your firm have in its R&D department? Is innovation managed primarily in-house?
3) Is your firm engaged more in radical or incremental innovation? Radical innovation is innovation that is new to the industry, while incremental innovation is new to the firm only.
4) For each of the following open innovation activities defined in the document that was sent to you prior to our meeting, would you be able to tell me please whether your firm is engaged in it or not, how much, how does your firm do it while giving me some examples please and why does it do it?
   External technology acquisition, subcontracting R&D, using external networks, idea and start-up competitions, collaborative innovation with external partners, crowdsourcing, customer co-creation in R&D projects, scanning for external ideas and intellectual property in-licensing?

   - Does your firm do other than those open innovation activities? Which ones, how, give examples please and why does it do it (or why do you do them)?
5) What strategy does your firm use, (or what are the processes and capabilities) your firm develops to help doing the open innovation activities discussed above, more easily and successfully? Please provide examples.
6) Is there in your firm a special team that takes care of doing open innovation? How many members are in this team? If no, who is in charge in leading the way to do open innovation in your company?
7) Does your firm do training for your employees for a smooth and successful open innovation? How, give examples please.
8) How does the involvement of all employees in decision making and the cooperation between the different departments to acquire and use external knowledge help open innovation?
9) How do the rewards (incentives) given by your firm to its employees for acquiring and sharing external knowledge help open innovation?
10) Can you talk about how your firm develops its relational capability to find external partners and develop effective relationships with them during the innovation process?
11) What information systems, advanced tools and techniques or technologies does you firm use that help in finding, acquiring, understanding and using external knowledge?
12) Does the fact of staying up to date in terms of the latest manufacturing technologies help your firm in doing open innovation? How please?

Thanks for your participation.

Appendix 2: Confirmation e-mail of the pilot interview

(E-mail subject: "Meeting confirmation")

Dear Mr./Mrs. X,

I would like to thank you for accepting to participate in my study I am conducting about open innovation at Newcastle University Business School under the supervision of Dr. Hanna Bahemia and Professor Savvas Papagiannidis.

This letter is just to confirm that the meeting we have agreed on will take place on… at… (depends whether face to face or over the telephone) and to give you again an overview about my research study and some key points you may wish to know about our meeting.

As we have discussed over the phone, the study aims to examine how different factors influence firms' successful implementation of open innovation. Thus, it will highly contribute to firms in this concern. During our meeting, you will be simply reflecting on the main aspects you tend to develop to do open innovation successfully while also I will be highlighting some important ones to see how your company perceives them when doing open innovation.

- In return for your participation in this study, you will receive a summary report, and you will be invited to a workshop where the final research results will be presented.
- Our meeting will approximately take 20 minutes.
- The meeting will be recorded and transcribed.
- All questions are voluntary, and you are able to stop at any time you wish.
- All information you will provide will be confidential and anonymous and only used for the purpose of completing this research project.
- Only my 2 supervisors and I will have access to the information you provide during our meeting.

Kindly find attached a list of the open innovation activities and their definitions that we will be discussing during the meeting. Also, kindly note that this research has been reviewed and approved by Newcastle University Ethics Committee for this project to progress. If you have any questions in this concern, you can contact the Policy & Information Team, Newcastle University Research Office: res.policy@ncl.ac.uk.

If you have any questions regarding this project in general, please do not hesitate to contact me: n.el-maalouf2@newcastle.ac.uk.

Thank you again and looking forward to our meeting.

Kind regards,

Nicole EL Maalouf

Appendix 3: Definitions of open innovation activities

I would greatly appreciate if you could just tick the appropriate boxes in the 2 tables below.
For each of the following open innovation activities in this table below, just tick the box please for the activity that you do in your firm. For the activity that you do not do in your firm, just leave the box empty please. As you will see, each open innovation activity is defined for clarification.

Open innovation activity name	**Open innovation definition**	**Please tick the box in this column for each open innovation activity that you do in your firm. For the activity that you do not do in your firm, just leave the box empty please**
1) External technology acquisition	the absorption of external technologies	
2) Subcontracting R&D	employing a firm or external partner to do R&D for your firm	
3) using external networks	Networking with external partners such as suppliers, customers, universities, competitors, entrepreneurs, consultants…	
4) Idea and start-up competition	the invitation to present business ideas	
5) collaborative innovation with external partners	Collaborating for innovation with different types of external partners (suppliers, customers, universities, competitors, entrepreneurs, consultants…)	
6) Crowdsourcing	outsourcing innovation problem solving to external firms to propose ideas	
7) customer co-creation in R&D projects	the engagement of customers in the development, evaluation, and testing of new ideas for products and services	
8) scanning for external ideas	Looking outside the firm for ideas to do innovation and develop new products	
9) Intellectual property in-licensing	licensing of external intellectual property rights (trademarks, patents…).	

Appendix 4: Pilot test outputs

	Mr. A, Vice-President and General Manager biopharmaceutical company (phone interview)	**Mr. B, Manager: Gluten and milk free biscuit manufacturer (interview questions answered by e-mail).**	**Mr. C, Technical Director Sustainability Project Manager: chemicals manufacturers: manufacturers of performance and specialty chemicals (phone interview).**	**Mr. D, strategic business & development manager: manufacturers of remote intervention equipment (face to face interview).**	**Mr. E, managing director, manufactures medium-size and large crawler excavators and working gear excavators. (phone interview).**	**Mr. F, technical Manager: engineering and manufacturing high-performance integrated vessels and equipment, and providing sustainable services. (phone interview).**
1) How much engaged is your firm in research and development (R&D)?	• very engaged	• new product development team involved with all R&D. • very much engaged with new products and research: their primary role. • Up to 80 new launches/year.	• Lots of R&D work.	• Very engaged. • Setting up a strategic investment business unit with the company: ✓ Budget for investment ✓ Dedicated team for offline development • This is where investment and innovation are: on the basis of market insight, intelligence and business need.	• Some design and development activities. • fairly limited compared to the mother company in Japan.	Pretty well engaged: especially over the last 4 years.
2)How many people does your firm have in its R&D department? Is innovation managed primarily in-house?	• small to medium (40-50 people). ○ mixture: • own innovation workshop and innovation development: trying to make the environment in the firm good for innovation. • consultants: to look outside the box.	• 4 members: • manager • senior new product developer • 2 new product development technologists.	• 15 people. • It depends on the project. • They do both.	• 20. • Yes (internal and external innovation). • If they have the skills and expertise about the market and technical development: they do in-house (for example for subsea equipment design, they have the experience). • When they do something new, it is going to be "collaborative" and "collaboration" for them is what is called OI (collaborative development=OI). • Collaboration: ✓ Brings new expertise into the business and learning. ✓ Brings new suppliers and partners. ✓ Brings different views of the market into the company as well. ✓ Learning about the market.	• 40. • Primarily in-house.	Just him in the UK. There are 200 people: this includes the Dutch colleagues, not only UK. It depends on what it is with developing: Resource limited: they refer to external partners. If they need an outside competence, like electronic sensor, they go externally. He prefers not to say a lot with whom they cooperate (e.g. confidentiality) externally, but they do work with suppliers (competence) and customers.
3)Is your firm engaged more in radical or incremental innovation?	• mainly incremental • doing things now that will be transformational.	• Mainly focus on incremental innovation • Due to being primarily a gluten free manufacturer, there is often radical innovation involved.	• Both.	• 3 types of innovation where in each they have projects: ✓ incremental improvement. ✓ New market: diversification ✓ Disruptive: new market, very disruptive, technology disruptive. • They have to have some risky projects.	• Incremental in his department.	Both. For incremental innovation: they refer to in-house (they have the confidence within the organisation). For radical innovation: externally sourced. It is a big step change in radical innovation, it is something new, and they have to look externally (competencies…).
4) For each of the following open innovation activities defined in the document that was sent to you prior to our meeting, would	○ Activity #2: • outsource lots of clinical research work • management of clinical trial to clinical research organisations.	○ Activity#5: • Using suppliers and buyers ○ Why: • to see what is trending and what they can offer them to	○ Activity #1: evaluating technologies • Improving their process intensification • Range of different	○ Activity #1: • did it historically and will do in the future but have not done it recently. • They acquired a division: new	○ Activity #1: • Involving some suppliers. • Incorporating their technologies into their machine, and	Activity#1: merger/acquisition, buying technology. Why: Commercial gain, open up larger markets (that are attractive). Activity#2: looking for a party to do the competency they don't have.

you be able to tell me please whether your firm is engaged in it or not, how much, how does your firm do it while giving me some examples please and why does it do it?	○ why: very important, to get specialists people that you need their help in certain things. ○ Activity#3: • number of associations groups (the Associations of the British Pharmaceutical Industry; The European Medicines Information group); • Cambridge network for networking and events around Cambridge area; • Patients organisations to network on a regular basis; and many other ways. ○ Why: • generating new ideas; • looking at things that other people did and that are successful; • learning from other people's mistakes; • helping to improve the knowledge as a business person. ○ Activity#5: • number of contacts that he worked with before in innovation projects and relying on consultants specialised in OI; • organising a meeting; • making the environment different; • giving people the time to think outside the box; • helping people to be creative and innovative. ○ why: • looking at things and patients differently. • Makes you look at everything from a different perspective. ○ Activity #7: • doing research with patients and their families, with doctors and nurses on the pack testing (Before launching some products). ○ why: • Benefits for patients: making the patients like the product and hence having it successful. ○ Activity #8: • Part of it networking: hear other industries, and what other people are doing	help them make an innovative product. ○ Activity #7: • Customers often give them a brief to work on with their ideas which they expand on and make a new product. • Submissions are made with the developed product which is then assessed and changed by the customer. ○ Activity #8: • Benchmarking to current market is used. ○ Why: • to see trends and help create new ideas and favor concepts.	technologies that bring their chemicals together in different formats. ○ Why: • Improving the amount of materials, they make: process intensification (more materials out per area). ○ Acivity3#: routinely: • CROs (contact research organisations) • CPI (crisis prevention institute). • ACT • SEMAC • Universities (Nottingham, Bath, Durham, Newcastle). • Working closely with their suppliers. ○ Why: • Using the best available people and skills inside and outside the company: make things go better. ○ Activity #5: • Universities: develop and improve new products. ○ Acivity#7: • Working closely with customers to define the product and get it to market quickly ○ Why: • Developing based on customers' needs helps them and helps the firm to grow. ○ Activity#8: • Constantly talking to their customers. ○ Why: • Develop products and grow their existing ones. ○ Activity#9: • Developed their own IP and protected it by patent • 10 years ago for a large project, technology was licensed in conjunction with Nottingham University ○ why: • giving access to technology that universities for example have to develop.	capability through acquisition. ○ Why: • To increase their capability and grow the company. ○ Activity #3: • University network. • Research technology development organisation networks • Market networks. • (they don't rely on them but they are sources). • Customers are the strongest source for them. • They also refer to their customers' customers (because they don't work with the end company). ○ Why: • Universities and research organisations do research for 10-20 years (long term) • SMD does little: applied research, their technology development view is short term (1 to 3 years of realisation of ideas). • They look to commercialise their ideas in their own existing technologies or markets. ○ Activity #5: • They do it very well but it is not easy. • Universities • Research org all over the world not only UK • Customers. ○ Why: • Customers are interested in route to market • Other collaborators provide them with expertise and knowledge. ○ Activity #7: • Customers operate equipment offshore • Working with key clients: open relationship to learn from them. • Learn from customers to design the products (redesign the room, making it more comfortable). ○ Activity #8: looking but there is no scanning activity. • Looking for ideas always. • When they have an idea, they look for funding internally or externally. • They don't look for funding then find an idea that	engaging with them to modify technologies and apply it to their machines. • Purchasing components which have their technologies. ○ Why: • It is a technology they don't have in-house. • Too expensive. • Not a good return on investment to do it independently if it already exists within suppliers. ○ Activity #3: • Suppliers and customers. • Suppliers as mentioned how and why above. • Customers: to get some good ideas using their products and future innovation. ○ Activity #5: • Customers primarily. • Suppliers • (As mentioned before, how and the reason). ○ Activity #7: • Same reason as mentioned above (evaluation and testing of new ideas through customers). ○ Activity #8: • Not in the UK. ○ Activity #9: • It is about purchasing license from an external company that has an intellectual property that they want to use: not in the UK, but in Japan they do it.	Activity#3: suppliers for competencies + customers. Benefit is the incentive. Activity#5: interesting business model, accessing the market of the supplier. Activity #7: competencies: cost effective manner, good relationships with customers. Activity#8: they don't license external information unless through a joint venture for example. They also refer to research centers, universities (Newcastle, Durham) if they have something interesting, UK funded activities, joint industrial projects (JIP) that involve direct competitors.

	• Reading what is happening in the market. • Talking to friends in different industries at google and linkedin (get insights of what is happening outside the industry). • Harvard Business review: what other people and companies are doing (very business focused). ○ Activity #9: • When developing a molecule, there will be a patent to protect that molecule • Trademark of Sobi by the legal team ○ Why: • Protecting the product from competition • No one can copy it. • The very high value of the brand.			matches the funding. • They only look for funding if they have an idea that matches the funding. • They don't go for funding unless it is strategically important for the business to do the innovation. • They don't chase funding at all. • Funding comes after the idea. • They do OI regardless of the funding. • Funding is an opportunistic thing for their projects. ○ Activity #9: • Technology • Ideas • Raw patents. • Completing the technology and taking it to market. • They develop new product from the idea. • Why: • To get an exclusive position in the market.		
-Does your firm do other than those open innovation activities? Which ones, how, give examples please and why does it do it (or why do you do them)?	• Using consultants • Using networks • Team meetings • Always having time on agenda for innovation (timing). • People can bring forward their ideas. ○ Why: • The business has to move forward. • To evolve. • To give people an opportunity to be as inputs for success. • To be innovative which hence leads to competitive advantage in the business.		• Working with a number of committees that give ideas and best practices to apply in house. • Working with a number of universities to get skills for employees in industry. ○ Why: • Training people and making them have the right skills.	• Their whole company encourages to bring forward the ideas from any source: very open company when it comes to sharing ideas: dedicated department to deal with people. ○ Why: • Good ideas come from any source (no one is good).		They are still in the learning curve. They do OI generally for electronic sensors, to look for competencies…, they refer to universities….
5) What strategy does your firm use, (or what are the processes and capabilities) your firm develops to help doing the open innovation activities discussed above, more easily and successfully? Please provide examples.	As per before: • Making time for innovation (give people time). • Giving people the right location and environment. • Encouraging people to speak out and be brave. • (however, they are not doing enough in terms of strategies in their firm, he said). • No ideas silly • No ideas too small • No ideas too big • Taking the team once a year for a 2-day workshop to really focus on innovation (at the management team level) (this is for OI as well): this is a specific	Main strategy is organisation and communication (weekly meetings): to keep up to date with what customers want.	• Strategy wise: having a long history of OI. • Doing this before it became fashionable. • Procedures grown with that. • Naturally pre-disposed to take risks. • Naturally doing OI. • Giving them a range of skills to manage projects and seek more OI.	• They use video conferencing to talk to partners and skype to share info, so the location and timing of where their partners are located is an obstacle and barrier: time and distance (location) barriers for OI. • Gate process that they follow: initial idea-launch • Stage process: assess the technical progress of the project and the market potential at every stage: discuss and agree that technical progress is good and market is strong. • They seek to understand why this is important, they challenge	• Since they are still at an early stage, no particular strategy or capability.	It is only him mainly at the minute. Reading on standard text on the subjects. Doing OI is mainly when they can't afford full-time employees and training. When the requirement of the knowledge is limited.

	workshop but they do more than that as well).			every stage, challenge themselves: continuation of development of an idea (riguour). • See what about Return on investment. • Strategic learning. • What the company is looking for. • They consider these points for any innovation, not only OI, for any new development. • Looking for developing a new software.		
6) Is there in your firm a special team that takes care of doing open innovation? How many members are in this team? If no, who is in charge in leading the way to do open innovation in your company?	• No. • General managers: encouraging OI.	• No • One of the new product development technologist is responsible for innovation.	• No. • Dr. Grant: technical director.	• No. • Individuals in the R&D team mainly.	• No. • Project manager basically: particular development activity and particular projects.	No. Just him in the UK. Outside the UK (Dutch colleagues,): there are people dedicated to innovation, but not to OI.
7) Does your firm do training for your employees for a smooth and successful open innovation? How, give examples please.	• Not specifically.	• New concept within the firm, therefore no procedure as of yet.	• No. • But they do develop skills when creating new products to get into markets quickly. • Identifying what requirements are needed, seeking where they are out and they go out to find them (seeking capabilities out) (they can do joint venture): this is on project basis to move innovation quickly. • They do invest in training, but if they can't afford, they can get a service from universities to get the information they need to their firm.	• No formal training. • Wilson is the leader of the team and he has a long history working with companies overseas and in the UK (he is a good communicator; he helps engineering team). • When finding partners, the most important is to have shared and clear goals with them.	• No.	No Self-teach. People in R&D, in innovation and himself take care of OI.
8) How does the involvement of all employees in decision making and the cooperation between the different departments to acquire and use external knowledge help open innovation?	• Linking people together. • Making the right environment. • Making sure everyone has training and development plan • Making sure people are encouraged to network, get info from other people and get outside ideas.	• All departments are involved due to mainly working with retailers. • The marketing team helps with information on trend and sales while developing a new product for an innovative concept.	• It is not only their R&D project, it is company wise as well. • Skills • Training • Number of roles defined. • Voice of the customer • Project manager • Suppliers • Operations • Engineering • Logistics • Quality • Customers and suppliers • Making sure all of the above from the start are altogether	• Decision making through the gate process. • They have to fight for investment • Everyone has to present the best proposals and possible priorities agreed. • Learning through OI is used in future projects and current products.	• Decision making is mainly by managers. • There is cooperation. • It is about having an understanding of what is happening outside the factory, the intelligence, about what customers and suppliers are doing…(basic knowledge to take it to the next stage). • Yes, they do this (the points above) cooperatively	Each area tends to be efficient. They are all controlled by budget requirements and a business plan. Considering cost/benefit (financially) always and safety (safe operations). Safety of the product or process (specifications). Safety implications.

			(Involving all departments); also involving the finance department to see how money is spent from concept to marketing. • This is how they manage projects and do OI.		for this purpose.	
9)How do the rewards given by your firm to its employees for acquiring and sharing external knowledge help open innovation?	No rewards, but they should definitely do.	Not applicable.	• Having clear objectives and ensuring that those objectives are met • Monetary rewards	• No.	• No.	They used to, but not recently because it is a small number.
10) Can you talk about how your firm develops its relational capability to find external partners and develop effective relationships with them during the innovation process?	• Not enough what they do he said. • They use existing partners that they already know to find new ways to develop.	• Reputation is key to acquire partners • Most of the companies which they produce for have been their buyers for years (hence good relationship over time).	• They have a strong record in innovation. • People asking them to join in a project (the reputation of Thomas swan plays a role). • People know about what they can focus and Thomas swan knows its own limitations.	• They clearly post on the website things they work on or that they do. • The website is very important. • Universities: funded by research type organisation funding (funding application). • Potential to commercialise. • Good relationships: leads to more. • Useless relationships: not worth it to work with them anymore, and they can stop the relationship. • It all depends on the performance.	• Customer-based: good communication with distributors: gathering information and understanding customers through distributors.	It does play a role whether they have been working with them in the past or new to them… Considering whether they are capable to help… Making sure everyone is happy with that… Negotiation.
11) What information systems, advanced tools and techniques or technologies does you firm use that help in finding, acquiring, understanding and using external knowledge?	• Market research • Online research • Getting ideas from customers and patients • Networks.	• Benchmarking to scoop what is already in the market • Use resources such as Mintel to understand trends to make a new product which is meeting what is popular.	• Facility to rely on academic literature. • Data mining. • Customers are their biggest source to understand the market. • They have a good relationship with their customers and they simply see them (not online) to get that information. • They also use Internet (absolutely he said).	• Not at the moment • Manually: e-mails, lots of sources they look at, calls for funding, newswires, market intelligence, strategic government type papers, but they are working on a software that will definitely have a potential.	• Nothing specific. • Simple Internet searches. • Lots of different design and development departments throughout the world: communication is very important among them. • They also work with universities and research organisations from time to time. • Komatsu limited (the parent company) work with UK universities. • Parent company has a chief technology officer involved with many universities and R&D institutions (Komatsu global basis). • Komatsu limited work with UK universities as well, but not handled through this plant.	Not really actively seeking things. They rely on social media, LinkedIn, people in the same industry, journals, magasines, conferences, choosing conferences where their suppliers and customers go: gaining lots of information.

12) Does the fact of staying up to date in terms of the latest manufacturing technologies help your firm in doing open innovation? How please?	• He can't answer this question as he is not the one involved in manufacturing.	• Yes, as there are always new technologies introduced within the food industry: using up to date means that we can offer a new product and be first to market.	• Universities • Lots of readings. • Manufacturing is becoming more sustainable and with less energy, making more from less. • Keeping in top of the novel. • They can't keep on using what they were using before. • Technology scout • Talking to people not only academics: industry associations. (talking to people on how to apply the new technology in their industry). • CROs • Customers: customers can advise them what to use etc…: access to info (your product needs X, Y...) (beneficial relationship).	• Yes • Their technology and the clients' requirements are evolving • Staying up to date with things like Internet of Things and data drive open innovation. • So, they don't have all skills and they need to bring them from outside through partnership and investment: looking at partners to do this and acquiring and bringing those expertise into the company. • There is a software called PLC (computerised) • New equipment embedded new technology into the drive. • Software engineering is different than the ones before • Evolving customer and product development push to do OI. • They need to find partners, they need expertise: collaboration.	• Yes • Connection with universities doing innovation in manufacturing to get access to technology and for understanding and new innovations. • Universities are the primary source in this concern.	They don't manufacture in that sense. They are high value, but they subcontract to suppliers who have the skills, that this company can assemble into products. So, they look to see how and when they can integrate this into their products.
1)External technology acquisition			✓	✓	✓	✓
2)Subcontracting R&D	✓					✓
3)Using external networks	✓		✓	✓	✓	✓
4)Idea and start-up competition						
5)Collaborative innovation with external partners	✓	✓	✓	✓	✓	✓
6)Crowdsourcing						
7) Customer co-creation in R&D projects	✓	✓	✓	✓	✓	✓
8)Scanning for external ideas	✓	✓	✓			✓
9)Intellectual property in-licensing	✓		✓	✓		

Appendix 5: Survey e-mail sent to participants

(E-mail subject: "Open innovation – Newcastle University")

Dear Mr. Y,
As per our phone call this morning/afternoon, I would like to thank you for accepting to complete for me this online survey for which the link is provided in this e-mail below, and that is part of my three-year research project on open innovation at Newcastle University, as highlighted over the phone.

Your completion of this survey is highly needed and appreciated to be able to complete this research study.

The survey will only take 15 minutes to be completed and all responses are anonymous, confidential, and used only to complete this research project.

Once this study is completed, I will share with you the report of the findings, and you will be entered into a prize draw with the chance to win 100 GBP Amazon voucher.

Please follow the link below to the survey.

Many thanks again and looking forward to receiving your responses very soon.

Kind regards,
Nicole EL Maalouf

Appendix 6: Survey of the study

Survey cover letter

This survey is part of a research project at Newcastle University Business School conducted by Nicole El Maalouf under the supervision of Dr. Hanna Bahemia and Professor Savvas Papagiannidis. It aims to explore how firms in the UK are implementing an open innovation (i.e., collaborative innovation) strategy.

Your participation in this study is important, as a limited number of studies has been carried to examine the challenges of implementing an open innovation strategy. By participating in this study, you are helping to provide data for a largely unexplored area of research.

In return for your contributions, you will receive a summary report of the findings of this research which will be beneficial to your firm in terms of a successful implementation of open innovation. If you are interested to receive the report, please leave your e-mail at the end of the survey in the appropriate box.

The survey will only take 15 minutes to be completed. Your responses are voluntary and will be confidential, and will not be individually identified. They will be compiled together and analysed as a group.

For any additional questions or clarifications, please do not hesitate to e-mail me at: n.el-maalouf2@newcastle.ac.uk

Thank you very much in advance for your participation.

Open Innovation (i.e., collaborative innovation) survey

Open innovation or collaborative innovation is a model that integrates external knowledge with internal research and development (R&D) during the development of new products, services or processes.

Firms engaging in open innovation tend to collaborate in the innovation process with external partners such as suppliers, customers, universities and research centers. They also seek to be involved in different types of open innovation activities such as intellectual property in-licensing, external technology acquisition, subcontracting R&D, using external networks, idea & start-up competitions, collaborative innovation with external partners, crowdsourcing, customer co-creation in R&D projects, and scanning for external ideas.

External partners included in some questions of this survey can refer to any of these different types of partners such as customers, universities, suppliers, public research organisations, entrepreneurs and start-ups, contracted R&D service providers, external consultants, competitors, unrestricted communities (a voluntary group of actors from outside the firm having all a shared goal which is to create, adapt, adopt or disseminate innovations) and open innovation intermediaries (an agency which connects companies with a broad range of external partners).

All questions in this survey are related to your **firm's** general open innovation strategy during the **last three years inclusively**.

General information about the respondent and the firm

Respondent and firm information

Please answer the following questions related to some general information about you and your company.

What is your position?	
How long have you been working for your company?	
To which industry does your firm belong? Examples of industries include but not limited to the following: Pharmaceuticals; Medical, precision and optical instruments; Electrical machinery and apparatus, n.e.c.; Motor vehicles, trailers and semi-trailers; Chemicals excluding pharmaceuticals; Railroad equipment and transport equipment, n.e.c.; Machinery and equipment, n.e.c.; Building and repairing of ships and boats; Rubber and plastics products; Basic metals and fabricated metal products; Food products, beverages and tobacco; Textiles, textile products, leather and footwear; Any other than the mentioned industries your firm belongs to, please specify:	
Approximately, how many people are employed in your company?	

The internal research and development (R&D) in your firm

Section 1: Please indicate the extent to which you agree or disagree with the following statements regarding the capability of the R&D department in your firm in the last three years

	Strongly disagree	**Disagree**	**Somewhat disagree**	**Neither agree nor disagree**	**Somewhat agree**	**Agree**	**Strongly agree**
	1	2	3	4	5	6	7
1. Our R&D department has high quality and quick feedbacks from manufacturing to design and engineering							
2. Our R&D department has good mechanisms for transferring technology from research to product development							
3. Our R&D department has great extent of market and customer feedback into technological innovation process							

The collaboration with different types of external partners in your firm

Section 2: Please indicate which of the following different types of external partners your firm has been collaborating with in its innovation activities in the last three years.

	Yes	No
1. Customers		
2.Universities		
3. Suppliers		
4. Public research organisations		
5. Entrepreneurs and start-ups		
6. Contracted R&D service providers		
7. External consultants		
8. Competitors		
9. Unrestricted communities (a voluntary group of actors from outside the firm having all a shared goal which is to create, adapt, adopt or disseminate innovations.		
10. Open innovation intermediaries (an agency which connects companies with a broad range of external partners)		

The adoption of open innovation activities in your firm

Section 3: Please indicate which of the following different open innovation activities your firm has been conducting in the last three years.

	Yes	**No**
1. Intellectual property in-licensing (licensing agreements of external intellectual property rights such as trademarks, patents, etc.)		
2. External technology acquisition		
3. Subcontracting R&D		
4. Using external networks		
5. Idea & Start-up competitions		
6. Collaborative innovation with external partners		
7. Crowd sourcing		
8. Customer co-creation in R&D projects		
9. Scanning for external ideas		

The innovation climate in your firm

Section 4: Please indicate the extent to which you agree or disagree with the following statements that represent the innovation climate in your firm in the last three years.

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. Our company provides time and resources for employees to generate, share, exchange, experiment with innovative ideas and solutions							
2. Our employees are working in diversely skilled work groups where there is free and open communication among the group							

members							
3. Our employees frequently encounter non-routine and challenging work that stimulates creativity							
4. Our employees are recognised and rewarded for their creativity and innovative ideas							

Open innovation team in your firm

Section 5: Please answer the following questions in relation to the dedicated open innovation team in your firm.

	Yes	No
5.1 Is there an open innovation team in your firm to develop the open innovation strategy and support its activities?		

5.2 Please indicate **the year** when the open innovation team was set up in your firm

5.3 **Open innovation team size:** Please indicate the total number of members in the dedicated open innovation team in your firm: less than 5, 5-10, 10-20, more than 20.

5.4 **Open innovation team functional background diversity:** Please indicate which of the following categories reflect the functional specialty of the open innovation team members in your firm. Please tick the applicable box (es) below:

Finance	Human resources	General management	Marketing	Operations	Research & Development	Strategic planning	Any other department (s), please indicate

Training in open innovation in your firm

Section 6: Please indicate the extent to which you agree or disagree with the following statements in relation to the training in open innovation in your firm in the last three years.

	Strongly disagree						Strongly agree
	1	2	3	4	5	6	7
1. Open innovation-related training is given to employees throughout our organisation							
2. Open innovation-related training is given to managers and supervisors throughout our organisation							
3. Training is given in the "open innovation strategy" (i.e., what open innovation signifies for the firm, individual and task) throughout our organisation							
4. Training is given in statistical tools and techniques in the organisation as a whole to collect and analyse information (i.e. market, technology, patents) quickly							
5. Our organisation's top management is committed to employee training for open innovation							

6. Resources are provided for employee training in open innovation							

Your firm's relational capability

Section 7: As mentioned at the beginning of this survey, external partners included in some questions of this survey can refer to any of these different types of partners such as customers, universities, suppliers, public research organisations, entrepreneurs and start-ups, contracted R&D service providers, external consultants, competitors, unrestricted communities (a voluntary group of actors from outside the firm having all a shared goal which is to create, adapt, adopt or disseminate innovations) and open innovation intermediaries (an agency which connects companies with a broad range of external partners).

Please evaluate your firm's relational capability in the last three years in terms of:

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. Identifying potential types of external partners and initiating relationships with them							
2. Designing effective governance mechanism for managing relationship with key types of external partners							
3. Developing and managing mutually beneficial relationships with key types of external partners							
4. Establishing effective working relationship with different types of external partners through both formal and informal channels							

Your firm's Social information systems capabilities

Section 8: Social information systems are represented by the utilisation of: Social networks, microblogging, web conferencing, instant messaging, wikis, blogs, video sharing, and shared database.

Please indicate the extent to which you agree or disagree that social information systems assist your firm in the last three years in:

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. Searching for relevant external information							
2. Identifying and considering different types of external partners							
3. Acquiring relevant external information							

4. Analysing and sharing ideas and concepts							
5. Interpreting and understanding external information							
6. Quickly exchanging information between business units							
7. Discussing new insights							
8. Structuring and using newly collected information							
9. Preparing newly collected information for further purposes and making it available							
10. Integrating new information into their work							
11. Accessing stored information, e.g., about new or changed guidelines or instructions							
12. Developing prototypes or new concepts							
13. Applying new knowledge in the workplace to respond quickly to environment changes							

Your firm's capability to anticipate new manufacturing technologies

Section 9: Please indicate the extent to which you agree or disagree with each of the following statements regarding your firm's capability to anticipate new manufacturing technologies in the last three years.

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. We pursue long-range programs, in order to acquire manufacturing capabilities in advance of our needs							
2. We make an effort to anticipate the potential of new manufacturing practices and technologies							
3. Our plant stay on the leading edge of new technology in our industry							
4. We are constantly thinking of the next generation of manufacturing technology							

Innovation incentives for employees in your firm

Section 10: Please indicate the extent to which you agree or disagree with the following statements which relate to the innovation incentives given by your firm to its employees in the last three years.

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. In terms of promotion and salary raises, our firm gives priority to employees who actively engage in innovation activities.							
2. Our firm recognises and rewards employees for their knowledge-sharing initiatives.							
3. Our firm gives commendation and praise to employees for their knowledge exchange and improvement.							

Your firm and its resources

Section 11: Please indicate the extent to which you agree or disagree with the following statements concerning your firm's resources in the last three years.

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. Our firm has uncommitted resources that can quickly be used to fund new strategic initiatives							
2. Our firm has few resources available in the short run to fund its initiatives							
3. Our firm is able to obtain resources at short notice to support new strategic initiatives							
4.Our firm has substantial resources at the discretion of management for funding new strategic initiatives							

Section12: Firm innovativeness: Please indicate the degree to which you agree or disagree with each of the following statements that describe your firm's innovativeness in the last three years.

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. We invent new products and services.							
2. We experiment with new products and services in our local market.							
3. We commercialise products and services that are completely new to our organisation.							
4. We frequently utilise new opportunities in new markets.							

Uncertainties in your firm

Section 13: Protection of innovation: Please indicate the extent to which you agree or disagree with the following statements that represent the extent to which your firm protects its technological knowledge from others in the last three years.

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. Our organisation has implemented firm-specific mechanism to protect innovations.							
2. Our organisation has implemented mechanisms to protect innovations by law.							

Environmental uncertainties of your firm

Section 14: Market volatility: Please indicate the extent to which you agree or disagree with each of the following statements that represent the market volatility of your firm in the last three years**.**

	Strongly disagree						**Strongly agree**
	1	2	3	4	5	6	7
1. Customers' preferences for our products change constantly.							
2. Our customers demand the very latest technologies.							
3. Our competitors rapidly advance their product technologies.							
4. Nothing stays the same for long in our industry.							

If you are interested to receive the report of the findings of this study, please leave your e-mail in the box below.

Thank you very much for your participation.

----------The End ----------

Appendix 7: Mahalanobis distance

Output from SPSS

Mahalanobis distance (D^2) measure	**D^2 /degree of freedom (p-value)**
16.37294	0.00256
15.09972	0.0045
13.06444	0.01097
12.90407	0.01175
12.39042	0.01467
12.10927	0.01656
11.97652	0.01753
11.84644	0.01853
11.82451	0.01871
11.61263	0.02048
11.42659	0.02217
10.57379	0.0318
10.50398	0.03274
10.37813	0.03452
10.36685	0.03468
10.16539	0.03773
10.14924	0.03799
10.05079	0.03958
10.00532	0.04034
9.90373	0.04208
9.83794	0.04325
9.63464	0.04705
9.12805	0.05798
8.9427	0.06255
8.83651	0.06532
8.63345	0.07094
8.27383	0.08205
8.04939	0.08979
8.00453	0.09141
7.52682	0.11053
7.50687	0.11141
7.40557	0.11595
7.38686	0.1168
7.25819	0.12286
7.10944	0.13022
6.84212	0.14447

6.82176	0.14561
6.57975	0.15983
6.52297	0.16335
6.50799	0.16429
6.49226	0.16528
6.45766	0.16748
6.38341	0.17229
6.22454	0.183
6.1738	0.18654
6.13679	0.18916
6.12891	0.18973
5.94721	0.20313
5.65639	0.22632
5.53485	0.23668
5.38398	0.25012
5.22338	0.26514
5.21676	0.26577
5.0663	0.28056
5.04042	0.28318
5.02811	0.28443
5.00573	0.28671
4.93602	0.29393
4.85746	0.30224
4.85447	0.30256
4.7741	0.31127
4.7518	0.31373
4.74387	0.3146
4.72615	0.31657
4.71724	0.31756
4.65365	0.32472
4.56777	0.33459
4.50436	0.34203
4.39526	0.35515
4.31118	0.36553
4.28426	0.3689
4.27023	0.37067
4.25803	0.37221
4.2573	0.3723
4.21188	0.37809
4.07623	0.39579
4.05526	0.39858
4.03744	0.40096
3.8781	0.42275

3.84649	0.42718
3.78025	0.43656
3.76863	0.43822
3.73052	0.4437
3.70849	0.44689
3.70767	0.44701
3.69583	0.44873
3.64703	0.45588
3.63767	0.45726
3.6306	0.4583
3.59327	0.46384
3.53952	0.47189
3.50147	0.47765
3.46624	0.48303
3.41093	0.49155
3.39681	0.49374
3.33655	0.50316
3.30843	0.5076
3.20627	0.52392
3.14047	0.5346
3.08391	0.54388
2.99458	0.55873
2.98848	0.55975
2.98526	0.5603
2.98491	0.56035
2.88661	0.57698
2.85977	0.58156
2.76739	0.59747
2.74451	0.60145
2.73749	0.60267
2.71534	0.60653
2.69684	0.60977
2.66848	0.61474
2.62867	0.62175
2.62227	0.62288
2.58928	0.62872
2.549	0.63588
2.52455	0.64024
2.50197	0.64428
2.46211	0.65143
2.44884	0.65382
2.44242	0.65498
2.41382	0.66013

2.34975	0.67173
2.33403	0.67458
2.32799	0.67568
2.3089	0.67915
2.26588	0.68699
2.26575	0.68701
2.24758	0.69033
2.23213	0.69315
2.22786	0.69393
2.22321	0.69478
2.15081	0.70805
2.14888	0.7084
2.13694	0.71059
2.09395	0.71848
2.09226	0.7188
2.06419	0.72395
2.0154	0.73293
2.00054	0.73566
1.89737	0.75463
1.89671	0.75475
1.86614	0.76036
1.85949	0.76158
1.84277	0.76465
1.80988	0.77067
1.79109	0.77411
1.77568	0.77693
1.76883	0.77818
1.72208	0.7867
1.70239	0.79028
1.67275	0.79566
1.67192	0.79581
1.66609	0.79687
1.64354	0.80095
1.63118	0.80318
1.61969	0.80525
1.60723	0.80749
1.59511	0.80967
1.57744	0.81284
1.57229	0.81376
1.57166	0.81388
1.5347	0.82048
1.52021	0.82305
1.51032	0.82481

1.50687	0.82542
1.50008	0.82663
1.46997	0.83195
1.43577	0.83795
1.35668	0.85169
1.34321	0.854
1.26338	0.86756
1.26206	0.86778
1.25433	0.86907
1.22958	0.8732
1.21656	0.87536
1.20582	0.87714
1.19242	0.87934
1.17538	0.88213
1.1262	0.89009
1.10733	0.89311
1.10643	0.89325
1.10136	0.89406
0.97623	0.91338
0.97403	0.91371
0.96041	0.91574
0.95575	0.91643
0.9456	0.91793
0.83193	0.93412
0.82682	0.93482
0.78793	0.94006
0.77151	0.94223
0.75122	0.94487
0.73019	0.94755
0.70862	0.95026
0.70844	0.95028
0.68837	0.95275
0.64382	0.95807
0.64167	0.95832
0.54142	0.96935
0.44005	0.97907
0.41019	0.98163
0.39542	0.98285
0.38268	0.98387
0.38111	0.98399
0.36877	0.98495
0.35801	0.98577
0.35774	0.98579

0.32733	0.98798
0.26741	0.99182
0.09492	0.99891