The Effect of Firm-specific Factors on Firms' Decisions to Invest in Exploration and Exploitation

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Abstract

Prior theoretical and empirical research emphasizes the importance of allocating investment between exploratory and exploitative R&D (March, 1991; Mudambi & Swift, 2014). However, the firm-specific factors that determine exploratory and exploitative R&D investment have remained largely unexplored. We attempt to address this research gap by examining the effects of inter-organizational relationships (innovation collaboration and external information sourcing), R&D personnel educational level and internationalization statuses (exporting and geographic scope) on firm investment in exploratory and exploitative R&D.

Building on the organizational learning theory, we argue that different firm-specific factors generate different effects on firm investment in exploratory and exploitative R&D because they stimulate different learning mechanisms. We empirically test the model by using panel data on more than 4000 firms from Technological Innovation Panel, which is a Community Innovation Survey-based data, for the period 2006-2011. Our findings show that the influence of a determinant on exploratory R&D investment may be different from its influence on exploitative R&D investment, and the determinants of exploratory R&D investment may differ from the determinants of exploitative R&D investment. These findings stress on the need for future research to be careful in extrapolating conclusions from analysis that studies a specific type of R&D investment into studies that analyze on another type of R&D investment or into studies that analyze on the overall R&D investment. The study contributes to organizational learning theory by identifying direct factors and moderators that facilitate firm investment in activities of organizational learning.

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IC	Innovation Collaboration
EIS	External Information Sourcing
PITEC	Technological Innovation Panel
INE	National Statistics Institute
COTEC	Foundation for Technical Innovation
FECYT	Spanish Foundation for Science and Technology
CIS	Community Innovation Survey
OECD	Organization for Economic Cooperation and Development
GLS	Generalized Least Squares
RE	Random-Effect Estimators
FE	Fixed-Effect Estimators
IHS	Inverse Hyperbolic Sine
HRM	Human Resource Management
FTE	Full-Time Employment
TME	Train Maintenance Equipment
CIE	Current Internal Expenditure

Chapter 1 Introduction

Investment in organizational learning is a critical decision for managers. In this study, exploration and exploitation are two types of R&D activities for learning in an organization. In a world of rapid developments in technology, firms not only need to invest in exploitation to maintain growth but also need to invest in exploration to enhance ability to adapt to technological environments (Benner & Tushman, 2003). For instance, many carmakers such as Volvo[1], Genaral Motors, Honda[2] and Toyota[3] increasingly put their efforts into launching electric cars. These firms not only need to invest in science experiments and applied research such as battery technology, hydrogen fuel-cell and solar energy to close the gap with more-established electric car makers such as Tesla, but also need to invest in commercialization, production and refinement to ensure incomes. However, as exploration and exploitation compete for scarce resources, firms tend to make investment choices between the two (March, 1991). Given this background, it is important for researchers and managers to understand the determinants of firms' investment decisions in exploration and exploitation, the drivers behind these two activities of organizational learning.

According to the organizational learning, organizations adapt over time. They revise their goals, shift their attention and change their search rules as a function of their experience (Cyert & March, 1992). Organizational goals and attention adapt to organizational experience and the previous performance of competitors or other comparable organizations. Organizations learn to shift their attention toward criteria

[1] Volvo announced that they will call time on diesel and petrol cars and will apply electric motors in all models from 2019 (McGee, 2017).
[2] Honda's 2017 Clarity fuel cell is hydrogen-powered that can overcome disadvantages of battery-powered cars, it only need three to five minutes to get the tank filled up (Fleming, 2017).
[3] Toyota set a target to launch an electric car with a new type of battery (all-solid-state batteries) in 2022. It has a shorter charging time and longer driving range compared with current electric cars, which use lithium-ion batteries (Kim & Tajitsu, 2017).

that tend to generate satisfactory results. Organizational search rules will change as the organization experiences success or failure with current solutions. (Cyert & March, 1992). Therefore, we argue that we can analyse the investment decisions of firms in two activities of organizational learning (exploration and exploitation) by examining factors that affect firms learning from their own and others' experiences and their search rules.

Scholars who study organizational learning examining the determinants of exploration and exploitation mainly focused on organizational factors such as firm size (Csaszar, 2013; Beckman, et al., 2004) and organizational structure (Fang et al., 2010; Sato, 2012; Burns & Stalker, 1961), as well as environment factors such as competitive intensity (Voss et al., 2008; Nicholls-Nixon et al., 2000) and environmental dynamism (Saemundsson & Candi, 2014; Lant & Mezias, 1992). However, the impact of firms' external knowledge linkages (e.g. inter-organizational relationships and internationalization) and internal learning ability remains unclear. Inter-organizational relationships influence firms' exploration and exploitation investment through facilitating firms' external distant search and the learning of others' experience. Internationalization influences firms' investment decisions mainly through enabling firms to learn from more and valuable reference groups. Some recent scholars argued that the external knowledge linkages that links firms with their embedded environment might better predict firms' exploration and exploitation investment (Marin-Idarrraga et al., 2016; Blindenbach-Driessen & van den Ende, 2014). Internal learning ability influences a firm's investment decisions in exploration and exploitation by affecting the firm's search patterns and attitudes toward learning from others' experiences.

In this study, the lack of attention to external knowledge linkage variables and internal learning ability is addressed through focusing on three firm-specific factors: inter-organizational relationships, R&D personnel educational level and the internationalization of a firm. First, although several studies investigated the effect of innovation collaboration (IC), a formal form of inter-organizational relationship, on firms' investment decisions in internal exploratory and exploitative R&D (Un & Asakawa, 2015; Soh & Subramanian, 2014), no attention has been paid to the informal form of inter-organizational relationships, especially, the influence of external information souring (EIS). The existing literature suggests that IC and EIS are different in terms of cooperation, time saving, risk sharing, the value of knowledge transfer, organizational interaction, resource sharing access possibilities and ties of network. We argue that as IC and EIS differ considerably in their nature, they may affect firms' internal investments in exploratory and exploitative R&D differently. IC is complementary to firms' internal exploratory and exploitative R&D investment, whereas EIS has mostly a substitutive effect on firms' exploratory and exploitative R&D investment. The examination of both IC and EIS effects is critical because it enables us to compare their effects on exploration and exploitation, and understand better how the information and capacities developed in IC and EIS cause firms to make different investment decisions in exploratory and exploitative R&D. It helps researchers and managers design appropriate R&D investment strategy to develop competitive advantages in different inter-organisational relationships.

Second, we examine the effect of educational levels of R&D personnel. Much of the literature focuses on education of the higher level of decision makers such as managers and entrepreneurs (Adomako et al., 2017; Lynskey, 2016; Tuncdogan et al., 2015; Hmieleski & Baron, 2008; Ganotakis, 2012). This research extends current thinking on firm-level exploration and exploitation by revealing that the highest-educated internal R&D researchers drive variations in firms' exploratory and exploitative R&D investment. Researchers with different educational levels have different influences on firms' exploratory and exploitative R&D investment. Their past experience influences the ability and acceptance of learning new knowledge and the definitions of a problem facing the organization. In other words, R&D personnel constructs a firm's innovative climate and openness to technological innovation (Hosseini et al., 2003) and influences a firm's ability to process new information and knowledge (Toner, 2011; Nelson & Phelps, 1966). Therefore, paying attention to researchers dedicated to internal R&D activities within firms can enhance the understanding of firms' investment in exploration and exploitation (Sauermann & Cohen, 2010).

Third, while past studies recognized the positive effect of internationalization on organizational learning (Love & Ganotakis, 2013; Kafouros et al., 2008; Goerzen & Beamish, 2003; Castellani, 2002), they often focused extensively on the impact of internationalization on productivity and innovation performance (Castellani, 2002; Kafouros et al., 2008). Our research contributes to internationalization and organizational learning literature by investigating the impact of internationalization on firms' investment in organizational learning. To be more specific, it investigates the relationship between export and geographic market scope respectively with regard to firms' two types of internal R&D investment: exploratory and exploitative. The result shows that these two internationalization statuses generate different effects on exploratory and exploitative R&D investment. Moreover, the influence of export/geographic scope on exploratory R&D investment is different from its influence on exploitative R&D investment.

Fourth, by reviewing the empirical literature on determinants of firm-level exploration and exploitation, we find the need to incorporate learning mechanisms, which have often been ignored in prior research, in our conceptual framework of exploration and exploitation. This study stresses four learning mechanisms: experiential learning, vicarious learning, learning from distant knowledge and searching. It summarizes that the vicarious learning and learning from distant knowledge contributes to firms' exploratory R&D investment, whereas the experiential learning and searching contributes to both exploratory and exploitative R&D investment. Therefore, we apply the introduced learning mechanisms to inferring the relationship between our firm-specific factors and firms' exploration and exploitation investment.

Following the organizational learning theory, this thesis aims to examine the effect of firm-specific factors on firm investment in exploitation and exploration. It considers firms are different in EIS, IC, researchers' education, as well as export and geographic market scope. This aim can be fulfilled by addressing three research objectives: (1) Investigating the effect of IC and EIS on firms' investment in exploration and exploitation. (2) Investigating the effect of researchers' education level on firms' investment in exploration and exploitation. (3) Investigating the effect of export and geographic scope on firms' investment in exploration and exploitation.

There are some important contributions of the thesis.

First, it advances the prior frameworks of determinants of exploration and exploitation, which mainly focused on organizational and environmental factors, by presenting results of one of (1) the first research comparing the effects of formal (IC) and informal inter-organizational (EIS) relationships on the exploratory and exploitative R&D investment, (2) the first research on the effect of educational level of R&D

personnel on exploratory and exploitative R&D investment, (3) the first research that separates R&D investment into exploratory and exploitative R&D investment when considering the learning-by-exporting effect and (4) the first research that pays attention to R&D investment when investigating the impact of geographic market scope. This contributes to the organizational learning theory as it focuses on firm-specific factors to which extant studies in this field often do not pay much attention. It helps researchers and managers understand a firm's investment decisions in exploration and exploitation. With that knowledge, a firm can optimize its investment decisions in exploration and exploitation to maximize the benefits of inter-organizational relationship, employee education, and internationalization and further develop its competitive advantages.

Second, it reveals the moderating role of a firm's development tendency on the relationship between EIS and exploitative R&D investment. The influence of external information on a firm's internal exploitation is conditional upon a firm's tendency towards core-development or periphery-development. When a firm is core-development oriented, which aims at developing goods and services in-house to outperform other similar-type products or services currently in market. EIS increases firms' exploitation in-house by providing understanding of the market and strengthening the firm's control over its internal exploitation activities, leading to increased core capabilities to beat or outperform the market. In contrast, when a firm is periphery-development oriented, which means it aims at developing goods or services externally to allow it to bring them to market in a quicker manner, EIS enables it to reduce the costs and risks of replicating externally available technologies. This leads to reduced investment in internal exploitation associated with periphery-development.

Third, by gaining information on the amount of investment in internal exploration and exploitation, the current research offers an important complement to the traditional measures of exploration and exploitation such as using dummy variables to measure the newness of product innovation (Blindenbach-Driessen & van den Ende, 2014), introducing point scale to measure exploration and exploitation tendencies (He & Wong, 2004; Bierly & Daly, 2007) or applying the proportion of turnover by exploration and exploitation (Laursen & Salter, 2006). These previous empirical studies measure exploration and exploitation from an outcome perspective. However, theoretical research on this subject such as March (1991) and Levitt & March (1988) proposed the concept of exploration and exploitation from an input-driven perspective. It highlights the importance of investment allocation between internal exploration and exploitation. We use exploratory and exploitative R&D investment to detect that two activities of organizational learning is more concrete and straightforward compared with previous empirical studies. It contributes to building a thought figure that simplifies and provides firms a sense of orientation when firms come to thinking about allocation of R&D funding to exploratory and exploitative activities.

This research is based on data drawn from the Technological Innovation Panel (PITEC). The PITEC contains information on the education background of R&D personnel, internationalization of firms such as export and geographic market scope, inter-organizational relationships of firms on innovation activities such as IC and EIS, other innovation indicators such as the number of employees and the type of firms, as well as the information on firms' allocation of current internal expenses on R&D by type of research. While firm internal R&D investment, staff qualification, geographic markets and other variables used in this study are available from 2003 to 2011, data on total exports are only available from 2006 to 2011, therefore we only focus on the later survey (2006-2011) in this study. Companies in this PITEC data belong to 14 industrial classification groups, including agriculture, extractive, manufacturing, recycling, production and distribution of electricity, gas and water, construction, transport, wholesale and retail trading, financial, real estate activities, social service, education, film and radio, scientific research and others. Since our model contains some time-invariant variables, there are considerable advantages of using random generalized least squares estimator (RE GLS) in this study (Greene, 2012). We conduct a panel specific RE GLS regression analysis using the STATA command 'xtreg re'.

The remainder of the thesis follows through six integrated steps. Chapter 2 summarizes prior concepts of exploration and exploitation since the seminal work of March (1991) and reviews empirical literature on determinants of firm-level exploration and exploitation. This chapter contains four sections. The first introduces the connotations of exploration and exploitation. Then, we indicate that both the meanings of exploration and exploitation will change depending on the level of analysis. By reviewing literature on the individual-level, team-level and organization-level connotations of exploration and exploitation, we find that the organization-level research mainly relies on learning and interaction across individuals while individual-level research only attributes the heterogeneous to individuals' inherent characteristics. Since external knowledge linkages influence the learning and interaction between the firm and external knowledge, as well as individuals within the firm, we suggest exploration and exploitation should be better to study at the organizational level in this study. Furthermore, the organizational level of analysis highlights the importance of adopting an input-driven approach (R&D investment) to study the exploration and exploitation since it can clearly reflect an organization's effort towards exploratory and exploitative learning activities. Finally, we present determinants of exploration and exploitation of a firm. Chapter 3 introduces learning mechanisms and the conceptual framework of exploration and exploitation investment. Chapter 4 introduces the data and variables. The statistical description and correlation of variables have presented in this methodology chapter. There are three sub-chapter of empirical chapters of this thesis: Chapters 5a, b and c. They provide hypotheses for three firm-specific factors by using learning mechanisms presented in Chapter 3 to infer the relationships between firm-specific factors and exploratory and exploitative R&D investment. Each of the sub-chapters contains an introduction, a relevant literature review, hypotheses, results and discussion. In Chapter 6, conclusions are drawn.

Chapter 2 Literature Review

2.1 Introduction

We first explain the connotation of the exploration and exploitation in this specific research, then highlight that our study of firm investment decisions in exploration and exploitation focuses on organizational level of analysis. This is because the organizational level of exploration and exploitation better expresses the mutual learning between the firm and external knowledge. Firm-specific factors influence the learning and interaction between the firm and external knowledge, as well as individuals within the firm, so they are more likely to result in a variance in firms' exploration and exploitation investment. This shows the importance of adopting an input-driven approach to study the exploration and exploitation since it can perfectly reflect an organization's efforts of exploration and exploitation. By introducing the determinants of an organization's exploration and exploitation in previous studies, we consider that the influence of external knowledge linkages and firms' internal learning ability on exploration and exploitation remains unclear. To narrow the research gap, we aim at examining the effect of EIS and IC, R&D personnel educational level, exporting and geographic market scope on the firms' exploration and exploitation investment, and we will provide a new explanation by focusing on organizational learning literature.

2.2 Connotations of the Exploration and Exploitation

In line with Blindenbach-driessen and van den Ende (2014) and D'Este et al. (2017), exploration and exploitation in this study are defined in conformity with March's (1991) original definitions. Exploration is defined as firms' investment on original work such as experimentation or theoretical work aimed at acquiring new knowledge on the substantial of facts (March, 1991; Lavie et al., 2010). It results in a shift to a different or an entirely new knowledge trajectory (Bengtsson et al., 2005). Such fundamentally new knowledge can be pure science, and also can be abstract ideas driving firms to introduce novel or entirely new products (Blindenbach-Driessen & van den Ende, 2014).

Exploitation is defined as the firms' investment on systematic work based on existing knowledge, acquired from research and/or accumulated experience (Gupta et al., 2006), aimed at refining existing activities (March, 1991; Lavie et al., 2010; Blindenbach-Driessen & van den Ende, 2014), manufacturing new materials, products or services (He & Wong, 2004; Xu, 2015), and building new processes and systems (Benner & Tushman, 2003; Blindenbach-driessen & Ende, 2014). In other words, exploitation emphasizes production, implementation and refinement. Firms that invest in exploitation can obtain new knowledge, but unlike exploration, the new knowledge in exploitation is generated along a firm's existing technological trajectory (Gupta et al., 2006).

Building on this definition, we make a distinction between exploration and exploitation in a firm's R&D activities. Both firms' investment in basic and applied research relate to exploration (Blindenbach-Driessen and van den Ende, 2014) because they focus on undertaking creative work primarily for obtaining new knowledge and increasing the stock of firms' scientific and technical knowledge (OECD, 1970; NSF, 1959). On the other hand, we refer the firm investment in experimental development to exploitation because it focuses on undertaking systematic work based on using existing knowledge directed to the production of useful materials, products, devices, systems and processes or the substantial improvement of those existing ones (OECD, 1970; NSF, 1959).

Our connotations of exploration and exploitation are more concrete compared with previous studies, as we associate them to firms' internal organization of research. Hence, they contribute to building a thought figure that simplifies and provides firms with a sense of orientation when they come to thinking about the allocation of R&D funding to exploratory and exploitative activities.

2.3 Exploration and Exploitation in Organizational Level

Exploration and exploitation are studied at different levels such as the individual level (Amabile, 1996; Mom et al., 2007), the team level (Lin & McDonough, 2014) and the organizational level (March, 1991; Zhou &Wu, 2010). The importance of identifying the level of analysis in explaining the meaning of the exploration and exploitation has been emphasized in recent studies, since the meaning of the exploration and exploitation will change depending on the level of research (Gupta et al., 2006; Lavie et al., 2010). For instance, an employee might search and experiment to explore a new technology, but then the firm where he or she works might exploit the technology for profit (Gupta et al., 2006). Therefore, in this section, we would like to highlight our level of discussions, organizational level of exploration and exploitation, and explain the reasons why we are interested in studying exploration and exploitation at the organizational level after summarizing characteristics of exploration and exploitation at individual, team, and organizational level. Our study is in line with March (1991) and Kogut and Zander (1992), and highlights the important role of social context in organizational learning. Knowledge is possessed by individuals, and also embodied in regularities by which members cooperate within organizations. There is mutual learning of firms and their individuals. It is interesting to note that firms' knowledge will not change simply by employee turnover. Therefore, we study exploration and exploitation in the context of organizational learning and suggest organizational level is best for studying firms' investment decisions in exploration and exploitation.

Individual Level

The individual level of exploration and exploitation mainly focuses on who knows what type of knowledge. Researchers interested in individual's investment decisions in exploration and exploitation mainly focused on the effect of individuals' inherent characteristics such as risk aversion and decision-making styles on exploration and exploitation investment. For example, since the returns from exploitation are more certain and immediate, risk aversion managers who are heavily motivated by rewards, are more likely to engage in exploitation to avoid the failure (Amabile, 1996). In contrast, risk-taking managers who are intrinsically motivated by advancement are more likely to engage in exploration to maximize their achievements (Amabile, 1996). Matzler et al. (2014) has drawn attention to the effect of intuitive and deliberate decision-making styles on exploration and exploitation investment. They found that an intuitive decision-making style has a positive effect on organizations' success of exploration, whereas a deliberate decision-making style is positively related to organizations' success of exploration and exploitation (Matzler et al., 2014). Due to the success trap, entrepreneurs and managers tend to invest in the activities in which they have successful experience. The investment decisions of exploration and exploitation made by an individual through learning from his or her own experience are too limited. "Human learning in the context of an organization is influenced by the organization and generates phenomena at the organizational level that go beyond anything that could infer simply by observing learning processes in isolated individuals" (Simon, 1996, p176). Therefore, from this point, the organizational level is more suitable than individual level for us to adopt in learning to explain different decisions on the allocation of exploration and exploitation investment.

Team level

The investment decisions in exploration and exploitation can be influenced at a team or organization level because learning tends to occur at levels that contain individuals with various in skills, experience and knowledge (Gupta et al., 2006). Team level learning benefits from the aggregation of individual knowledge structures (Lin & McDonough, 2014). At the team and organizational levels, individuals can learn from others and the variation across individuals contributes to an organization's exploration (March, 1991). For instance, if individuals in senior-management teams become more homogeneous and more internally focused, they are more likely to repeat routines to enhance their existing competencies, while driving out exploration (Hambrick et al., 2005; O'Reilly & Tushman, 2008). Saemundsson and Candi (2014) found that senior-management teams consisting of individuals with dissimilar backgrounds have better ability to recognize the environmental cues, so they have stronger incentives to invest in exploration to overcome threats coming from changes in environmental characteristics compared with teams consisting of individuals with similar backgrounds.

Moreover, the variance relative to existing knowledge also can generate a positive effect on exploration. For instance, Mom et al. (2007) found that bottom-up and horizontal knowledge flows increase variety in experience and interactions between the knowledge donor and knowledge recipient, which facilitates the exploration. Lin and McDonough (2014) found that a strategic business unit, which concentrates on considering, analysing and evaluating issues from multiple angles, is more likely to engage in exploration because such reflection cognitive style facilitates inter-strategic business unit learning. In contrast, they found that a strategic business unit, which focuses on exchanging ideas and information among internal employees (intra-strategic business unit learning), is more likely to engage in exploitation.

Organizational level

The above analysis contributes to understanding the organizational level of investment decisions in exploration and exploitation. Organizational learning stresses the social dimension of individual learning processes (Ibert, 2004). In an organization, each individual contributes a certain cognitive foundation to any management decision such as perception of uncertainty and risk, knowledge about alternatives and an evaluation of the influence of choosing each alternative (March and Simon, 1958). On the one hand, organizational codes such as languages, beliefs and practices learn knowledge from their individuals and adapt to individual beliefs. Meanwhile, individuals in the organization are also socialized to the organizational codes (March, 1991). Same as the logic of team level of exploration and exploitation, the deviation between codes and individuals enhances the incentives of organizations to invest in exploration. In addition, the more variance is related to organization's existing knowledge, the more exploratory activities are likely to happen (March, 1991).

After summarizing characteristics of exploration and exploitation at the individual, group and organizational level, we conclude that (1) individuals, group and organization can adapt their performance by cumulated experience but learning mostly happens at the organizational level. (2) Learning at the organization level is more likely to be influenced by organizational factors and its interaction with the external environment. Therefore, in this study, exploration and exploitation are understood in the context of organizational learning, and we suggest organizational level should be the most suitable unit of analysis for studying the firms' exploration and exploitation investment decisions. The organizational level of analysis also highlights the importance of adopting an input-driven approach to study the exploration and exploitation, since it can perfectly reflect an organization's effort to exploration and exploitation. The following section elaborates on the input-driven approach while providing a critical review of weaknesses in studies utilizing the output-driven approach.

2.4 The Exploration and Exploitation from an Input-driven Perspective

Previous studies showed that the development of exploration and exploitation relies on distinctive technology trajectories, which requires firms to invest in different organizational structures, processes and cultures. Exploitative activities are related to enhance a firm's current knowledge base by utilizing existing skills and capabilities (Lavie et al., 2010). Therefore, it encourages firms to invest in new knowledge generated along a firm's existing technological trajectory (Gupta et al., 2006). Exploratory activities compared with exploitative activities are more distant from a firm's locus of knowledge and action (March, 1991). It results in a shift away from a firm's existing experience, knowledge and skills (Lavie et al., 2010) so exploratory activities encourage firms to invest in the new knowledge developed along a novel trajectory that is markedly different from the old one (Gupta et al., 2006).

Structures and processes designed for exploitation are different from those designed for exploration (Burns & Stalker, 1961; Argyris & Schon, 1978; Burgelman, 1991). Exploitation requires firms to invest in mechanic and single-loop learning structures to maintain stability and enhance efficiency, whereas exploration requires firms to invest in organic and double-loop learning structures to facilitate experimentation and adaptation (Burns & Stalker, 1961; Argyris & Schon, 1978). Exploration requires a new set of processes that is normally incompatible with existing ones (Zhou & Wu, 2010). It encourages firms to disrupt their own advantages in existing systems of routines and actively invest in creating new routines for new knowledge. In other words, exploration requires firms to invest in variation-increasing autonomous processes, whereas exploitation requires firms to invest in variation-reducing induced processe (Burgelman, 1991). The development of exploration and exploitation also relies on different organizational cultures. Firms that conducting exploration should invest in building a decentralized environment with loose cultures and flexible processes, whereas firms conducting exploitation should invest in building a centralized environment with tight cultures and strict control (Benner & Tushman, 2002, 2003).

As a result, firms focusing on explorative R&D in their adaptive process tend to invest in things characterized by discovery, search, experimentation or flexibility, whereas firms focusing on exploitative R&D in their adaptive process tend to invest in things characterized by refinement, production, efficiency or implementation (March, 1991). A firm often needs to invest in both exploration and exploitation because both are valuable to the success of the firm (March, 1991). However, exploration and exploitation are fundamentally mutually exclusive, exploration of new possibilities may come at the cost of improvement of existing competence (exploitation) and in turn enhancing skills at current procedures may reduce the attraction of conducting experimentation (exploration) (Levitt & March, 1988). Moreover, over investment in exploration can result in high costs of experimentation without achieving any advancement (Baum et al., 2000). If explorative activities failed, there is not any outstanding success in the new field to compensate for the losses in current operations (Mitchell & Singh, 1993). Similarly, the over investment in exploitation can limit firms' ability to adapt to the changing environment and result in taking suboptimal routines. Therefore, there is an increasing need for firms to make decisions in resource allocation between the two and the core on how much to invest in these two different learning activities (March, 1991; He & Wong, 2004).

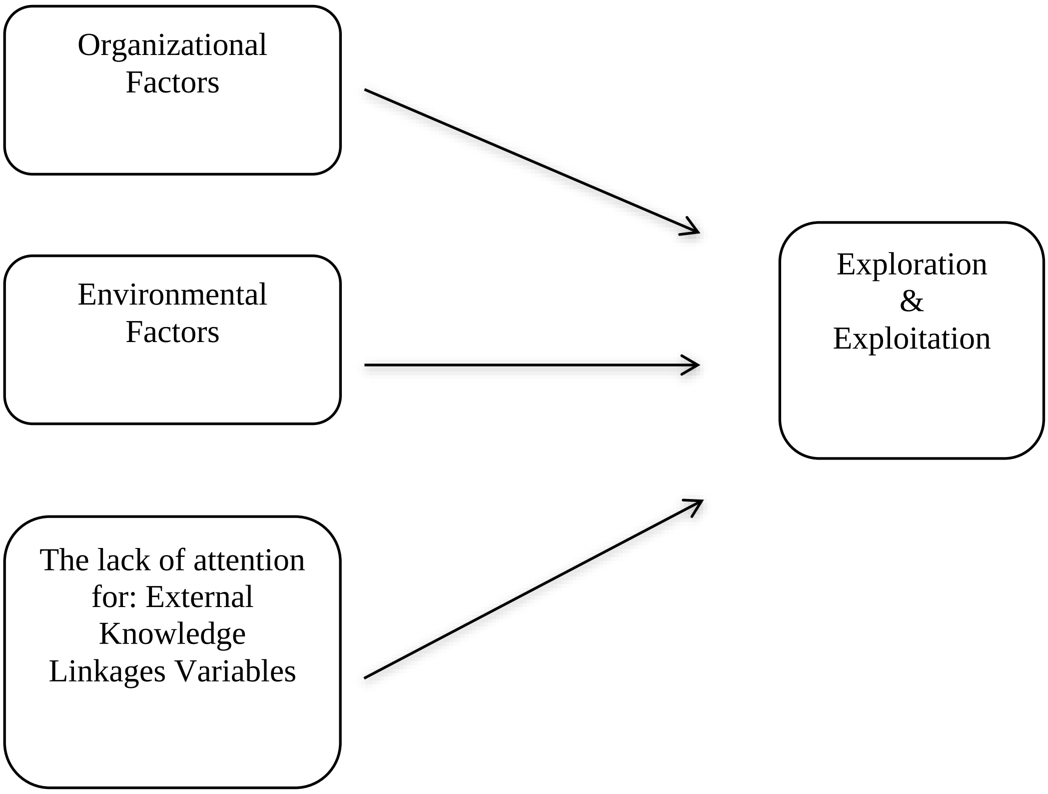
Input-driving perspective highlights the importance of investment allocation between exploration and exploitation. It focuses on firms' current investment on exploration and exploitation and suggests that firms often obtain exploration and exploitation through different types of activities (March, 1991). Hence, studying firms' exploration and exploitation from an input-driven perspective can help us to understand firms' investment decisions in exploration and exploitation. Many studies distinguished exploration and exploitation from an ex-post outcome perspective by referring to the firm's radical innovation and incremental innovation (He & Wong, 2004). However, there are considerable weaknesses of considering exploration and exploitation from an outcome perspective. Firstly, a radical innovation product or an incremental innovation product could result from investment in both exploratory and exploitative learning activities. It is often inaccurate to conclude that a radical product totally derives from radical innovation or an incremental product is totally an outcome of incremental innovation. In Cohen and Levinthal's (1990) absorptive capacity literature, they considered that the organization' ability to obtain and build new knowledge is contingent on its existing knowledge base. Therefore, previous investment in exploitation enhances the firm's ability to conduct the subsequent exploratory activities and in turn, successful exploration allows firms to further exploit that newly obtained knowledge (Gupta et al., 2006). This natural cycle blurs the boundary of radical innovation products and incremental innovation products (Rothaermel and Deeds, 2004). Secondly, there is no consensus on a single definition for radical innovation. For instance, Xu (2015) and Rothaermel and Deeds (2004) pointed out that new technology is an essential element for radical innovation. However, some studies such as Kok and Ligthart (2014) and Song and Montoya-Weiss (1998) appeared to treat all new products with substantial or entire changes as radical innovation even if these new products do not involve a new technology. Moreover, it is very difficult to define what an entirely new or substantially changed product is. Studies such as Kok and Ligthart (2014) and Garcia and Calantone (2002) considered both new-to-firm and new-to-market products as radical innovation, but there are also some studies such as Xu (2015) and Rothaermel and Deeds (2004) considering that only those products that bring entirely new experience to customers could be viewed as radical innovation.

Overall, given the drawback of defining exploration and exploitation from an outcome perspective, this thesis argues that exploration and exploitation should be considered from an input-driven perspective and should best be examined at the organizational level, because it ensures that our concepts of exploration and exploitation are in line with March's (1991) original definitions and to be best fitted for answering our specific research questions.

2.5 Determinants of Exploration and Exploitation

From the above discussion, we know that organizations need to make decisions on how much to invest in exploration and exploitation (March, 1991; He & Wong, 2004). Scholars (e.g. Lavie et al., 2010; Fang et al., 2010) identified a variety of factors that can influence the exploration and exploitation investment. As shown in Figure 2.1, these studies mainly focused on the environmental and organizational factors. Amidst these contributions, three gaps persist.

Figure 2.1 Determinants of Exploration and exploitation



First, whereas prior studies on determinants of exploration and exploitation focused on these traditional variables, several scholars argued that the external knowledge linkages that link firms with their embedded environment might better predict firms' exploration and exploitation investment (Blindenbach-Driessen & van den Ende, 2014). Many studies on exploration and exploitation, however, ignored the insights from external knowledge linkages of scholars. In this study, this lack of attention to external knowledge linkages variables is addressed through underlining EIS, IC, exporting and geographic market scope. Second, as we discussed in previous the sections, the organizational level of exploration and exploitation is an aggregation of individual knowledge structures, individual's learning ability within an organization may influence its exploration and exploitation, so we would like to shed new light on the effects produced by organizational factors by focusing on the educational level of researchers. And third, we suggest more attentions should be paid to the underlying mechanisms that facilitate firms to make decisions to invest in exploration and exploitation. We extract four learning mechanisms (experiential learning, vicarious learning, search and learning from distant knowledge) from previous studies and suggest that it should be interesting if we adopt them to explain determinants of firms' exploration and exploitation investment.

2.5.1 Organizational factors

Previous studies suggested that researchers should be aware of organizational factors such as organizations' structure, size, age, resources and culture in explaining the heterogeneity in exploration and exploitation investment across organizations as these factors are rooted in organizations' history and identity (Lavie et al., 2010). Through reviewing previous studies in organizational factors, we find the experiential learning and learning from distant knowledge can be considered as learning mechanisms behind these determinants facilitating firms to invest in exploitation and/or exploration. Moreover, we suggest firms' researchers' qualification as a reflection of firms' learning ability determining firms' investment in exploration and exploitation.

Organizational Structure

Organizations implement their operations through an organizational structure that specified the distribution of resources, authority and duties across different functions and units. Mechanistic structures are characterized by routine operations, functional specialization, hierarchical structures of authorities and duties, whereas organic structures support a less rigid hierarchy, they are characterized by loose rules and procedures, horizontal specialization and informal duties (Burns & Wholey, 1993; Lunenburg, 2012). These alternative structures can promote exploitation or exploration accordingly. For instance, Burns and Stalker (1961) suggested that mechanistic structures fit with the needs of exploitation, while organic structures fit with the needs of exploration. Similarly, Jansen et al., (2006) found that centralized decision making with a mechanistic structure tends to reduce the possibilities of firms to engage in exploration because it increases solutions to the routine problems and decreases the likelihood for firm members to seek new solutions.

We consider that the negative effect of centralized decision making on exploration can be explained by the close relation between the mechanistic structure and organizations' experiential learning. A mechanistic or formalized structure enhances firms' current routines that encourage firms to conduct more standardized activities, which facilitates experiential learning of firms (Nelson & Winter, 1982). Such learning through regular activities allows firms to improve their existing solutions through automatic accumulating repeated experience, and tend to result in a learning myopia (Rerup & Feldman, 2011). Therefore, experiential learning often facilitates firms to place their priority on exploiting exiting solutions rather than exploring solutions that deviate from existing ones (Sato, 2012). In this study, we would like to adopt experiential learning as a mechanism to explain firms' investment decisions in exploration and exploitation.

Firm size

Researchers investigating the effect of firm size on firms' exploration and exploitation have found mixed results. For instance, Beckman et al. (2004) found that exploration increases with firm size. In contrast, Rothaermel and Deeds (2004) found a negative moderating effect of firm size on new product development path. Csaszar (2013) applying a mathematical model of organizational decision-making found that both results are possible depending on the structure adopted. Firms with larger polyarchies would explore more as they tend to avoid missing a great investment opportunity, whereas firms with larger hierarchies would explore less as they tend to avoid making a bad investment (Csaszar, 2013). Taking an intermediate position in these two mistakes avoiding thoughts allows firms to achieve a high level of exploration and exploitation simultaneously (Csaszar, 2013). Nevertheless, other studies failed to found a relationship between organizational size and exploration in terms of scope of information acquisition (Sidhu et al., 2004) or prior alliance experience with partners (Lavie & Rosenkopf, 2006). One potential explanation of these mixed results could be that larger firms while enjoying more resources, richer product development experience, stronger bargaining power and greater marketing skills, also face bureaucracy and inertia that could hinder exploration from occuring (Damanpour, 1996; Hitt et al., 1990; Kimberly & Evanisko, 1981).

Firm Age

Younger firms and older firms may have different tendencies to explore or exploit. Sorensen and Stuart (2000) found in their work of semiconductor and biotech firms that younger firms are more flexible in structure and competence. As a result, they have stronger desires to learn from others, thus there is the propensity for them to engage in exploration. They also found that older firms have more self-citation than alter-citation in their patents which indicates a strong tendency towards exploitation in older firms. In line with Sorensen and Stuart (2000), Lavie et al. (2010) suggested that younger firms are short of internal resources and customer base, and have strong needs of investment in setting up organizational roles and structuring relations, so such firms are more likely to invest in exploration. They also suggested that older firms are more likely to invest in exploitation because they were subject to inertial pressures caused by established routines and skills, and pressures deriving from stakeholders who favour rational action and reliable performance. These previous studies showed that a flexible structure allows vicarious learning to occur and facilitates firms to invest in exploration, whereas a mechanistic structure enhanced experiential learning leads to inertia that hinder firms to invest in exploration and puts exploitation in first place.

Slack resources

Slack resources refer to the extent to which resources are beyond an organization's needs for day-to-day operations (Nohria & Gulati, 1996). Slack resources contain unabsorbed slack, which are uncommitted ready-to-deploy assets, and absorbed slack, which are excessive investments in the organization's existing operations that could be retrieved (Singh, 1986; Voss et al., 2008). Slack resources, both absorbed and unabsorbed, tend to help firms deal with environmental fluctuations and downside risk and protect them from losses in case of failure. As a result, slack resources encourage search, experimentation, risk taking and innovation and thus they promote firms to invest in exploration (Greve, 2007; Sharfman et al., 1988; Singh, 1986; Levinthal & March, 1993; Nohria & Gulati, 1996; Sidhu et al., 2004). However, organizations with slack resources may have weaker motivation to explore compared with organizations without slack resources, because the former is motivated by consuming current slack resources while the latter is motivated by enhancing the ability to survive through innovation (Bourgeois, 1981). In terms of these opposite arguments, Voss et al. (2008) suggested that slack resources can either boost or mitigate exploration but this mainly depends on the perceived environmental threat.

They found that absorbed, generic resources generate positive effects on exploitation but negative effects on exploration. However, unabsorbed resources, both generic and rare, lead to increased exploration and decreased exploitation only in the case of high perceived environmental threat (Voss et al., 2008). These studies implied that firms should pay attention to the environment where they are located and try to establish links with the external environment in order to reduce the risk of conducting exploration. This argument can be applied to our research. For instance, collaboration allows firms to share the risk of conducting exploration with their partners, so it may generate a positive effect on firms' investment in exploration.

Learning ability

Exploration involves nonlocal search that requires firms to shift to a new technological trajectory and to achieve a breakthrough through combining diverse bodies of knowledge (Argyres, 1996). Therefore, in this research, we refer to firms' learning ability as firms' ability to search new alternatives that distant from firms' existing knowledge trajectory. Some scholars are interested in investigating the effect of organizations' capabilities on exploration. Dai and Yu (2013) found that firms with better learning ability can efficiently learn the advanced technologies in diverse fields from the external environment and creatively apply them to exploration.

Qualification is one of the important factors that determines firms' learning ability (Lam, 2005). For instance, doctoral researchers can be used to provide access to critical knowledge channel (Cockburn & Henderson, 1998; Roach, 2009). They not only possess knowledge, which is often at the frontier of science and technology, but also facilitate firms to develop ties with prominent scientific communities such as through membership in professional societies, attending professional meeting and publishing (Cockburn & Henderson, 1998; Sauermann & Stephan, 2009). Therefore, they are supposed to facilitate firms to invest in basic research (Sauermann & Cohen, 2008; Baba et al., 2010) by enhancing firms' ability to search the relevant knowledge from the external environment. According to prior studies in learning ability, we suggest that it would be interesting to investigate the effect of firms' internal researchers' educational level on firms' exploration and exploitation investment.

Culture

Researchers also paid attention to the effect of organizational culture as it relates to the organization's values, attitudes, experiences and beliefs that constitute a foundation of the behaviour of organizational members (Alvesson, 2002; Schein, 2004). As an organization's culture represents the values and beliefs of behaviours that are shared among organizational members, it is likely to have a large and sustaining impact on the behaviours of members within the organization. Thus, a culture that stresses on standardization may cause individuals to lose the passion for seeking alternative ways of doing things (O' Relly & Chatman, 1996), whereas a culture that tolerates a deviation between individuals and organizational values is likely to prompt exploration of new possibilities (Sorensen, 2002). A strong culture requires individuals in organization to share a set of strongly embedded norms and values throughout the organization (O'Reilly & Chatman, 1996). It often acts as social control systems that set expectation of appropriate behaviours for individuals within the organization (O'Reilly & Chatman, 1996). It directs and constrains the behaviour of members in collective and consensus on organizational goals and values among members (Sorensen, 2002). It seems that organizations with strong culture are ill suited for exploration because they have greater difficulty in observing, recognizing and responding to environmental threats (Sorensen, 2002). Moreover, a strong culture requires individuals to be greatly devoted to organizations' goals and values, which develops a strong foundation for exploitation (Sorensen, 2002). For instance, in strong culture organizations, members may only able to act on the responsibility frame that firms set up for them and result in exploitation of existing capabilities at the expense of exploration (Andriopoulos & Lewis, 2009). In contrast, organizations with a weak culture allow individuals to retain their deviant values, and therefore the deviation between codes and individuals can remain a longer time in these organizations (Sorensen, 2002). A weak culture allows organizational codes to learn from individuals whose values differ from the organization's dominant values and hence tend to result in an increase in exploration (March, 1991). Based on these previous studies on cultural factors, we suggest that learning from distant knowledge should be considered as a mechanism facilitating firms to invest in exploration. In contrast, learning from similar knowledge hinders exploration and encourages firms to invest in exploitation.

2.5.2 Environmental factors

Some researchers considered the ability of conducting exploration and exploitation is different according to the context in which organizations are embedded. They are interested in investigating the effects of environmental factors such as competitive intensity (Levinthal & March, 1993), environmental dynamism (Sidhu et al., 2004) and appropriability regime (Lavie et al., 2010; Teece, 1986) on organizations' exploration and exploitation. In line with our views, these previous studies considered exploration and exploitation from an input-driven perspective when studying the determinants of exploration and exploitation.

Through reviewing studies on environmental factors, we find that (1) vicarious learning can be considered as a mechanism facilitating firms to invest in exploration and to search for knowledge in a new trajectory; (2) search is necessary for firms to develop technology along an entirely new trajectory, as well as for enhancing their technology in an existing trajectory; (3) EIS and IC as two different ways that firms establish linkages with the external environment, tend to generate various effects on firms' exploration and exploitation investment, hence it would be interesting to compare their effects in this study.

Competitive Intensity

Competitive intensity mainly indicates the extent to which firms in the same industry tend to retain zero-sum relations with one another as they compete for the same pool of scarce resources (Barnett, 1997). The high intensity of competition, caused by rising number of competitors results in prices falling, margins declining, and less organizational slack (Porter, 1980; Miller & Friesen, 1982). In such situations, firms are more likely to embrace more risks and engage in exploration because the continuous refinement of existing products, services, process and supportive systems becomes insufficient for them to stand out from the competition.

The prospect theory provides theoretical support for this positive impact between exploration and competitive intensity. It predicts that firms will pursue change and develop resources and capabilities to build new sources of competitive advantages when under threat (Kahneman & Tversky, 1979). In high competitive intensity environments, the results of firms' behaviour are uncertain and less predictable, as they mainly depend on behaviours of other competitors. Organizational learning arguments supported that exploration has more opportunities to occur in changing or turbulent environments, whereas exploitation has more opportunities to occur in predictable or stable environments (March, 1991; Levinthal & March, 1993).

Therefore, firms in competitive intensity environment tend to do more exploratory activities in order to withstand the threats to survival (Auh & Menguc, 2005).

Previous studies showed some empirical evidence. Voss et al. (2008) found that the perceived environmental threat increasingly drives organizations to search for new competencies, and to focus on investing financial and customer-relations resources instead of concentrating on refining their current strategic positions. Nicholls-Nixon et al. (2000) found the perceived environmental hostility increases the frequency of strategic experimentation. Saemundsson and Candi (2014) investigated the effect of competitive intensity on firms' exploratory innovation strategy. Their results showed that if firms are sensitive to changes in the environment, the increased competitive intensity tends to push them to adopt a more exploratory innovation strategy.

To sum up, competitive intensity scholars asserted that firms will invest in a variety of activities such as experimentation and customer-relations to build exploration and consequently, enhance their position in current markets and establish presence in new markets during periods of fierce competition. In contrast, firms will invest in certain activities to build exploitation when the competitive tension is low, because in such situations they can get reasonable return on investment through leveraging existing products, services, and technologies without incurring exploration risks. These are congruent with our discussion of the input-driven perspective of exploration and exploitation. It is important to analyse how much is invested in exploitation and exploration at the same time for the same firm, as each requires different inputs. Moreover, scholars in competitive intensity highlighted the importance of monitoring and collecting information from their customers as well as competitors to develop technology along an entirely new trajectory in competitive environments. It implied that vicarious learning can be viewed as a mechanism that facilitates firms to invest in exploration and search for knowledge in a new trajectory. However, no attention has been paid to the role of vicarious learning in exploration and exploitation in previous studies. Therefore, in this study we consider vicarious learning as one of the learning mechanisms that explains firms' investment decisions in exploration and exploitation.

Environmental Dynamism

Environmental dynamism refers to the degree of unpredictability of change in an organization's environment (Dess & Beard, 1984). Dynamic environments are characterized by changes in customer preferences, technologies and market demand (Saemundsson & Candi, 2014). It reduces the life span of products and services, resulting in exiting products and obsolete services (Jansen et al., 2005). Such conditions encourage organizations to explore (Jansen et al., 2006) as they can abandon expiring certainties through taking advantage of emerging opportunities in turbulent environments (Hannan & Freeman, 1984). While organizations may fail to do so, the failure can be quickly offset due to the high rate of opportunities in environments (Saemundsson & Candi, 2014). Accordingly, the increased opportunities in the environment induce organizations to do more extensive information search so as to understand and manipulate emerging opportunities (Sidhu et al., 2004). Moreover, the expanded search of information can also lessen managerial uncertainty because uncertainty tends to diminish when information search carries on beyond data acquisition and starts offering interpretations (Elenkov, 1997). Environmental uncertainty increases the needs of organizations to search for new alternatives routines and information about the association between organizational characteristics and outcomes. It also increases the need for knowledge about the viability of possible changes in organizational characteristics to achieve major changes in organizations and overcome the dilemma of decreased performance. It is for these two reasons that organizations tend to allocate more resources toward exploration. In other words, increase investments in exploration (Lant & Mezias, 1992). Saemundsson & Candi (2014) supported that the high level of environmental dynamism stimulates firms to adopt an exploratory innovation strategy, whereas the low level of environmental dynamism stimulates firms to adopt an exploitative innovation strategy.

However, some studies suggested that the appropriate response to environmental turbulence should be a focus of exploiting existing knowledge and opportunities because the consistent change in environment erodes the possibility of getting reward from obtaining new knowledge through exploration (Kim & Rhee, 2009; Posen & Levinthal, 2012). Organizations may choose to look for external resources from similar and familiar partners to manage the uncertainty (Beckman et al., 2004). They tend to search for alternatives that are close in temporal, organizational and strategic distance (Baum et al., 2000).

According to previous studies on environmental dynamism, acquiring and processing information about alternatives and the content of organizational adaptation depends on the outcomes of the organizational search process. These previous studies suggested that exploration needs inputs searched from a broader scope and more distant knowledge (Sidhu, et al., 2004) whereas exploitation needs inputs searched from the most proximate existing routines and knowledge (Lant & Mezias, 1992). Even though these previous studies implied that both exploration and exploitation require search, insufficient attention has been paid to its role on firm investment decisions. Therefore, in this study, this lack of attention to search is addressed through considering it as a learning mechanism that facilitates firms' investment in exploration and exploitation.

Appropriability regime

Appropriability regime is defined by the extent to which the environment allows organizations to appropriate value from their innovative research. A weak appropriability regime tends to diminish the value of exploration, because without sufficient government protection of intellectual property rights, organizations are not able to protect their proprietary assets efficiently (Teece, 1986). Therefore, under the weak appropriability regime, organizations prefer to invest in exploitation instead of exploration, especially when we adopt a knowledge-based definition of exploration and exploitation (Levinthal & March, 1993). It seems that the organizations need to increase the control of external knowledge in order to reduce the risk of losing proprietary assets. They may establish links with the external environment through collaboration in order to avoid the free ride behaviours of their partners and other outsiders. No studies have mentioned the different ways for firms to engage in external environments involving different level of controls of external knowledge may result in different effects on firms' investment decisions in exploration and exploitation. Therefore, we would like to investigate EIS and IC in a same study and compare their impacts on firms' investment in exploration and exploitation.

2.5.3 External knowledge linkages

There is a clear need for investigating the effect of the external knowledge linkages on firms' exploration and exploitation investment. Recent studies investigating the influence of external knowledge linkages on firms' exploration and exploitation have mainly focused on the formal form of inter-organizational relationships such as acquisition (Phene et al., 2012; Lin, 2014) and collaboration (Bierly III et al., 2009; Un & Asakawa, 2015). However, no study has compared the effect of different inter-organizational relationships on firms' exploration and exploitation investment. Especially, they have ignored the influence of the informal form of inter-organizational relationships, EIS, on firms' exploration and exploitation investment. Therefore, it would be interesting to investigate different inter-organizational relationships in one study to examine whether firms' informal and formal forms of inter-organizational relationships generate the same effects on exploration and exploitation investment or not. Therefore, we investigate both IC and EIS in this study and compare their effects on exploration and exploitation. Internationalization is also a way that firms can acquire external knowledge (Egan & Mody, 1992; Goerzen & Beamish, 2003; Kim et al., 2015). Prior studies investigating the effect of internationalization on organizational learning considered firms' internal R&D as a homogeneous construct (Manez et al., 2015; Neves et al., 2016). Different types of R&D activities (exploratory vs. exploitative) have been addressed insufficiently in prior internationalization research. To address this gap, we investigate the impact of internationalization in this study to see whether future research can extrapolate conclusions from analysis that study overall R&D investment into studies that analyze exploratory R&D investment/ exploitative R&D investment.

Acquisitions

Phene et al. (2012) suggested acquisitions facilitate firms' exploration and exploitation investment in the semiconductor industry. They looked at the effect of three specific factors on firms' exploration and exploitation: technological uniqueness of the target firms, commonality of geographic bases between acquirer and target firms and the extent of control of target firm post-acquisition. They gained the following findings. First, the technological uniqueness will increase the opportunities of acquirers to effectively search inputs for exploration but it will impede acquirers' exploitation; second, the commonality of geographic bases will allow firms to absorb similar knowledge from target firms that contribute to firms' exploitation; third, strong control tends to reduce the capabilities and motivation of the innovation of the target firms in the post-acquisition period and therefore generate a negative effect on exploration. It should be noticed that Phene et al.'s work attributed the changes of exploration and exploitation to the acquirers' increased motivation of overcoming learning myopia. For instance, learning from target firms' uniqueness knowledge enhances opportunities for firms to alter its innovation trajectory and to operate exploration in target firms' areas. In the next chapter, we will introduce our selected mechanisms in detail and explain how they influence firms' investment in knowledge trajectories.

Another research that focused on acquisition is by Lin (2014), which found that related acquisitions with high extents of integration have a positive relationship with combined firms' exploitation; in contrast, unrelated acquisitions have a positive relationship with combined firms' exploration. This is consistent with our discussion on organizational factors, suggesting that learning from distant knowledge can be considered as a mechanism facilitates firms' exploration investment.

Collaboration

Studies that investigated the role of collaboration on firms' exploration and exploitation tend to focus on different types of R&D collaboration partners. Un and Asakawa (2015) compared the effect of four different types of R&D collaboration partners including universities, suppliers, competitors and customers on firms' exploitation. They found that establishing R&D collaboration with suppliers or universities has a higher positive effect on exploitation than establishing R&D collaboration with competitors or customers. Some studies classified different types of collaboration partners in terms of two strategic orientations: exploitative-oriented and exploratory-oriented. They suggested that collaboration with customers or suppliers contains a more exploitative nature because it typically focuses on enhancing performance within a certain value chain (Tripsas, 1997), whereas collaboration with universities and research institution contains a more explorative nature as it mainly focuses on creation and development of discernments about new technologies (Bowie, 1994; George et al., 2002). Soh & Subramanian (2014) suggested that firms should adapt their internal R&D focus in terms of different strategic orientations in order to prevent the overlap with the knowledge obtained from external collaboration partners. Some studies are interested in investigating the effect of partners' technological relatedness (Bierly III, et al., 2009) or geographical proximity (Bishop et al., 2011) on firms' exploration and exploitation investment. They thought knowledge from distant sources is applied more to exploration, which is consistent with our previous discussion.

Although there are already some studies investigating the effect of collaboration on firms' exploration and exploitation, it still needs further attention by scholars. For instance, Blindenbach-Driessen and van den Ende (2014) adopted traditional paradigms of the innovation management discipline to study the influences of a separate innovation unit on manufacturing and service firms' exploration, exploitation and ambidexterity, but interestingly, in their regression model they found that collaboration has greater positive effects on exploration, exploitation and ambidexterity than the variable of having a separate innovation unit. They suggested further researcher to draw more attention to the role of collaboration versus internal R&D activities.

Overall, most of the studies examining the determinants of exploration and exploitation focus on organizational factors and environment factors, the influences of external knowledge linkages and firms' internal learning ability on firms' exploration and exploitation investment remain unclear. To narrow the gaps, we investigate the effect of IC and EIS, internationalization and R&D personnel educational level on firms' investment decisions in exploration and exploitation. We provide a new explanation for the determinants of exploration and exploitation by turning to organizational learning literature that emphasizes learning mechanisms to explain the exploration and exploitation investment of firms. In doing so, four learning mechanisms: experiential learning, vicarious learning, learning from distant knowledge and searching are adopted in this study.

Chapter 3 Conceptual Framework

3.1 Introduction

Learning is a more reasonable mechanism than calculative rationality in helping firms to explain organizational action as it has increasingly been considered as a unique source of sustainable competitive advantages for a firm (Levinthal and March, 1993). An understanding of different learning mechanisms in organizational learning would help us to explain the differences in firms' investment decisions in exploration and exploitation. In the last chapter, we extracted four learning mechanisms from previous studies in determinants of exploration and exploitation: experiential learning, vicarious learning, learning from distant knowledge, and searching. We summarized that vicarious learning and learning from distant knowledge contribute to firms' exploration investment, whereas learning from experiential learning and searching contribute to both firms' exploration and exploitation investment. In this chapter, we first introduced these four learning mechanisms in detail and explained how these learning mechanisms link to exploration and/or exploitation. Then, we reviewed previous studies on output and input models of innovation and we summarized what mechanisms firms learnt in different firm-specific factors. Once we know what learning mechanisms occur in each firm-specific factor, we are able to predict the relationship between firm-specific factors and exploratory and exploitative R&D investment. These two steps help us to understand the influence of firm-specific factors on firm internal exploratory and exploitative R&D investment.

3.2 Organizational Learning: Learning from Experience

Scholars in both theoretical and empirical research emphasized the role of experience as the first source of organizational learning (March, 2010; Argote, 2013). Organizational learning as a change in organization's knowledge happens because the organization obtains experience (Argote & Miron-Spektor, 2011). Organizational learning theory supported that learning through experience facilitates performance as it generates effects on knowledge creation and transfer, forcing organizations to change their strategies, structures and practices (Cyert & March, 1963; Levitt & March, 1988). The processes of learning from experience are important means of and aids for organizations to cultivate intelligence (Levinthal & March, 1993). Experience is accumulated in an organization as it conducts or attempts to conduct tasks. Organizations learn from their intentions to conduct tasks, no matter if these tasks are complete or incomplete, a success or failure (Argote, 2013).

Many empirical studies in organizational learning found positive returns to the accumulative operating experience (Argote, 1999). For instance, the well-known learning curve indicates that the unit cost of producing manufactured items will reduce due to the function of cumulative output (Yelle, 1979; Muehlfeld et al., 2012). These findings are consistent with the psychological theory of reinforcing learning by repetition (Muehlfeld et al., 2012). Moreover, the lessons organizations learn through experience can be transferred from one operating unit to another (Argote, et al., 1990) or spillover from one activity to another (Udayagiri & Balakrishnan, 1993). As there are various types of experience that can influence organizational learning processes and each experience generates different outcomes, scholars tend to characterize experience at a fine-grained level along different dimensions (Argote et al., 2003). Whether the experience is obtained directly by the unit in the focal organization or indirectly from other units has been considered as the most fundamental dimension of experience (Argote, 2013). Learning from this former type of experience is referred to as experiential learning (Tsang, 2002), whereas learning from the latter form of experience is referred to as vicarious learning (Bandura, 1977). The differences between experiential learning and vicarious learning and their influence on exploration and exploitation have been summarized in Table 3.1 below.

Table 3.1 Experiential learning and vicarious learning

Experiential Learning	**Vicarious Learning**
Direct experience (Echajari & Thomas, 2015; Argote, 2013; Tsang, 2002); First-hand experience (Huber, 1991) Learning from one's own experience (Argote, 2013)	Indirect experience (Echajari & Thomas, 2015; Argote, 2013); Second-hand experience (Huber, 1991) Learning from the experience of other units (Argote, 2013); The experience does not belong to the organization itself (Echajari & Thomas, 2015)
Exploit-related learning (automatic; based on the development of routines; trial-and-error is solved by refined routines): learning curves and honing routines is an accumulated practical skill aiming at maximizing private gains (Echajari & Thomas, 2015; Kogut and Zander, 1992)	n/a
Explore-related learning (intentional, experimenting new routines, trial-and-error is solved by replaced routines): extend the firm's background knowledge; own knowledge oriented explore (Echajari & Thomas, 2015; Huber, 1991; Hitt et al., 2005) "create	Explore-related learning (learning others' skills and technology): Other's knowledge oriented explore, create new knowledge by firms' external learning (Kogut and Zander, 1992)

new capabilities through a process of trial-and-error learning" (Kogut and Zander, 1992, p.393)	
Need: Repeated task, Accurate feedback (Rerup & Feldman, 2011)	Need: Interaction, Absorptive capacity and trust

3.2.1 Learning from experience: experiential learning

Now we will introduce the first learning mechanism, experiential learning, and show how it facilitates firms to engage in exploratory and exploitative R&D activities. Experiential learning highlights that organizations can acquire knowledge through direct and first-hand experience (learning by doing) (Tsang, 2002), where a currently performed task tends to improve the firm's performance in future tasks (Echajari & Thomas, 2015). Sometimes the experiential learning is a consequence of intentional, systematic efforts, but more frequently it is an automatic learning (Huber, 1991; Zollo & Singh, 1998). Experiential learning is a result of creation and accumulation knowledge by repeated experiences in the production process (Argote & Miron-spektor, 2011). This automatic accumulation is favoured by trial-and-error learning (Echajari & Thomas, 2015). During the time when firms conduct regular activities, they tend to revise their routines as needed after comparing the outcomes of these activities with objectives (Rerup & Feldman, 2011). This automatic experiential learning encourages firms to make changes along with their existing technological trajectory on the basis of the development of routines. The enhanced reliability in experience allows firms to achieve learning curves and maximize their private gains, and hence benefit firms' exploitation. For instance, the accumulated direct experience of manufacturing a product in a country allows firms to apply other products to that country, since now they have more information of the country's local suppliers.

Experiential learning not only contributes to firms' exploitative activities but also allows firms to conduct own knowledge oriented exploration. The intentional and systematic experiential learning goes beyond simple refining routines and suggests a replacement of old routines (Rerup & Feldman, 2011). This mechanism deploys when selecting a routine or revising the old routine cannot solve the problem that firms have recognized from the accumulated experience. In this situation, firms will conduct self-discovery and try to explore their own capabilities to reach the desired level again. They will replace the old routine through selecting and experimenting a new routine from a sample that exists in their environment (Gong et al., 2005) and will maintain this process until a new routine is found that provides a solution successful enough to take over the old one (Miner et al., 2001). Therefore, the intentional and systematic experiential learning is stimulated by big errors or negative performance feedback, aiming at creating variety in experience, and hence facilitating firms to replace old routines and do more exploration-related activities (Rerup & Feldman, 2011).

According to the discussions above, experiential learning requires two factors. First, firms must carry out regular activities to allow trial-and-error. Second, increasing the availability and accuracy of feedback about cause-effect relationships between organizational actions and outcomes allows firms to benefit from experiential learning. Previous studies on unintentional or automatic experiential learning mainly focused on its application to organizations' production processes but recent researchers who worked on intentional experiential learning proposed that learning from direct experience can also occur in other domains such as the formation of strategic alliances (Kale and Singh, 2007), mergers and acquisitions (Zollo and Singh, 2004) and the processes of internationalization (Bingham and Eisenhardt, 2011). They suggested firms can learn first-order skills and routines through engaging in external knowledge

(Kale & Singh, 2007). However, the intentional experiential learning mechanism is still underexplored (Echajari & Thomas, 2015). Therefore, in this study, we attempt to adopt both automatic experiential learning and intentional experiential learning to explain the effect of our determinants on exploration and exploitation.

3.2.2 Learning from experience: vicarious learning

The second learning mechanism is vicarious learning. It refers to learning from the experience of other units (Argote, 2013) to increase firms' investment in exploratory R&D activities. Firms could either replicate other organizations' successful experiences or learn from their unsuccessful experiences. Other's failure or success can drive firms to invest more in exploratory R&D activities. For example, Nokia's failure may signal to other peers in the Smartphone market to give up their current successful platform and innovate on Smartphones with new features (e.g. touchscreen) (Chang, 2012). Tesla's success in the electric car industry signals to traditional carmakers to invent in battery technology (Kim & Tajitsu, 2017). Moreover, vicarious learning refers to the case where firms try to learn technologies owned by other organizations in its environment (Tsang, 2002; Echajari & Thomas, 2015). Others' different but complementary technology provides firms with more valuable resources for exploratory R&D activities, resulting an increase in exploratory R&D investment.

Bandura (1977) considered vicarious learning as learning from indirect experience because those experiences are not owned by firms, but by other actors in their environments such as their competitors or customers (Echajari & Thomas, 2015). Borrowing from other organizations is a type of organizational learning (Eells and Nehemiks, 1984). Own knowledge oriented exploration through trial and error cannot always be considered as a viable tool because the costs attached to the errors and failures can be extremely high and trials that are available to firms can be very scarce.

Moreover, the feedback that ties exploration to its consequences is usually uncertain, lasting for a long time and being slow and ambiguous. Therefore, vicarious learning not only allows organizations to benefit from the knowledge accumulated by others but enables them enjoy the saved costs and time associated with this accumulation at the same time (Bingham & Davis, 2012). It can originate within an organization between different units, between two or more organizations that established a formal relationship (collaboration) and also in non-affiliated organizations (Mitsuhashi, 2011).

Early studies suggested that firms can obtain other actors' information through consultants, professional meetings, trade exhibitions, publications and in less competitive environments involving professionals. They supported a one-way learning process of vicarious learning, which means firms can simply learn from others through imitation (Meyer & Rowan, 1977; Zucker, 1987). Imitation enables a firm to observe others' actions, relate their actions to specific outcomes, obtain lessons from these relationships and choose best practices to transfer them internally (DiMaggio & Powell, 1983). However, some studies such as Bourgeois and Eisenhardt (1988) and Dutton and Freedman (1985) argued that imitation is too limited for organizations to learn. First, it is often not viable in highly competitive or fast-changing environments; second, it is associated with waiting and jumping into an occupied niche, so the value of the knowledge is relatively low compared with the knowledge learned through other ways (Bourgeois & Eisenhardt, 1988). Recent scholars such as Myers (2015), Dailey and Browning (2014) and Bailey and Barley (2011) stressed the value of the interaction in vicarious learning. They suggested that a person or an organization is likely to be unable to deduce the "lesson" of other entities' experience through passive observation without exchange of ideas and decision-making processes with those experience holders (Myers, 2015). Therefore, interactivity and back-and-forth discussions help firms to understand what can be learned vicariously from other's experiences (Myers, 2015). In addition, the successful knowledge transfer requires firms to enhance their absorptive capacity and build trust with the sources of knowledge, because the absorptive capacity enables firms to better assimilate and apply the knowledge and experience that are transferred from other actors (Cohen & Levinthal, 1990). Futhermore, trust can increase the amount and value of information exchanged between firms and the source of knowledge (Tsai and Ghoshal, 1998) and enhance the cooperation with the source of knowledge (Dirks & Ferrin, 2001).

3.3 Learning from Distant Knowledge

The third learning mechanism we would like to introduce is learning from distant knowledge. Learning from distant knowledge facilitates firms investing in exploratory R&D activities. Firms could learn from previous experience but different experience trajectories might result in various learning consequences (Kogut & Chang, 1991; Chang, 1995). The extent of homogeneity among the experiences might determine whether the previous experience can generate positive spillovers to the current ones (Cormier & Hagman, 1987). Therefore, learning from homogeneity knowledge can benefit exploitative learning of firms. In contrast, learning from more distant knowledge is typically in use with exploratory learning contexts.

March's (1991) model of mutual learning indicated a positive relationship between distant knowledge and exploration. Organizations accumulate knowledge in procedures, norms and rules over time. Such organizational knowledge and beliefs influence the people within the organization in various forms of cultivation, instruction and prototype (March, 1991). Slow learners of codes keep diversity for a longer period contributing to an organization's exploration that enables the knowledge found in the organizational code to enhance (March, 1991). This slow learning process encourages firms to explore possible alternatives and achieve balance in the development of specialized competences (March, 1991). Conversely, fast learners who learn rapidly from codes reduce the deviation between codes and individuals quickly and hence it is hard for the code to learn from individuals (March, 1991). It seems that fast learning processes are more likely to generate a good effect on routinization or automatic experiential learning but an adverse effect on enhancing organizational knowledge. This long-term individual enhancement shows advantages of increasing variation in organizations for innovation. An example of the implication in organizations is that firms recruit new employees with untypical skills or genders, which leads to an expectation of bringing new knowledge and as a result increases the variance relative to existing knowledge, thus contributing to firms' exploration (March, 1991). According to this idea, increasing the variation in organizations could facilitate exploration (March, 1991), whereas with less distant knowledge comes closer to exploitation.

Many studies considered this issue beyond organizational and technological boundaries. They suggested knowledge that is either technologically or geographically distant can benefit a firm's innovation (Rosenkopf & Nerkar, 2001; Henderson & Cockburn, 1994; Von Hippel, 1994). Learning from distant knowledge that is beyond a firm's technological and organizational boundaries gives the firm an opportunity to create new and innovative linkages and associations (Phene et al., 2006). However, very distant knowledge may also limit a firm's ability to understand, assimilate and integrate that knowledge and at the same time increase the costs of exploiting the potential value of distant knowledge, hence firms need to develop knowledge in that area to build upon distant knowledge (Cohen & Levinthal, 1990). As such capability-building activities take time to complete, it increases the difficulty of conducting vicarious learning in order to effectively replicate recent external innovative results (Dosi, 1988). Therefore, variation within or beyond firms contributes to firms' exploration but such positive effects might be hindered by the lack of absorptive capacity and the neglect in organizational strategies.

3.4 Search

Table 3.2 Search

	Exploration		**Exploitation**
Costs and Risks	Experiential Learning	Vicarious Learning	Experiential Learning
High	Search additional alternatives (Feldman & Kanter, 1965); multiple sources (Sidhu et al., 2004)	Search and scan environments for information about changes (Fahey et al., 1981); search more distant of knowledge (Sidhu et al., 2004)	n/a
Low	n/a	n/a	Search current alternative or search near problem symptoms (Cyert & March, 1963)

The fourth learning mechanism is the search. Searching new solutions near problem symptoms relates to firms' exploitative R&D investment, while searching innovative solutions in new experience trajectories or in environments where symptoms located relates to firms' exploratory R&D investment. As we learnt from environmental dynamism studies, a searching process allows firms to acquire and process information about alternatives and the outcomes of firms' search process determine the content of organizational change and adaptation. Scholars in environmental dynamism suggested that exploration needs inputs searched from a broader scope and more distant of knowledge (Sidhu, et al., 2004) whereas exploitation needs inputs searched from the most proximate existing knowledge trajectories (Lant & Mezias, 1992).

Search can drive a firm to conduct exploratory and exploitative activities through enhancing the firm's experiential learning. One of the most prevalent forms of organizational search is performance monitoring, a formal and routine performance assessment (Huber, 1991). During the performance monitoring, individuals in the organization realize a performance gap between what they expect (aspiration level) and what exists (March &Simon, 1958; Cyert & March, 1963). This recognized gap promotes a search process on the part of individuals in the organization that takes one of two forms of learning (exploration and exploitation) (Arthur & Aiman-Smith, 2001). Exploitative activities will be increased if firms tend to search in present alternative or in the vicinity of the problem symptoms (Cyert & March, 1963), which means firms choose to use the options that are easily available or use the experience learned from similar problems. Exploratory activities will be increased if firms abandon their current alternatives and search for new alternatives, which require firms to search knowledge from multiple sources (Feldman & Kanter, 1965; Ansoff, 1975). In this situation, there is a large distance between new knowledge and firms' immediate experience or its local environmental condition (Katila & Ahuja, 2002).

Search also can facilitate firms to conduct exploratory activities through vicarious learning. If there is a large gap between a firm and the environment in which they are located, the firm will face a threat of survival and suffer a costly transformation (Tushman & Romanelli, 1985). Being aware of this, firms often search information about changes of their environments (Fahey et al., 1981). For instance, automobile and computer companies have, for years, conducted detailed routine inspection of their competitors' products that appear in the marketplace (Eells & Nehemiks, 1984). Searching and collecting information about what others are doing and how they do these things constructs the firm's intelligence (Fuld, 1988; Gilad & Gilad, 1988). The relationship between search and exploration and exploitation has been summarized in Table 3.2.

However, searching results mainly counts on the accessibility of sources (O'Relly, 1982). There are some thresholds for searches to be undertaken by firms. The thresholds refer to comparing the consequences associated with not searching with the costs and benefits associated with searching, and also refer to a consideration on the possibilities of suffering these costs and benefits (O'Relly, 1982). Due to the increasing availability of information and communication technologies in the recent world, many studies propose knowledge is sourced through a direct and costless process (Dahlander & Gann, 2010). For instance, the Internet provides convenience for searching for knowledge from external sources through refining technology intelligence (Veugelers et al., 2010), facilitating crowdsourcing or broadcast search (Jeppesen & Lakhani, 2010) and building online communities (Dahlander & Wallin, 2006) and platforms such as blogs and virtual worlds (Droge et al., 2010; Kohler et al., 2009). Obviously, the advanced information and communication technologies have enhanced the potential and reduced the costs of searching for knowledge from external sources (Dodgson et al., 2006). However, there are still many significant costs involved in the searching process, which cannot be ignored. Stuermer et al. (2009) found that if firms rely on the knowledge from external sources, they tend to face hidden costs associated with communication and control. Integrating new knowledge into a firm's knowledge base requires changes in networks of relations and communication relationships both within and outside the firm (Henderson & Clark, 1990).

The broad search can limit the search effectiveness of firms (Jeppesen & Lakhani, 2010). As problems in developing and managing integration increases with the increase of the search scope, eventually, the costs of integrating new knowledge will become higher than its benefits (Katila & Ahuja, 2002). Moreover, the costs of control will increase because increased search scope tends to reduce a firm's reliability. The large distance between new knowledge and firms' existing experience increases the difficulty of responding to new information correctly (Katila & Ahuja, 2002). The overly positive attitude towards external sources of knowledge will increase the risk of facing costly recalls or significant delays in manufacturing (West & Bogers, 2014). Firms should launch strategies to ensure their influence and control on the innovation process when searching technologies that are maintained externally (West & Bogers, 2014). Therefore, the risk and costs of exploration through broad scope of search are higher than local search.

3.5 Through What Mechanisms Firms Learn in Each Firm-specific Factor.

This study examines firm decisions to invest in exploratory and exploitative R&D activities by analyzing some firm-specific factors: IC, EIS, R&D personnel educational level, the level of export and geographic market scope. Given the importance of learning in explaining organizational action, we adopt organizational learning theories to examine the determinants of exploratory and exploitative R&D investment model.

Organizational learning theories suggested that learning through experience generates effects on organizations' knowledge creation and transfer, stimulating organizations to change their strategies, structures and practices (Cyert & March, 1963; Levitt & March, 1988). Organizations adapt over time as a function of their experience (Cyert & March, 1992). Organizational goals and attentions adapt to an organization's past experience (Direct experience, Echajari & Thomas, 2015) and other comparable organizations' previous experience (Second-hand experience, Huber, 1991); organizations prefer to attend to some criteria of performance evaluation that normally creates satisfactory results. Levinthal and March (1993) expanded further on the organizational learning theories. They suggested that learning has a self-reinforcing nature, which means organizations are more likely to sustain current focus and participate in activities of which they are more capable with higher frequency. For example, organizations with rapid rates of turnover of decision makers often prefer local refinement rather than exploration, resulting in overinvestment in exploitation (Levinthal & March, 1993). Organizational search will change as the organization experiences success or failure with current solutions (Cyert & March, 1992). Success reduces search, while failure increases distant search (Levithal & March, 1993). Failure stimulates firms to search for new ideas and technologies (Levithal & March, 1993) and alternative solutions in an entirely new way (Cyert & March, 1992). Therefore, we argue that the investment decisions in firms' exploratory and exploitative R&D activities can be analyzed by examining factors that affect firms learning from their own and others' experiences, search rules and the distant between firms' prior and existing learning.

First, following organizational learning theory, we focus on the influence of firm external knowledge linkages: IC and EIS. Many studies found that IC facilitates efficient organizational learning and enables firms to access to externa1 knowledge that they need for innovation (Tsang, 2002; Powell, 1998). Some studies adopted an output model and found that IC results in a higher possibility of realizing innovation (Becker & Dietz, 2004) and contributes to achievement in new product development, product innovation, and process innovation (Bierly III et al., 2009; Powell, 1996; Un & Asakawa, 2015). For example, Bierly III et al. (2009) found that IC helps firms to tap into distant knowledge and this knowledge is important for developing new products and processes. They also found that the overlap between the knowledge domain of the firm and its partners is positively associated with improvement of existing products and processes. Powell (1996) argued that being a practitioner in collaboration can effectively help firms to learn valuable know-how of their partners. He suggested that learning-by-doing is a mechanism through which collaboration helps improve firm product innovation performance. Un and Assakawa (2015) showed that firms that have a close inter-organizational relationship and a small contextual knowledge distance with their partners are more likely to achieve process innovation.

Unlike these studies focused on the impact of IC on innovation output, some studies are interested in the effects of IC on firm innovation input measured by internal R&D investment. For example, Colombo (1995) studied the effect of interfirm cooperation on R&D intensity in the information technology industries. Their extensive econometric analysis of 100 international firms found evidence for a complementary relation between interfirm collaboration and firm internal R&D spending. Veugelers (1997) examined the relationship between R&D cooperation and the level of internal R&D investment using Flemish firm-level data, and found that IC stimulates firms' internal R&D, but only for firms with a full-time staffed R&D department. She also found that the more frequently these firms engaged in IC the more they spend on internal R&D (Veugelers, 1997). Using a data of 2048 firms in the German manufacturing industry, Becker and Dietz (2004) found evidence for complementary relations between R&D collaboration and firm internal resources in the innovation process. They provided estimation results both for the innovation input and output model. On the input side, they found R&D collaboration has a statistically significant and positive impact on firms' R&D intensity. On the output side, they found R&D collaboration positively stimulate the probability of realizing new product development (Becker & Dietz, 2004).

In this thesis, we focused on the input model, we investigated the relationships between the IC and firm two types of internal R&D investment: exploratory and exploitative R&D investment. It is important to consider the R&D activities as a heterogeneous construct because although both exploratory and exploitative R&D are R&D activities, they differ in several aspects, such as risk, certainty and speed of the return and competitive impact (March, 1991). Due to these differences, exploratory and exploitative R&D tend to be stimulated by different learning mechanisms. In section 3.1-4 of this chapter, we introduced the relations between learning mechanisms and exploratory and exploitative R&D. During IC, firms' exploratory R&D can be facilitated by three learning mechanisms: learning from distant knowledge (access partners' distant knowledge), vicarious learning (learning from partners' experience about collaboration markets and learning from partners' complement knowledge) and experiential learning (learning through own experience of developing new ideas with commercial use that satisfies the needs of the market) (Howard et al., 2016; Tsang, 2002). Firms' exploitative R&D during IC is however facilitated by mainly experiential learning (gaining of market and management skills that are essential for accomplishing commercialization and manufacturing). As a result, IC can increase both exploratory and exploitative R&D investments but this may not be to the same extent. There seem to be more mechanisms through which IC can impact exploratory R&D investment than exploitative R&D investment. IC's influence on learning partners' knowledge and firm's own experience of developing new ideas is of more fundamental nature and is more difficult to acquire through other channels, while gaining market and management skills can be achieved through, for example, hiring talented people. Therefore, we expect the influence of IC on exploratory R&D investment to be higher than that on exploitative R&D investment.

EIS is another important method to make external knowledge usable (Kang & Kang, 2009). EIS allows firms to find solutions to a problem by searching other actors in the embedded environment and increases the amount of information available to firms for drawing inferences. It is closely relates to firms' search strategy rather than vicarious learning or experiential learning as it does not require firms to engage in the knowledge creation process (Veugelers & Cassiman, 1999). For example, IC allows firms to have access to non-marketable resources by deep interaction with partners, which cannot be realized in the form of EIS (Granovetter, 1973; Hansen, 1999). Given the IC and EIS induce different learning mechanisms, they tend to have distinct effect on firms' exploratory and exploitative R&D investment. However, prior studies investigate the influence of external knowledge on R&D investment without considering different impacts of various external knowledge linkages. They have not considered that the influence of external knowledge on exploratory and exploitative R&D investment can vary with different external knowledge linkages: IC and EIS. Therefore, it is necessary to study different effects of IC and EIS on exploratory and exploitative R&D investment.

Moreover, existing studies mainly focused on investigating the influence of EIS on firm innovation. For example, Kang and Kang (2009) found that information transfer from informal networks has a positive effect on firm technological innovation performance. Veugelers and Cassiman (2006) also offered evidence of complementarity between external information sourcing and innovation. They found various information sources tend to enhance firm innovation performance. Mention and Asikainen (2012) demonstrated EIS shapes firm R&D investment and influence innovation output. However, there is not much study investigating the influence of EIS on R&D investment and of these studies, they mainly considered the R&D as a homogenous construct. For example, Masso and Vather (2008) demonstrated sourcing information from suppliers increases firm R&D investment. As we introduced in section 3.4, firms can search alternative solutions near problem symptoms or scan environment for distant solutions. We suggest that if external actors' specialized knowledge and skills are in the same technological field as the firm, firm can use the others' information to improve their existing solutions. While if external actors' specialized information is not related to firms' existing knowledge domains, it tends to substitute firms' internal exploratory investment because external solutions can help firms to avoid the costs and risk of developing solutions in new scientific areas (Rosenkopf & Nerkar, 2001). As a result, searching solutions from external environment tends to positively influence firms' internal investment in exploitative activities but negatively influence firms' internal investment in exploratory activities. Since current studies ignore such differences, it would be necessary to study the effect of EIS on exploratory and exploitative R&D investment.

The third firm-specific factor we focus on is the educational level of firm R&D personnel. Education is often found to be positively related to firms' attitude towards innovation (Coronado et al., 2008; McGuirk et al., 2015). Some studies considered R&D investment as a crucial input to innovation activity (Griliches, 1990). They investigated the effect of educational level on firm R&D investment. However, most of them focused on the top management team. For example, Lynskey (2016) found the higher education of the entrepreneur has a significantly positive relationship with R&D investment because education enables entrepreneurs to be more receptive to new knowledge and more open to new experience (Lynskey, 2016). As a result, education facilitates firms learning from distant knowledge. As we introduced in section 3.3, learning from distant knowledge contributes to firms' exploratory R&D activities but not exploitative R&D activities. Therefore, highly-educated (university education) R&D personnel tend to facilitate firms' investment in exploratory activities but not exploitative R&D activities.

Moreover, previous studies have not paid much attention on the influence of non-university degree. According to organizational learning theory, educational level plays a critical role in forming of preferences of individuals because it makes individuals consider different things as important and has different attitudes toward new knowledge (Cyert & March, 1992). Researchers with non-university degree tend to have different preferences on exploratory and exploitative R&D investment compared with researchers with higher education. For example, the main objective of non-university degrees such as technical architects and specific professional training aims at teaching students specialized knowledge in a specific domain. This encourages students to adopt experience from previous innovation projects to solve problems (Lin & Sanders, 2017). Therefore, researchers with non-university degree may be more likely to facilitate experiential learning of firms, resulting in an increase in exploitative R&D investment. While researchers with non-doctorate university degree tends to facilitate vicarious learning of firms, resulting in an increase in exploratory R&D investment due to the teamwork skills they have learnt at university (Grant, 1996). In this study, we investigate the impact of different educational levels of R&D personnel on exploratory and exploitative R&D investment. It is important to focus on R&D personnel because they are the people who work on firm R&D activities on a daily basis (Sauermann & Cohen, 2010). These R&D researchers create knowledge and insight shaping important inputs to the innovation process (Lundvall & Johnson, 1994). By focusing on them, it can help researchers to better understand firms' internal R&D investment strategies.

Knowledge and learning is generated in the internationalization of firms such as knowledge spillover in export markets (Coe & Helpman, 1995) as well as diverse market information and unique technologies in a broader geographic market (Geletkanycz & Hambrick, 1997). International expansion stimulates the experiential learning and searching. The experiential learning and distant search happens within the firm contribution to developing knowledge along existing trajectory and knowledge along an entirely new trajectory (Casillas & Moreno-Menendez, 2014; Belderbos et al., 2011). Therefore, internationalization tends to directly influence firms' efforts to invest in exploratory and exploitative R&D activities.

Learning-by-exporting literature mainly examines the influence of exporting on productivity (Bai et al., 2017) and innovation (Love and Ganotakis, 2013). They suggested that firms gain better performance through exporting activities because of export's facilitating role in learning, e.g. improving production knowledge through experiential learning (Klepper, 1996). We contribute to this literature by reviewing the influence of the exporting on a firm's investment in exploratory and exploitative R&D activities. The literature of geographic scope suggests that firms with business in a broader geographic scope tend to experience the benefits of learning and flexibility (Goerzen & Beamish, 2003). These firms are very likely to learn from distant experience because the broader geographic scope allows them to discover a richer pool of technologies and access more valuable reference groups (Kim et al., 2015; Mol & Birkinshaw, 2009). In researching geographic scope and learning, most of the extant empirical studies captured the learning effects by using firms' performance (Wiersema & Bowen, 2011; Delios & Beamish, 1999). Our study makes an effort to understand the relations between geographic scope and learning by demonstrating that geographic scope influences a firm's investment in exploratory and exploitative R&D activities.

The purpose of this study is to examine the influence of firms-specific factors: IC, EIS, R&D personnel educational level and internationalization statuses on exploratory and exploitative R&D investment, which is considered as an important input measure of exploratory and exploitative R&D and an impetus to innovation (D'Este et al., 2017). Prior studies mainly pay attention to output model and examined the determinants of innovation output (Un & Asakawa, 2015; Kang & Kang, 2009). This is surprising, because exploratory and exploitative R&D are the most crucial inputs for innovation and are important drivers of competitive advantages (Banker et al., 2008). They may determine the extent to which firms capture the benefits from these firm-specific factors. Exploratory and exploitative R&D investment helps us to understand a firm's effort expended to experiment and manufacture new products and services.

According to organizational learning theory, we introduce four learning mechanisms through which these firm-specific factors affect firms' investment in exploratory and exploitative R&D activities. First, vicarious learning allows firms to learn from partners' knowledge, which increases the variation of firms' knowledge and hence stimulates firms' exploratory R&D investment. Second, experiential learning facilitates firms in finding new solutions by either refining routines or replacing existing routines, and hence it can generate effects on both firms' exploratory and exploitative R&D investment. Third, learning from distant knowledge facilitates firms in obtaining new experiences that are distant from their current experience trajectories. This stimulates firms' exploratory R&D investment. Fourth, searching can either occur near problem symptoms or in environments where symptoms are located, and so can relate to both firms' exploratory and exploitative R&D investment. In this thesis, we provide a new explanation for the determinants of exploratory and exploitative R&D investment by emphasizing learning mechanisms to explain firms' learning that is generated by different firm-specific factors. The following figure 3.1 shows the output and input model of innovation research. It helps us to position our work in current research of innovation. Figure 3.2 summarized how learning mechanisms work and affect my theorization.

Figure 3.1 The output and input model of innovation research

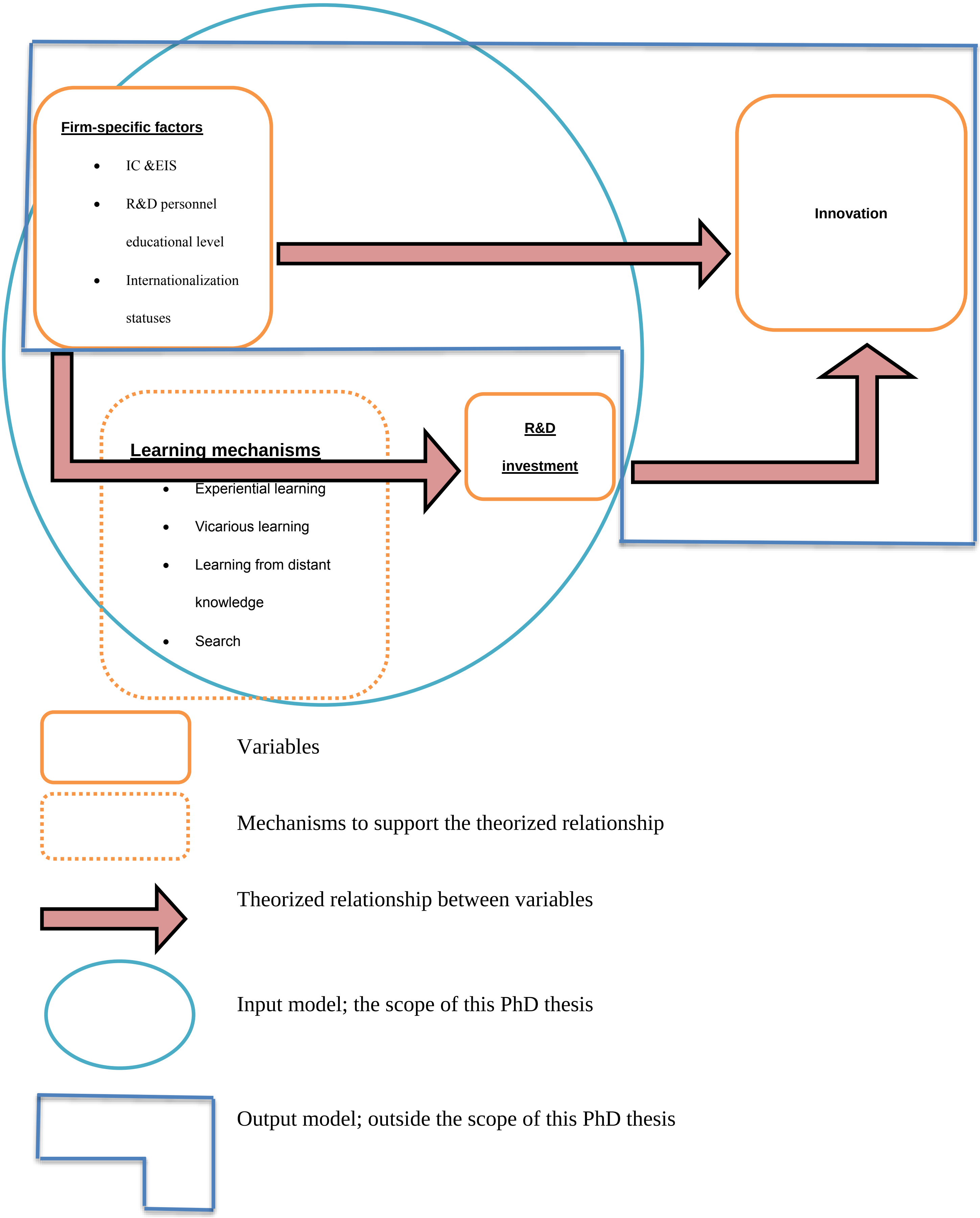
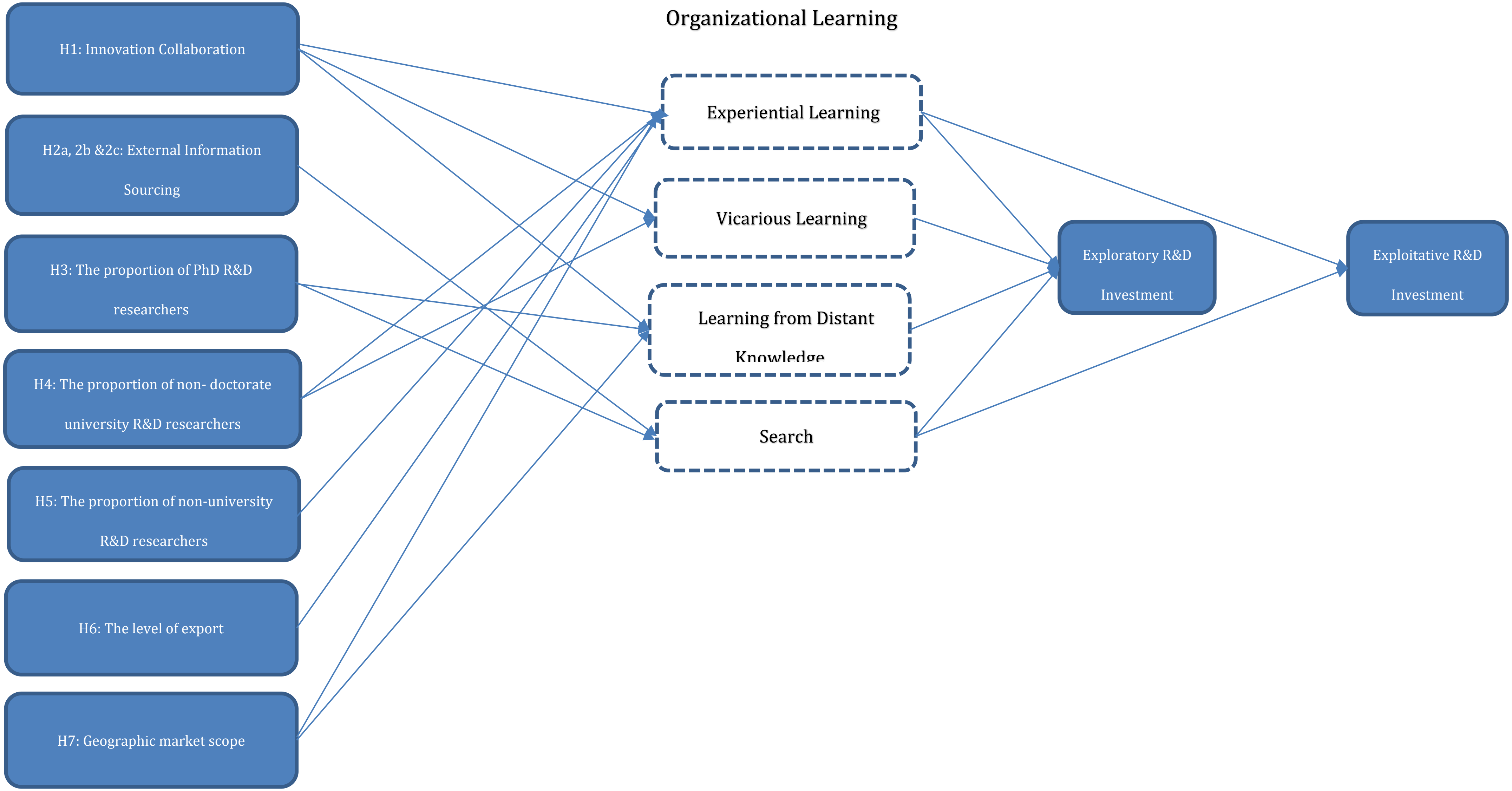


Figure 3.2 Through which mechanisms firms learn in each firm-specific factor



Chapter 4 Methodology

4.1 Data

In order to answer the central research question that is concerned with the effect of firm-specific factors on firms' decision to invest in exploratory and exploitative R&D activities, we need datasets that contain firm level information about their internal spending on exploration (basic and applied research) and exploitation (technological development), information on the firms' innovation projects and associated information sourcing and collaboration details, the educational levels of firms' internal R&D researchers and the level of exporting and the geographic market scope. The datasets should also cover a substantial period of time of the firms' operations and include firms from a variety of industries. The Technological Innovation Panel (PITEC) fulfill these requirements and is considered an ideal instrument for statistical analyses of the technological activities of firms (Barge-Gil and Lopez, 2014). The database is co-developed by the National Statistics Institute (INE), the Foundation for Technical Innovation (COTEC) and the Spanish Foundation for Science and Technology (FECYT). PITEC is publicly available. It can be accessed by filling out required form on the FECYT web site. PITEC is a Community Innovation Survey (CIS)-type, firm-level panel database (D'Este et al., 2017). The core part of PITEC adopts the CIS, a standardized survey organized by Eurostat and Organization for Economic Cooperation and Development (OECD) based on the guidelines in Oslo Manual (OECD, 2005). The PITEC data is specifically suited for this study as it contains information on firm-specific determinants of innovation activities such as the sources of information for technological innovation and the partners of technological innovation cooperation, internal R&D researchers' educational qualifications, export levels, the firm's geographic market scope, possible membership of a group, number of employees, and industry sectors they belong to (Mairesse & Mohnen, 2010; Martinez et al., 2017).

In addition, there are three major benefits of using PITEC for this study. Firstly, unlike other CIS-type datasets (which are carried out at two-year intervals), the PITEC is carried out yearly and designed as a panel data survey. The PITEC provides data for a panel of about 12000 firms with more than 460 variables since 2003, allowing us to track a firm's innovation activities and strategies over time. Tracking of the same firm over time and on an annual basis improves the quality and reliability of observations (FECYT, 2018). Moreover, because panel data allows us to observe changes over time (e.g. the changes of R&D spending), such data structure enables the analysis of the heterogeneity in the firms' decisions.

Secondly, this database contains detailed information about firms' R&D activities. Specifically, it allows the differentiation between exploratory and exploitative characteristics of a firm's internal R&D expenditures. A breakdown of firm's internal expenditures by exploration and exploitation activities is seldom available (Barge-Gil and Lopez, 2014) -this partly explains the lack of studies of firms' internal expending on different R&D activities, but is essential to this doctoral research. PITEC therefore offers an important dimension of R&D data to the traditional measures of exploration and exploitation using binary variables (Blindenbach-Driessen & van den Ende, 2014), point scale measures (He & Wong, 2004; Bierly III & Daly, 2007), or ratios based on turnover (Laursen & Salter, 2006).

Thirdly, the PITEC is a CIS-type database (D'Este et al., 2017; Barge-Gil and Lopez, 2014) and therefore allows findings to be compared with other studies using CIS data which is being used increasingly by economists and policy observers to carry out many innovation related studies (Cassiman and Veugelers, 2002; Laursen and Salter, 2006; Czarnitzki and Toole, 2011) (for a review of CIS survey, see Mairesse and Mohnen, 2010). Moreover, since PITEC has open-access policy, findings can be also compared among studies using PITEC (e.g., see a list of PITEC-based publications at: (https://services.icono.fecyt.es/PITEC/Paginas/descarga_bbdd.aspx).

The dataset comes from one country, Spain. Spain is a developed economy where firms benefit from mature institutional conditions and are actively engaging with innovation. However, compared to with other European economies, Spain has a relatively lower R&D investment to GDP. In 2016, the investment in R&D was only 1.22% of GDP, versus an EU average of more than 2% (SGI, 2017). The PITEC survey has specifically classified internal R&D researchers in terms of education and skills, and more importantly included questions on firms' detailed investment in different R&D activities. These are significant advantages of the PITEC database over standard CIS survey data (Martinez et al., 2017). It is expected that focusing on firms' R&D investment in a country environment where R&D spending is relatively low, this study is conducting a hard test of the firm-specific determinants of exploratory and exploitative R&D investment. The findings using this database are expected to add value not only academically but also practically to firms operating within an EU country or across Europe. It also helps the government to design a better research and innovation policy to facilitate Spanish firms' R&D spending. A further benefit of using data from one country is that it controls country-level social and macroeconomic changes while allowing for the analysis to focus on firm-level (and industry level) effects.

4.2 Sample Selection and Statistical Descriptions

Using information from nine PITEC annual survey for the period 2003-2011, we have a large sample of firms to start with and this enables us to carry out rigorous sample selection.

First, because our research questions are concerned with how firms actively commit internal investments to different types of R&D activities, we first exclude observations that report incorrect information on current internal R&D investment and also control variables (e.g., negative values because of accounting reasons or missing observations) and report 0 value on their current internal R&D investment. This step leaves us with only firms that reported positive expenditures in current internal R&D activities. In other words, we restrict analysis just to firm with current internal R&D activities.

Second, because we are interested in the internal expenditure on different types of R&D, we next filter the sample by examining their reporting of the different internal R&D activities. The survey requires firms to breakdown their current internal R&D investment into basic research, applied research, and technological development by percentage, and therefore the sum of these three types of research should be always 100%. Excluding those who reported the percentages incorrectly (i.e., those do not add up to 100%), this step leaves us with R&D active firms that have correctly reported their different types of research activities.

Thirdly, because our hypotheses rely on a number of constructs (such as collaboration partners, information sources, R&D researchers' qualification, export and geographic market scope) and we have excluded observations when a firm did not report data of these constructs in a particular year, resulting in an unbalanced panel data. In particular, the question content about export has changed since 2006[4], consequently we cannot compare the answers of the earlier surveys to the later ones, and therefore only the later survey data are used (2006-2011). Fourthly, we further excluded the year of observation that did not have data of the control variables we require for the estimation.

Table 4.1 summarizes key statistics of variables from the initial sample and the final sample.

Table 4.1 Key statistics of variables from the initial sample and the final sample.

Variable	Observations		Mean		Std. Dev.		Min		Max	
	Initial Sample	Final Sample	Initial Sample	Final Sample	Initial Sample	Final Sample	Initial Sample	Final Sample	Initial Sample	Final Sample
Exploitative R&D investment	95392	13388	4.760	10.074	6.095	5.448	0	0	20.384	20.384
Exploratory R&D investment	115452	13388	3.477	8.729	5.605	6.056	0	0	19.172	19.103
Internal R&D researchers with PhD qualification in FTE	92094	13388	1.986	3.801	8.713	10.740	0	0	100	100
Internal R&D researchers with non-doctorate university qualification in FTE	92094	13388	12.457	22.42	22.335	24.018	0	0	100	100
Internal R&D researchers with non-university qualification	92094	13388	4.280	7.532	14.277	17.609	0	0	100	100
Firm size	95392	13388	0.500	0.635	0.500	0.481	0	0	1	1
Membership of a group of companies	95306	13388	0.391	0.490	0.488	0.500	0	0	1	1
Collaborate with other companies of its own group	71996	13388	0.096	0.185	0.295	0.389	0	0	1	1
The importance of information source: within company or group	65882	13388	1.687	1.362	0.951	0.628	1	1	4	4
Collaborate with external partners	71996	13388	0.833	1.533	1.519	2.016	0	0	7	7
External information sourcing	65882	13388	2.953	2.631	0.674	0.600	1	1	4	4
Make-to-buy (product): The degree of external sourcing in product innovation	43927	13388	1.232	1.202	0.508	0.439	1	1	3	3
Make-to-buy (process): The degree of external sourcing in process innovation	45568	13388	1.379	1.283	0.667	0.540	1	1	3	3
Firm age	96664	13388	3.539	3.802	0.829	0.739	0	0	6.998	6.426
Number of employees	95392	13388	4.879	5.210	1.698	1.554	0	0.88	11.327	11.327
Public company	95392	13388	0.021	0.018	0.143	0.132	0	0	1	1
Private national company	95392	13388	0.837	0.788	0.369	0.409	0	0	1	1
Private multinational company	95392	13388	0.130	0.173	0.336	0.378	0	0	1	1
Research association and other research institutions	95392	13388	0.012	0.021	0.110	0.145	0	0	1	1
The level of exporting	65963	13388	0.993	1.644	1.570	1.766	0	0	5.298	5.298
Geographic market scope	88154	13388	0.976	1.425	0.906	0.799	0	0	2	2

Note: Exploitative R&D investment, Exploratory R&D investment, firm age, number of employees and the level of export are all in logged form.

[4] The question about export on questionnaire year 2003, year 2004 and year 2005 is: From turnover, indicate the total exports. The Question about export on questionnaire year 2006, year 2007, year 2008, year 2009, year 2010 and year 2011 is: From turnover, indicate the total exports (do not include intra-community deliveries, that is, EFTA countries or EU candidate countries).

The final sample thus contains data of 4,105 firms from 2006 to 2011, resulting in an unbalanced panel of 13,388 observations. These companies belong to 14 industrial classification groups, including agriculture (152), extractive (39), manufacturing (6976), recycling (54), production and distribution of electricity, gas and water (85), construction (418), transport (296), wholesale and retail trading (1902), financial (246), real estate activities (64), social service (1063), education, film and radio (524), scientific research (1532) and others (37).

Table 4.2 provides the correlations of variables. As showed in the analysis of the correlation matrix and the VIF scores (all VIF values are less than 10), there is no issue of multicollinearity within this random GLS regression models (Hair et al., 1995). Although there is a high correlation (-0.88) between the private national company variable and private multinational company variable, the VIF values of these two variables are less than 10. The private national company variable has a VIF value of 8.75 and the private multinational company variable has a VIF value of 8.65. Although there is a relatively high correlation (0.64) between the level of export and geographic market scope, the VIF values of these two variables are around 2 in both exploration and exploitation model. Moreover, the correlation between the number of employees and firm size is 0.68. However, they also have very low VIF values in both exploration and exploitation model.

Table 4.2 Correlations

Variables	1	2	3	4	5	6	7	8	9	10	11
1.Exploitative R&D investment											
2.Exploratory R&D investment	-0.32***										
3. Internal R&D researchers with PhD qualification in FTE	-0.03**	0.14***									
4. Internal R&D researchers with non-doctorate university qualification in FTE	0.01	0.09***	-0.09***								
5. Internal R&D researchers with non-university qualifications in FTE	-0.00	-0.07***	-0.11***	-0.17***							
6. Firm size	0.10***	0.08***	-0.06***	-0.04***	-0.09***						
7. Membership of a group of companies	0.14***	0.07***	-0.00	0.01	-0.07***	0.46***					
8. Collaborate with other companies of its own group	0.15***	0.10***	0.02*	0.04***	-0.03**	0.23***	0.49***				
9. Importance of information source: within firm or group	-0.08***	-0.05***	-0.01	-0.03***	0.01	-0.06***	-0.09***	-0.11***			
10. Collaborate with external firms	0.21***	0.20***	0.09***	0.09***	-0.06***	0.10***	0.15***	0.44***	-0.08***		
11. External information sourcing	-0.14***	-0.18***	-0.11***	-0.07***	0.07***	-0.07***	-0.08***	-0.18***	0.12***	-0.43***	
12. Make-to-buy (product): The degree of external sourcing in product innovation	0.01	0.01	-0.00	-0.01	-0.05***	0.00	-0.02*	0.07***	0.05***	0.27***	-0.11***
13. Make-to-buy (process): The degree of external sourcing in process innovation	0.03***	-0.00	-0.00	0.00	-0.02**	0.01	-0.03**	0.08***	0.06***	0.25***	-0.10***
14. Firm age	-0.01	0.07***	-0.07***	-0.06***	-0.02**	0.36***	0.14***	0.07***	0.00	-0.00	0.00
15.Number of employees	0.20***	0.14***	-0.06***	-0.03***	-0.08***	0.68***	0.51***	0.33***	-0.09***	0.22***	-0.12***
16. Public company	0.00	0.03**	0.00	0.01	-0.04***	0.03**	-0.03**	0.01	0.02*	0.10***	-0.04***
17. Private national company	-0.07***	-0.11***	-0.06***	-0.04***	0.04***	-0.22***	-0.31***	-0.20***	0.05***	-0.14***	0.05***
18. Private multinational company	0.05***	0.06***	0.04***	0.01	-0.02**	0.27***	0.39***	0.23***	-0.05***	0.04***	0.02**
19. Research association and other research institutions	0.05***	0.12***	0.07***	0.08***	-0.02*	-0.12***	-0.12***	-0.05***	-0.02**	0.21***	-0.16***
20. The level of export	0.06***	0.05***	0.00	-0.00	-0.01	0.20***	0.09***	0.04***	-0.04***	0.03**	-0.03***
21. Geographic market scope	0.06***	0.08***	-0.02*	-0.02*	-0.01	0.27***	0.14***	0.07***	-0.06***	0.03**	-0.05***

Variables	12	13	14	15	16	17	18	19	20
13	0.38***								
14	-0.01	0.01							
15	0.05***	0.04***	0.39***						
16	0.12***	0.04***	0.00	0.12***					
17	-0.03**	0.01	-0.06***	-0.31***	-0.26***				
18	-0.04***	-0.05***	0.10***	0.30***	-0.06***	-0.88***			
19	0.07***	0.06***	-0.09***	-0.04***	-0.02*	-0.29***	-0.07***		
20	-0.04***	-0.02*	0.19***	0.09***	-0.08***	-0.02**	0.09***	-0.09***	
21	-0.06***	-0.03**	0.25***	0.18***	-0.12***	-0.06***	0.15***	-0.09***	0.64***

N= 13388 observation. Significant Levels: + $p<0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

4.3 Measures

4.3.1 Dependent variables

Exploratory R&D investment and *Exploitative R&D investment* are the dependent variables of this study. As mentioned in Chapter 2, R&D is not a homogenous activity (D'Este et al., 2017; Barge-Gil and Lopez, 2014; Czarnitzki et al., 2010). Following the discussion in Section 2.2, we draw on the features of exploration and exploitation introduced in March (1991), and the standard definitions of different R&D activities (basic, applied and technological development) (OECD, 1970), and established that exploration investment can be assessed based on companies' investment in basic and applied research, whereas exploitation investment is better to be assessed based on companies' investment in technological development, this is also in line with D'Este et al.(2017). Basic and applied research (experimental or theoretical work aimed at obtaining completely new and original knowledge) (OECD, 2002) involves uncertainty and longer time horizons, which obviously contains a nature of exploration since it is about searching of new possibilities (March, 1991). In contrast, the technological development of R&D is closely related to exploitation of old certainties as the research is based on using existing knowledge that is obtained from the science experimentation or from practical experience (D'Este et al., 2017). The outcomes of it are more predictable and required shorter time horizons, which are clearly exploitative in nature (March, 1991). The PITEC data allows us to make a distribution of companies' current expenditure on internal R&D activities in the year that survey was executed, by three types of research, which is, basic research, applied research and technological development. Based on these definitions, the exploratory R&D in this research is obtained by firms' investment in basic and applied research.

While, the exploitative R&D is obtained by firm's investment in technological development.

As the sum of these three types of research is always 100%, basic and applied research expenditure as an indication of the exploration investment is calculated by total current internal expenditure (CIE) on R&D multiplied by the sum of the ratio of basic research and applied research to CIE on R&D. Technological development expenditure as an indication of the exploitation investment is calculated by total amount of CIE on R&D multiply the ratio of technological development to CIE on R&D. The formula is as follows:

$$Exploratory\ R\&D\ Investment = Total\ current\ internal\ R\&D\ expenditure * \frac{Basic\ research + Applied\ research}{Total\ current\ internal\ R\&D\ expenditure}$$

$$Exploitative\ R\&D\ Investment = Total\ current\ internal\ R\&D\ expenditure * \frac{Technological\ development}{Total\ current\ internal\ R\&D\ expenditure}$$

Given that the two dependent variables are measured by the amount of expenditures in Euros (Tognazzo et al., 2013) and contain zero values (Burbidge et al., 1988), it is necessary to log them in the regression models by using an inverse hyperbolic sine transformation (IHS). The IHS that we employed in the regression model "can be interpreted in the same way as a standard logarithmic variable but unlike a log variable, the IHS is also defined at zero." (Di Cintio et al., 2017, p.841).

4.3.2 Independent variables

We developed one hypothesis for the direct effect of innovation collaboration on firms' exploratory and exploitative R&D investment. One variable *Innovation collaboration with external partners* was introduced to test this hypothesis. Like other CIS-type surveys, survey questions on cooperation partners and information sources for technological innovation capture a firm's activities during the past 3 years. For example, "Indicate the type of partner you cooperated with during 2008-2010" (PITEC Survey, 2010, p.11). Innovation collaboration with external partners in this thesis is measured by number of types of external partners that a firm cooperated with for technological innovation activities in a 3-year period. Cooperation in innovation activities or more specifically in R&D is often addressed by firms with strong needs of knowledge, risk and costs sharing and aims at benefiting from partners' complementarities (Kleinknecht & Reignen, 1992; Lopez, 2008). Many researchers found that cooperating firms tend to increase their investment in R&D (Kaiser, 2002; Miotti and Sachwald, 2003; Belderbos et al., 2004a). PITEC has information on innovation cooperation with different partners. There are seven different types of cooperation partners, including (1) customers, (2) equipment suppliers, (3) competitors, (4) consulting firms, (5) commercial labs/ R&D companies (6) universities or (7) public research bodies, in PITEC survey. Each type of partners has equal value. A company gets a 0 when it did not cooperate with any type of partners, while the company gets the value of 7, when it cooperated with all types of external partners.

We developed one hypothesis for the direct effect of external information sourcing on firms' exploratory R&D investment. We introduce *External information sourcing* to test this hypothesis. It is measured by the average importance of information extracted from all external sources for firms' technological innovation. This measure relies on following survey question "During 2008-2010, how important was for this business' innovation activities the information from following sources?" (PITEC Survey, 2010, p.11). The PITEC has 10 external sources of information for innovation including (1) equipment suppliers; (2) customers (3) competitors (4) consultants, private labs or institutes (5) universities (6) public research bodies (7) technology centres (8) conferences, fairs, expos (9) scientific journals, technical publications (10) professional and industrial associations. As a starting point, respondents indicated on a 4-point scale how important for the company's innovation activities was the information from the type of source (e.g. customers) in a 3-year period. In this case, 4 as the highest value means high level of importance of the type of source and 1 as the lowest value means non-use of that type of source. Subsequently, we added up sources so that a company gets the score of 40 when all external information sources are highly important for its innovation activities, while the company gets the value of 10 when no external information sources are used in its innovation activities. The measure indicates the average importance of all external sources for a company's innovation activities. Therefore, it is calculated by the sum of a company's scores on all types of external information sources divided by ten, and for each company, the results spread from 1 to 4 (not used, reduced, intermediate, high importance). For example, a company gets the value 4 when the average importance of all external sources for a company's innovation activities is high, while gets the value 1 when the company does not use any external sources for its innovation activities.

Education specifically has an impact on transformation of knowledge, which is about building new routines, leading to an increase in exploratory R&D investment once the new knowledge is assimilated and diffused in the company (Hurtado-Ayala &

Gonzalez-Campo, 2015). To test hypotheses about the influence of internal R&D researchers' educational level on firms' exploratory and exploitative R&D investment, we include three levels of educational qualification. This is in line with the research of Hurtado-Ayala and Gonzalez-Campo (2015), which separates education levels into PhD level, degree level or below. The dataset adopted in this study provides information on the educational qualification of internal R&D researchers of firms is as follows:

Internal R&D researchers with doctorate qualification in full-time employees (FTE) is measured by the ratio of internal R&D researchers with doctorate in FTE to R&D staff (Dahlander et al., 2016). It is reasonable to separate PhDs from other educational degrees because they can bring an indirect influence on firms' R&D investment (Lynskey, 2016). For example, PhDs researchers facilitate social networks that may allow firms to overcome barriers in detecting technological opportunities outside the firm (Herrera & Nieto, 2013; Lynskey, 2016).

Internal R&D researchers with non-doctorate university qualification in FTE is measured by the ratio of internal R&D researchers with degree in FTE to R&D staff. Non-doctorate university qualification focuses on developing individual's collective learning ability, which helps to facilitate knowledge integration within an organization (Lin & Sanders, 2017).

Internal R&D researchers with non-university qualification in FTE is measured by the ratio of internal R&D researchers with other qualifications in FTE (internal full-time R&D researchers with diploma and high school diploma, advanced and intermediate vocational training qualification) to R&D staff. Hofheinz (2009) suggested that employees with secondary or equivalent education have a lower level of skills than employees with tertiary education. Moreover, as employees with lower educational qualifications tend to lack management capabilities, they are less willing to change than employees with higher educational qualifications (McGuirk et al., 2015).

To test hypotheses about the influence of firm internationalization on firms' exploratory and exploitative R&D investment, we include two variables *The level of exporting* and *Geographic market scope*. *The level of exporting* is calculated as the logarithm of the proportion of firm turnover that was derived from export sales by using IHS, since the results of Skewness/Kurtosis tests showed that the distribution of the level of exporting is highly and positively skewed (Mol & Birkinshaw, 2009; Girma & Hanley, 2008). There was a change in content of the question about firm export level. Since the questionnaire in year 2006, the question about export is specified that intra-community deliveries should not be included as exports. In order to ensure consistency, in this study, we only adopt the data from 2006 to 2011. We do not consider EU countries, EFTA or EU candidate countries as export markets.

Geographic market scope is a single-item that defines the firm's extent of internationalization (Delios & Beamish, 1999). The value of 2 means a firm sells goods or service in other EU countries, EFTA or EU candidate countries and all remaining foreign markets; the value of 1 means a firm sell goods or service in other EU countries, EFTA or countries or all remaining foreign markets; and the lowest value of 0 means a firm does not sell goods or service in the international markets (2=enter markets of other EU and EFTA countries and all remaining countries; 1= enter markets of other EU and EFTA countries or all remaining countries; 0= no international market). Due to data constraints, at this stage of this study, we are unable to account for the number of foreign countries that the firm enters. We consider it as a limitation of this study and have a detailed discussion of it in the limitation section of Chapter 7.

4.3.3 Moderators

We developed two hypotheses for the influence of a firm's make-to-buy orientation on the relationship between external information sourcing and exploitative R&D investment. Firm's make-to-buy orientation is captured empirically by examining a firm's objectives of engaging in internal innovation and whether the firm relies mainly on itself to conduct product/process innovation or on joint effort with the externals or on the market through external business organizations.

Make-to-Buy (product): The degree of external sourcing in product innovation is a measure that takes the value 1 (=make or conduct product innovation all by the firm itself); 2 (=conduct product innovation by a joint effort between the firm and external organizations); or 3 (=conduct product innovation by external organizations only). This moderator captures the changing tendency of a firm from "make" to "buy" on product innovation activities.

Make-to-Buy (process): The degree of external sourcing in process innovation is a measure that takes the value 1 (=make or conduct process innovation all by the firm itself); 2 (=conduct process innovation by a joint effort between the firm and external organizations); or 3 (=conduct process innovation by external organizations only). This moderator captures the changing tendency of a firm from "make" to "buy" on process innovation activities.

4.4.4 Control variables

We control for firm age and size as they have been found to influence the company's exploratory and exploitative R&D investment (Bierly III & Daly, 2007; Beckman, et al., 2004). For instance, exploration and exploitation investment might benefit from economies of scale and scope of firms (Escribano et al., 2009), and also firms' experience in conducting exploration and exploitation (Jansen et al., 2006). Some empirical studies found the negative influence of firm age on exploration, whereas others found a positive effect. For example, Sorensen and Stuart (2000) found that older firms prefer to invest in development of existing knowledge because age increases the reliability of existing routines and the rigidity of communication patterns of firms. They also found that younger firms tend to be more flexible and have a stronger incentive to invest in development of new and potentially influential domains of technology to upstart organizations. Hanna and Freeman (1984) found that older companies are more likely to invest in exploration due to the well-established partner network and rich experience in development of new technology products. To control for these effects, this study applies a *Firm age* measure that is calculated by using the year the survey was executed in minus the year the company was founded (Jansen et al., 2006). According to the prior studies, we opt for IHS for firm age (Eshima & Anderson, 2017).

We control for *Firm size* since prior studies based on CIS-type data illustrated the effect of size on firm's R&D investment propensities in terms of exploration and exploitation (Bierly III & Daly, 2007). Small firms tend to focus on exploitation because they prefer to develop competitive advantage through increasing the flexibility of production (Fiegenbaum & Karnani, 1991) and enhancing the performance of price and quality (Cooper et al., 1986). On the other hand, larger firms have more slack resources for exploratory and exploitative R&D activities (Bierly III & Daly, 2007; Damanpour, 1996). To ensure that the results are not influenced by size we include a dummy variable taking the value 1 when the firm's turnover is higher than the value of average turnovers of the sampled companies in the year where the survey was executed, and 0 otherwise (Kafouros & Wang, 2015).

Prior studies based on CIS-type data indicated that the tendency to develop new knowledge increases with number of employees (Blindenbach-Driessen & van den Ende, 2014; Bodas Freitas & Tunzelmann, 2013; Laursen &Salter, 2006). To control for this influence, we include a variable *Number of employees*. The number of employees is defined as the logarithm of total number of employees (including paid and unpaid employees) in the firm by using IHS (Astebro & Tag, 2015).

Some of the firms participating in the PITEC survey are part of an enterprise group. This may influence firms' R&D investment because these firms can get financial and also technological support from their enterprise group. To account for this a variable *Membership of a group of companies* is included to provide information on whether or not the company is part of an enterprise group (Blindenbach-Driessen & van den Ende, 2014; Leiponen, 2008). It takes the value of 1 when the company indicates that it belongs to an enterprise group.

Moreover, we control the firm type. In the PITEC survey, firms are asked to indicate the type of their company. The question has four answer options: (a) *public company*, (b) *private national company*, (c) *private multinational company* or (d) *research association and other research institutions*. Public companies may have short-termist behaviour because they are often under pressure of shareholders who emphasize short-term returns (EY Poland Report, 2017). As the return from exploration is uncertain and has longer time horizons (March, 1991), we can contend that public companies tend to "invest in exploration only when they have no alternative e.g. technology exhaustion in their existing portfolio of R&D activities" (Mudambi & Swift, 2014, p.129). Private multinational companies usually are large companies with richer resources than private national companies. For example, they may have more financial slack and more professional and skilled R&D personnel for innovation projects that tends to encourage firms to search for more distant knowledge (Dewar and Dutton, 1986; Damanpour et al., 1996). Research institutions tend to have a propensity to invest in basic research (Todtling et al., 2009). To account for this, four dummy variables are included to indicate the firm type.

Firms can obtain information and knowledge for innovation activities through their interaction with internal actors (Tamayo & Huergo, 2017). To account for firms' internal interaction for innovation activities, we include two variables, measured in a 3-year period. *Collaborate with other companies of its own group* is a dummy variable and provides information on whether or not the firm collaborated with other companies of its own group for technological innovation activities during the past three years. It takes the value 1 when the firm has the technological innovation collaboration with other companies of its own group. *The importance of information source: within company or group* provides information on level of importance of internal information source for the firm's technological innovation (not used, reduced, intermediate, high importance) during the past three years. The lowest value of 1 means the internal information source is not used for the firm's innovation activities and the highest value of 4 means the internal information source is highly important for innovation activities of the firm.

Industries differ in technological opportunities, appropirability regimes and technology life cycle, which all can generate an effect on the company's R&D

investment (Faems et al., 2005; Laursen & Salter, 2006; Veugelers, 1997). Given the significant impact *Industry dummies* often achieve, we include them in our model. Market conditions and the general economic environment such as economic recession or boom, can vary over time, making firms correspondingly change their R&D investment in exploration and exploitation (Katila & Ahuja, 2002). Therefore, we use *Year dummies* to control such period effects. The variable description has been summarized in the Table 4.2.

Table 4.3 Variable description

Dependent Variables	**Measure**	***Reference***
Exploratory R&D investment	The logarithm of firms' current internal expenses on basic and applied research activities.	D'Este et al. (2017)
Exploitative R&D investment	The logarithm of firms' current internal expenses on technological development activities	D'Este et al. (2017)
Independent Variables		
Geographic market scope	A single-item defines the firm's extend of internationalization. (0= no international market; 1= enter markets of other EU and EFTA countries or all remaining countries 2= enter markets of other EU and EFTA countries and all remaining countries)	
The level of exporting	The logarithm of the proportion of firm turnover derived from export sales	Mol and Birkinshaw (2009); Girma & Hanley (2008)
Collaborate with external partners	The number of types of external partners that a firm cooperated with for technological innovation activities in a 3-year period.	
External information sourcing	The level of importance of external information sources for firms' technological innovation.	Mention and Asikainen (2012)
Internal R&D researchers with PhD qualification in FTE	The ratio of internal R&D researchers with doctorate in full time employment (FTE) to R&D staff.	Dahlander et al. (2016)
Internal R&D researchers with non-doctorate university qualification in FTE	The ratio of internal R&D researchers with degree in FTE to R&D staff.	Hurtado-Ayala and Gonzalez-Campo (2015)
Internal R&D researchers with non-university qualification in FTE	The ratio of internal R&D researchers with other qualifications in FTE to R&D staff.	Hurtado-Ayala and Gonzalez-Campo (2015)
Moderators		
Make-to-Buy (product): The degree of external sourcing in product innovation	It captures the changing tendency of a firm from "make" to "buy" on product innovation activity. (1=conduct product innovation all by the firm itself, 2=conduct product innovation by a joint effort between the firm and external organizations or 3=conduct product innovation by external organizations only).	

Make-to-Buy (process): The degree of external sourcing in process innovation	It captures the changing tendency of a firm from "make" to "buy" on process innovation activity. (1=conduct process innovation all by the firm itself, 2=conduct process innovation by a joint effort between the firm and external organizations or 3=conduct process innovation by external organizations only).	
Control Variables		
Membership of a group of companies	A dummy variable (1=the company belongs to an enterprise group, 0=otherwise).	Blindenbach-Driessen and van den Ende (2014)
Firm size	A dummy variable (1=the company's turnover higher than the value of average turnovers of the sampled companies in the year where they survey executed, 0=otherwise).	Kafouros and Wang (2015)
Collaboration with other companies of its own group	A dummy variable (1=the company has the technological innovation collaboration with other companies of its own group, 0=otherwise)	Love & Ganotakis (2013)
The importance of information source: within company or group	The level of importance of internal information source for firms' technological innovation (1=not used; 2=reduced; 3=intermediate; 4=high).	Montoro-Sanchez et al. (2011)
Firm age	The number of years that the company established.	Love & Ganotakis (2013)
The number of employees	The logarithm of total number of employees (including paid and unpaid employees) of the firm.	Love & Ganotakis (2013)
Public company	A dummy variable (1=public company, 0=otherwise)	
Private national company	A dummy variable (1=private national company, 0=otherwise)	
Private multinational company	A dummy variable (1=private multinational company, 0=otherwise)	
Research association and other research institutions	A dummy variable (1= research institutions, 0=otherwise)	Todtling et al. (2009)
Year dummy	Year dummies for the period 2006 to 2011	Katila and Ahuja (2002)
Industry dummy	Industry dummies based on 14 industrial classification groups (see the sample selection section)	Veugelers (1997)

Note: For all logarithm transformation, we adopted the inverse hyperbolic sine (IHS) transformation because the variables have highly skewed distributions. The IHS that we employed in the random regression model is defined as $\ln(x+\sqrt{x^2+1})$ (Di Cintio et al., 2017).

4.4.5 Estimators

Panel data provides the firm-specific-effects model to achieve consistent estimates:

$$y_{it} = \alpha_i + X'_{it}\beta + \varepsilon_{it}$$

“Where X_{it} are explanatory variables, α_i are random firm-specific effects, and ε_{it} is an idiosyncratic error” (Cameron & Trivedi, 2010, p.237).

It is important to distinguish between fixed and random-effects models in microeconometrics analysis of panel data. Fixed and random-effects estimators are largely different in terms of the α_i. For a Fixed-effects model, the α_i in the above equation is allowed to be correlated with the explanatory variables X_{it}. This permits a limit form of endogeneity (Cameron & Trivedi, 2010). The error in the above equation has been considered as $u_{it} = \alpha_i + \varepsilon_{it}$. In the Fixed-effects model, it is assumed that X_{it} is correlated with the time-invariant part of the error, captured by α_i, but is uncorrelated with the idiosyncratic error ε_{it} (Cameron & Trivedi, 2010). For a Random model, the α_i in the above equation is assumed to be purely random and uncorrelated with the explanatory variables X_{it} (Cameron & Trivedi, 2010). The Hausman test is a common method to compare fixed and random-effects estimators. If the result of the test supports the null hypothesis: firm-specific effects are not correlated with explanatory variables, random-effect GLS estimator is more desirable, otherwise, fixed-effect GLS estimator needs to be applied (Baltagi et al., 2003). However, “using the results of the hausman test to make decisions on which estimator to perform seems opposed to theory. When the result of the test is significant (.000), researchers overwhelmingly rely on the fixed-effects model. The drawbacks of this approach, however, are that fixed-effects models simply discard all available between-firm variance. Consequently, using fixed-effects models prevents researchers from gaining any insights about between-firm relationships" (Certo et al., 2017, p.1537).

We conduct a panel specific random-effect GLS estimator for which independent variables are IC, EIS, the share of internal R&D researchers with doctorate, the share of internal R&D researchers with university degree (without PhDs), the share of internal R&D researchers with other qualifications, logarithm of the level of exporting and geographic market scope, and dependent variables are logarithm of exploration and exploitation investment. This model estimates how the firms' specific effects leads to the differences in firms' investment decisions in exploration and exploitation. Fixed-effect estimator model is the most common method for panel data analysis in strategy research (Certo et al., 2017). However, it is less efficient compared with random-effect models, because it does not consider the between-firm variance, and by definition, apply less information when calculating estimates (Certo et al., 2017).

We choose random-effect GLS estimators over fixed-effect estimators because of the following reasons. First, there are five time-invariant variables in our model: public company, research association and other research institutions, private national company, private multinational company, membership of a group of companies, and thus we cannot directly compare the RE and FE GLS estimators (Greene, 2012). In this situation, we prefer to use the RE model as "the FE GLS estimators cannot provide separate estimates of the parameters on the time-invariant variables while the RE GLS estimators can" (Greene, 2012, p.417). Second, our research assumes that firms are different in terms of inter-organizational relationships, R&D personnel educational levels and internationalization statuses, and these firm specific differences lead firms to make different decisions on exploratory and exploitative R&D investment. The random effects models allow us to estimate how firm-specific factors lead to different investment in exploratory and exploitative R&D (Greene, 2012). Therefore, we report the RE estimator and conduct analysis using the STATA command ‘xtreg re’ in this study (Cameron & Trivedi, 2010). When we run random effect, we include industry fixed effect and year fixed effects.

Chapter 5a External Information Sourcing and Innovation Collaboration

Abstract

We argue that because innovation collaboration (IC) and external information sourcing (EIS) differ considerably in their nature, they affect firms' internal investments in exploratory and exploitative R&D differently. Our central proposition is that while IC is complementary to firms' internal exploratory and exploitative R&D and hence encourages the firm to increase its own investment with increasing engagement in IC, whereas EIS has mostly a substitutive effect on a firm's internal exploratory and exploitative R&D investment because of the appeal of the market in facilitating a firm's exploratory and exploitative R&D. Moreover, we suggest that the impact of IC on exploration is expected to be higher than that on exploitation. These relationships are examined empirically using panel data of Spanish firms for the period 2006-2011. The results are consistent with our hypotheses. However, the influence of EIS on a firm's internal exploitative R&D investment is conditional upon a firm's tendency towards core-development or periphery-development. When a firm is core-development oriented, the higher the importance of information that is extracted from external sources for a firm's innovation activities, the higher the internal exploitation investment by the firm. When a firm is peripheral-development oriented, the higher the importance of information that are extracted from external sources for a firm's innovation activities, the lower the internal exploitation investment.

5.1.a Introduction

Evolutionary economics, the open innovation and organizational learning literature suggested that learning from others' knowledge facilitates learning in organizations. However, past empirical results are mixed. Some studies found that external knowledge is complementary to firms' internal R&D. The more knowledge that is obtained externally, the higher the internal R&D investment (Masso & Vather, 2008; Janz et al., 2004). External knowledge enables firms to overcome barriers of resources, skills and technologies in experimentation and production process, and consequently increase firms' internal R&D investment (Cassiman & Veugelers, 2002; Cassiman & Veugelers, 2007). Investment in internal R&D can also enhance firms' ability to capture external innovation (Cassiman & Veugelers, 2002; Cassiman & Veugelers, 2007; Becker & Dietz, 2004). By contrast, other studies indicated that firms' characteristics such as firm size and search strategy result in the substitution effects of external knowledge on internal R&D investment (Laursen & Salter, 2006; Veugelers & Cassiman, 1999). Hence, although several studies investigated the relationship between external knowledge acquisition and firms' internal R&D investment, it still remains unclear why some firms have strong incentives to invest in R&D during open innovation, yet others are not motivated to do so.

Innovation collaboration (IC) and external information sourcing (EIS) are familiar ways of firms acquiring external knowledge. Prior studies suggested that IC (a formal inter-organizational relationship) and EIS (an informal inter-organizational relationship) are different in terms of cooperation, time saving, risk sharing, the value of knowledge transfer, organizational interaction, resource sharing access possibilities and ties of network. We argue that as IC and EIS differ considerably in their nature, they may affect firms' internal investments in exploratory and exploitative R&D

differently. Therefore, this study aims at investigating their effects on firms' exploratory and exploitative R&D investment. It extends prior research by specifying the status under which complementary or substitution effects between knowledge that is obtained externally and internal exploratory and exploitative R&D investment are most likely to occur. It helps researchers and managers to understand how firms' internal R&D investment decisions (exploratory and exploitative R&D investment) in response to formal and informal inter-organizational relationships capture the benefits of open innovation and build competitive advantages.

This chapter is organized as follows: First we identify the critical gap by reviewing relevant studies in evolutionary economics, open innovation and organizational learning literature. In prior studies, a firm's internal R&D investment is considered to be a function of transaction costs, types of external actors, outside boundary conditions and formal inter-organizational relationships (e.g. collaboration). These studies have attributed the firm's internal R&D investment decision to the firm's capabilities that have been developed through IC (Lichtenthaler, 2011; Hardy et al., 2003). However, the literature does not examine how does this enhanced capacity influence firms' decisions to invest in exploration and exploitation and how does the informal inter-organizational relationship influence on firm internal exploration and exploitation investment.

We then specify the main differences in EIS and IC. In the hypotheses section, we construct arguments on the relationship between IC and EIS respectively with firms' internal exploration and exploitation investment by using an organizational learning perspective. We propose that IC develops participating firms' experiential learning and commercialization capabilities that motivate firms to invest in internal exploration and exploitation to materialize potential benefits and develop their competitive advantages, whereas EIS increased the appeal of using the market to find alternatives to unsolved problems through distant search, which decreases firms' investment in exploration.

We argue the influence of EIS on a firm's internal exploitation is conditional upon a firm's tendency towards core-development or periphery-development due to the risks of building on the market. When a firm is core-development oriented, which aims at developing goods and services in-house to outperform other similar-type products or services currently in market (Dutta & Weiss, 1997), EIS increases firms' exploitation in-house (commercialization, production and refinement) by providing understanding of the market and strengthening the firm's control over its internal exploitation activities, leading to increased core capabilities to beat or outperform the market. In contrast, when a firm is peripheral-development oriented, it aims at developing goods or services externally to bring them to market quicker. EIS enables the firm to reduce the costs and risks of replicating externally available technologies (Audretsch et al., 1996), leading to reduced investment in internal exploitation associated with peripheral development. We empirically test the hypotheses and draw a discussion based on results of the analysis.

5.2.a Theoretical Background

The importance of inter-organizational relationships on firm innovation has been emphasized in a broad variety of literatures. For example, evolutionary economics suggested that external knowledge linkages facilitate the transfer of resources and skills between organizations (Williamson, 1991; Teece, 1986). As the result of the impact of the evolutionary economics, innovation theory tended to move from the traditional linear model of innovation to the interacted innovation model (Kline &

Rosenberg, 1986). The interacted innovation model has attributed technological progress to the interaction between knowledge-creating and knowledge-using organizations (Veugelers, 1997). This concept was putted forward by studies of Freeman (1987) and Nelson (1993) that considered national innovation system as a series of related factors that simulate development by building, expanding and keeping an innovation environment in a historical process. “The key actors in this process are institutions, firms, markets, consumers and the government and the interactions among them construct the system dynamics” (Chaves et al., 2012, p1684). Therefore, firms should carry out and maintain interactive learning with a diverse set of agents surrounding it to achieve the innovation (Edquist, 1997; Breschi & Malerba, 1997).

The open innovation literature suggests that firms should surpass their own boundaries to join forces with external actors such as suppliers, competitors, customers and universities (Chesbrough, 2003; Rosenkopf & Almeida, 2003; Roper et al., 2013) for enhancing the possibilities of getting access to valuable new knowledge and achieving a better performance in innovation (Dahlander & Gann, 2010; Lichtenthaler, 2011). Chesbrough (2003, p.xxiv) suggested that firms can and need to apply “external ideas, as well as internal ideas, and internal and external paths to market, as the firms look to enhance their technology”. A prevalent assumption often considered openness as a panacea for firms to achieve innovation success (Gesing et al., 2015).

Both of these two research streams call for studies on the relationships between the knowledge that is obtained externally and firms’ internal R&D (Veugelers, 1997; Chaves et al., 2012; Gesing et al., 2015; West & Bogers, 2014). Early studies in evolutionary economics focused on the choice between internal and external R&D

(Make or Buy Decisions) and adopted Williamson’s economies of transaction costs theory to explain this issue. They supported that because of supplier opportunism and lower vendor incentives in dealing with uncertainty and asset specificity, transactions are carried out more effectively and hierarchically within a firm than through the market (Williamson, 1985). Following the assumption of economies of transaction cost theory, firms consider external knowledge acquisition and internal R&D as substitutes and they opt for either a make or a buy strategy. Some empirical studies such as Teece (1988) and Pisano (1989) applying these economic arguments to external versus internal R&D found a substitute relationship. Other studies such as Walker and Weber (1984) and Monteverde and Teece (1982) suggested that although their results support the transaction costs argument, the most important variable is the heterogeneous firm effects. Opportunism and the transaction costs of relying on external sources are not necessary a condition to explain firms’ make-buy decision, further studies investigate this issue should pay more attention to firm-specific characteristics (Kogut & Zander, 1992). For instance, Laursen & Salter (2006) and Veugelers & Cassiman (1999) found that firm size and search strategy result in substitution effects between external knowledge acquisition and firms’ internal R&D. Although some progress was achieved in the recent years in evolutionary economics research stream, research on the effect of firm-specific characteristics such as forms of inter-organizational relationships on firm internal R&D investment decisions is still in its infancy (Veugelers, 1997; Chaves et al., 2012).

Current empirical studies in open innovation investigate the relationship between external and internal R&D have shown conflicting results (Vega-Jurado et al., 2009). They mainly explained this issue by focusing on the effect of different types of external actors (e.g. suppliers, customers, universities and research institutions)

(Sofka &Grimpe, 2010), firms' internal structures and impediments (Arora et al., 2014) or outside boundary conditions (Lichtenthaler, 2011). All of these previous studies remained relatively silent on the effect of the actual way of firms acquiring external knowledge (the forms of inter-organizational relationships) on firms' internal investment in R&D. We aim to address this critical gap by focusing on EIS (informal inter-organizational relationship) and IC (formal inter-organizational relationship). Instead of considering firms' internal R&D as a homogeneous construct, we classify firms' internal R&D investment into exploratory and exploitative R&D investment (Mudambi & Swift, 2014).

Investment decisions on exploration and exploitation are important for facilitating firm innovation and sustaining competitive advantages (Mudambi & Swift, 2014). Literature on learning and innovation suggested the positive influence of the formal inter-organizational relationship (collaboration) on organizational learning (Tesavrita et al., 2017; Easterby-Smith et al. 2008). Collaboration can be considered as a vehicle for learning new knowledge from others (Lei and Slocum, 1992). Recent studies suggested that it not only allows firms to obtain knowledge and resources from partners (Dyer and Nobeoka, 2000; Kale et al., 2000), but also promotes firms to create new knowledge internally (Tesavrita et al., 2017; Anand & Khanna, 2000). The development of capabilities of collaborating participations is a critical impact of collaboration (Hardy et al., 2003). Such enhanced capabilities allow firms to carry out innovation activities that cannot be previously achieved by internal R&D, and tend to result in an increase in firms' R&D investment (Trist, 1983). As previous studies on organizational learning suggested that the characteristics of the enhanced capabilities by collaboration influence a firm's ability of building a competitive advantage (Hardy et al., 2003), we suggest that collaboration may have various effects on different types of activities of organizational learning. Prior studies on organizational learning and collaboration have not empirically tested this issue. Thus, it is unclear whether IC generates the same effect on exploratory and exploitative R&D investment.

Moreover, prior studies did not offer guidance on the effect of the informal inter-organizational relationship (e.g. EIS) on firms' exploratory and exploitative R&D investment. It is unclear whether EIS has the same effect as IC on firms' two types of R&D investment and whether its effect on exploratory R&D is the same as the effect on exploitative R&D investment. Prior studies on open innovation suggested that EIS involves a distant search strategy, which aims at using external sources to achieve and sustain innovation projects (Laursen & Salter, 2006; Mention & Asikainen, 2012). Firms receive knowledge, as well as are influenced by others' knowledge through EIS. Empirical studies in this literature mainly focused on the effect of EIS on firm R&D investment (Masso & Vather, 2008; Raffo et al., 2008). Exploratory and exploitative R&D investment express the learning process of inter-organizational relationships. As IC and EIS differ considerably in their nature (Kang & Kang, 2009), they may induce different learning mechanisms by which firms influence internal exploratory and exploitative R&D investment. Therefore, this study adopts organizational learning theory to explain firm internal exploration and exploitation investment on the basis of the influence of IC and EIS on four learning mechanisms: experiential learning, vicarious learning, searching and learning from distant knowledge. In the following section, we introduce IC and EIS and identify the main differences between them.

5.3.a Distinguish External Information Sourcing from Innovation Collaboration

In line with Mention and Asikainen (2012), we refer to EIS as the extraction of information from different sources for accessing external knowledge. An organization's sourcing activities often aim at acquiring external solutions and/or information for supporting new innovation projects or completing innovation projects in progress. The new knowledge that a firm obtains through EIS on the one hand can be embodied in a tangible asset that is acquired such as the equipment bought from suppliers and the attended conferences or exhibitions. On the other hand, the new knowledge can also be obtained through outsourcing the technology from universities, public research institutes or consultants (Cassiman & Veugelers, 2000). Such new knowledge is already produced by other organizations that used their own scarce resources to conduct innovation aims at fulfilling their own goals (Bogers et al., 2010) but the results of the innovation are used by receiver firms to their own idea generation processes (Morrison et al., 2000). Utterback & Abernathy (1975) found that firms are less likely to source the technologies that are still in an initial development stage, when the technologies are surrounded by much uncertainty. In contrast, they tend to tap into existing and often more specialized knowledge, which is available in external environments (Veugelers & Cassiman, 1999; Kogut & Zander, 1992). Therefore, in EIS, firms are explicitly absent in managing and creating the innovation. They mainly aim at efficiently exploiting economies of scale in R&D, enjoying time gains and saving research costs (Cassiman & Veugelers, 2000). They directly buy the technology or access the leaked information from innovators. Sometimes, embodied forms of acquiring knowledge allow firms to access the existing technology without gaining permissions from the innovator (Cassiman & Veugelers, 2000). However, without further support from the innovator, such as training courses or guidance, it is very difficult for firms to obtain tacit part of the knowledge transfer the knowledge they extracted into their own knowledge (Kang & Kang, 2009; Kogut & Zander, 1992). EIS through technology disembodied and embodied forms can be considered as a weak tie because EIS only involves a low level of time commitment, trust and reciprocal services with their external sources (Granovetter, 1973). The interaction between firms and their external sources is relatively lower than collaboration (Kang & Kang, 2009). The weak tie limits the resource sharing access possibilities between firms and sources and is unable to urge risk sharing between them (Kang & Kang, 2009). As a result of lack of organizational interactions and innovators' own accord in knowledge transfer, it is hard for firms to obtain critical capability, especially tacit knowledge from sources during EIS (Kang &Kang, 2009). Moreover, due to the weak tie, firms do not have much control of the information sources, which increases the risk of technological leakage and opportunistic possibilities of the other party. Firms are less likely to make specific investments because the other party may appropriate the rents. Therefore, firms choose EIS strategy expecting more on objectives of time and cost saving (Cassiman & Veugelers, 2000) rather than objectives of knowledge transfer. The knowledge that firms source externally are often codified, which contains less competitive value as it can be rapidly imitated by outsiders at a low cost. Hence, EIS firms, compared with collaboration firms have lower desire of assimilation of extracted ideas.

IC is a familiar way by which firms access complementary knowledge from outside (Smith & Tushman, 2005). Polenske (2004) defines collaboration as direct and active participation of two or multiple players in designing and/or manufacturing a product or process. Many prior studies on the effect of IC highlighted the importance of cooperation of IC on resource sharing and knowledge transfer between collaborating organizations (Majchrzak et al., 2015; Hardy et al., 2003). In line with previous studies, this thesis considers IC as innovation cooperation, which means the voluntary participation of other business or non-commercial actors in innovative activities. They collaborated for conducting and completing technological innovation activities and there is no requirement that both parts need to receive a commercial benefit. All innovation activities under the cooperation model will be considered as collaboration, otherwise will be excluded from it (Hardy et al., 2003). For instance, the subcontracting of works will not be considered as collaboration in this thesis because in subcontracting relationship firms do not cooperate with other organizations to conduct innovation activities.

In IC, firms aim at co-creating value with other organizations (Vargo & Lusch, 2004; Anand & Khanna, 2000). The value of the innovation results that they create together is often greater than the value that they create individually or with other partners (Selnes & Sallis, 2003). Unlike EIS, R&D collaboration requires a large maintenance cost and time to be effective (Kang & Kang, 2009). It takes time for firms to build effective communication paths with their partners (Dodgson, 1992; Hardy et al., 2003). Therefore, the strength of ties between firms and partners are strong. By taking the advantages of the strong ties, collaboration firms can enjoy a higher level of capability and resources sharing and organizational interaction with their partners than EIS (Granovetter, 1973; Hansen, 1999). They can access in-depth knowledge by building cross-functional teams with their partners (Selnes & Sallis, 2003). Communication and debates that happened in the sharing process promote the flow of the tacit knowledge such as organizational routines and commercialization skills (Tsang, 2002).

Therefore, the limitations of a firm's resources and capabilities for technological innovation activities can be overcome through R&D collaboration (Kang & Kang, 2009; Faems et al., 2008). R&D collaboration not only allows firms to obtain new knowledge and competencies but also helps them to decrease the uncertainty and opportunistic behaviours associated to the joint creation and development of new knowledge (Petruzzelli, 2009). The financial and organizational risk of failure can also be reduced through R&D collaboration as firms can share the costs and management issues with their partners (Kang & Kang, 2009). R&D collaboration allows firms to access their partners' proprietary knowledge and exchange concepts not easily obtained through market transactions (Powell et al., 1996; Teece, 1986; Faems et al., 2008). Therefore, firms engaging in R&D collaboration have a strong desire of learning and assimilation of the extracted information (Liebeskind et al., 1996; Muthusamy & White, 2005). Following Table 5.1 summarizes the main differences between EIS and IC:

Table 5.1 The main differences between the external information sourcing and innovation collaboration in this study

	External Information Sourcing	**Innovation Collaboration**	**Studies**
Participation in in-house R&D (knowledge creation)	Low	High and long term	Cassiman and Veugelers, 2000; Selnes and Sallis, 2003; Faems et al., 2008; Hardy et al., 2003
Cost and time saving	High	Low	Cassiman and Veugelers, 2000; Kang and Kang, 2009; Mention & Asikainen, 2012
Ties of network	Weak	Strong	Granovetter, 1973; Hardy et al., 2003

Organizational interaction	Low and short term	Strong and long term	Granovetter, 1973; Kang and Kang, 2009; Hardy et al., 2003
Resource sharing access possibilities	Low	High	Faems et al., 2008; Granovetter, 1973; Kang and Kang, 2009
Risk sharing	Low	High	Kang and Kang, 2009; Mention & Asikainen, 2012
The value of the knowledge transfer (codification, speed of imitation by market)	Low	High	Kang and Kang, 2009; Faems et al., 2008; Hardy et al., 2003
Desire of assimilation of the extracted ideas	Low	High	Cassiman and Veugelers, 2000; Mower and Rosenberg, 1989; Mention & Asikainen, 2012

Few studies investigated the effect of IC on firms' exploration and exploitation investment. However, no attention has been paid to the effect of the informal form of inter-organizational relationship, EIS, on firms' exploration and exploitation investment. Therefore, it is interesting to investigate firms' informal and formal inter-organizational relationships in the same study to examine whether EIS and IC generate same effects on exploration and exploitation investment. Therefore, we investigate both IC and EIS in this study and compare their effects on exploration and exploitation investment.

5.4.a Hypotheses Development

We argue that because innovation collaboration (IC) and external information sourcing (EIS) differ considerably in their nature, they affect firms' internal investments in exploration and exploitation differently. Our central proposition is that IC is complementary to firms' internal exploration investment and exploitation investment, whereas has mostly a substitutive effect on a firm's internal exploratory and exploitative R&D investment.

5.4.1.a Innovation collaboration and internal exploration investment

Innovation collaboration (IC) creates considerable benefits for participations and also drives the firm to commit investment in both internal exploration and exploitation. In the following discussions, we focus on explaining that a key benefit of IC is that participating firms develop experiential learning capabilities that motivate firms to invest in internal exploration. More specifically, with the knowledge learnt from the experience of IC, a firm may increase its internal exploration investment (1) in applied research to define the application of their own scientific ideas to their own targeted market which is not necessarily the same as the market targeted by the IC, (2) in scientific research to achieve the creation of new products or technologies, (3) in experimental work (involving distant search and the creation of new technologies) to avoid facing the same failures observed from their IC partners, (4) because of changing expectations of the return of exploration and the improved outcomes of exploration due to risk sharing, and (5) in absorptive capacity through expanding the set of technologies owned by the firm to materialize this benefit of IC.

IC induces internal exploration investment. Regardless of the collaboration outcomes, IC provides firms the opportunities to gain first-hand experience of a business environment and a specific scientific area, such as market potential, industry politics and customer needs (Hitt et al., 2005; Tsang, 2002). We are interested in the effect of IC in general, so the business environment can be either a domestic market, a foreign market or a new specific scientific area. This accumulated direct experience about the market helps firms to better define the application of their own scientific ideas that have been explored in firms' experimental or theoretical research (Hitt et al., 2005; Chesbrough & Teece, 1996). With the increase of accumulated experience of market information, firms can smoothly and efficiently define the applications of their scientific ideas or technologies that can be applied to IC market. During this process, firms learn the capability of generation of ideas that can be used for their own-targeted market, not the IC market, and application of these ideas to the own-targeted market. Therefore, the engagement in IC drives firms to invest in internal exploration to experiment practical applications of their independently developed science ideas to the market.

Firms very often establish IC with partners who possess different and complementary technologies from their own (Ireland et al., 2002; Harrison et al., 2001; Gulati et al., 2000; Nakamura et al., 1996) to achieve outcomes that none of them can reach individually (Kogut, 1988). The quality of the knowledge sharing determines the success of IC (Norman, 2002). As a result partnering firms are more likely to increase the communication and interaction (Wu & Cavusgil, 2006) and hence, this tends to result in disclosure of valuable information and knowledge to each other (Tsang, 1999). This information, such as the know-how of a master craftsman and organizational principles, is a form of tacit knowledge that is essential to firms' exploration and cannot be easily obtained by external market transactions (Muthusamy & White, 2005; Tsang, 2002; Hamel, 1991; Kogut, 1988). Hence, new skills and competences that firms learnt from partners drive firms to increase exploration investment to co-create advanced science concepts or abstract ideas of entirely new products with partners.

In the IC, firms typically assimilate partners' tacit knowledge through interactive forms of vicarious learning such as formal teaching occasions and the retelling of past experiences (Dailey & Browning, 2014). IC as an effective vehicle for vicarious learning allows firms to monitor their partners' experience (Powell et al., 1996) and learn from their success and failures (typically during the co-creation process). Failure indicates to the organization that its current knowledge base is inadequate and drives the organization to invest in exploration to develop new ones (Madsen & Desai, 2010). Organizational learning theory suggests that successful organizations possess capabilities for responding to experience through modifying their technologies, forms and practices (Stalk et al., 1992). As a result, failure brings a roadmap to indicate where firms' efforts will be most productive (Echajari & Thomas, 2015). However, firms like to purse success and tend to avoid failures, especially large ones occur rarely in an organization and hence, firms mainly learn from the failures of others through vicarious learning to identify the threat and changes of their environment (Echajari & Thomas, 2015). Therefore, if a firm, through vicarious learning, can observe that their IC partners encounter large failures and performance gaps (not necessarily within the IC project but generally within the IC partner's businesses), the firm is likely to learn from the partner's lessons and invest in its own internal exploration to avoid facing the same failures as their partners in the firm's own business by developing new technologies and breaking the original knowledge trajectory (Tidd et al., 2001; March & Simon, 1993). For instance, the experience of partners in failing to use an equation or a tool to predict selling performance of their products in IC market would induce the organization to use distant search to develop radically new alternatives. Partners' previous experience in failing to serve customers' needs in IC market tends to signal to each other a firm's commitment to perfect the functioning of products that serve the IC market (Tidd et al., 2001). Therefore, the engagement in IC drives firms to invest in exploration by conducting experimental work aimed at overcoming failures via incorporating distant search and introducing new technologies in their joint products.

From a dynamic perspective, firms' "success trap" (Levinthal & March, 1993) can be broken by the success experience of exploration that they learned from IC partners. The proven returns from partners' exploration investment may shift firms' own judgments to be aligned with partners' judgments and increase firms' expectations of returns in exploration (Offerman & Sonnemans, 1998; Bandura, 1977). For instance, Shell established IC with Gordon Murray Design and Geo Technology to co-engineer and develop a Shell Concept City Car with features of energy-efficiency in 2016 (Shell.com, 2016). One of its partners Gordon Murray Design successfully gained a reputation by launching a city car with similar breakthrough concept ideas in 2010 (Hull, 2016). Moreover, collaboration with others allows firms to know which conditions they should pay attention to for achieving desirable outcomes of exploration (Pfeffer, & Salancik, 1978). For instance, in this case, Shell learnt that developing a new formula of engine lubricant enables 600cc petrol engine to have less friction for greater efficiency (Hull, 2016). In other words, IC model allows firms to share the risks of exploration with IC partners (Powell et al., 1996), and control or absorb the uncertainty (Pfeffer, & Salancik, 1978). Moreover, IC allows partnering firms to predict the future performance of their own independent products, e.g. derivative products of the previous co-developed product that sold in the IC market, the reduced risk that subsequently motivates firms to invest in exploration (Tidd et al., 2001; Tabrizi & Walleigh, 1997). Overall, firms collaborating with others are more likely to invest in exploration because of lowered risks and higher returns.

While interactive forms of vicarious learning reduce the barriers for firms to learn distant knowledge from their partners (Dailey & Browning, 2014), internalizing partners' distant knowledge can be challenging. Without developing sufficient expertise in-house, cooperating firms cannot understand and use partners' technologies (Mower & Rosenberg, 1989; Cohen & Levinthal, 1990). To materialize this benefit of IC, firms need to invest in exploration by increasing their ability to absorb what they have learnt from partners (Cohen & Levinthal, 1989; Kamien & Zang, 2000). This can be achieved through investment in basic and apply research aimed at broadening the set of background knowledge and technologies owned by the firm (Cohen & Levinthal, 1990; Blindenbach-Driessen & van den Ende, 2014).

5.4.2.a Innovation collaboration and internal exploitation investment

In the following discussions, we focus on explaining that another key benefit of IC is that participating firms develop commercialization capabilities that motivate firms to decrease investment in internal exploitation. More specifically, with the knowledge learnt from the experience of IC, a firm may increase internal exploitation investment (1) in commercialization and manufacturing processes to translate their own abstract ideas into feasible products that are typically offered in the market which the IC project is concerned, (2) in intra-firm communication routines between different functional teams to materialize the benefits of commercialization capabilities, and (3) to build critical databases and in inter-firm communication routines aimed at better understanding and integration of partners' knowledge to achieve co-creation outcomes.

IC induced internal exploitation investment. IC provides firms the opportunity to learn about commercialization demonstrated by partners through observation (Powell, 1998). In the Shell joint Project M Concept Car, partnering firms learn about materials and manufacturing processes, lubricants, designing and engines (Hull, 2016). While partnering firms focus on the joint project, methods and techniques (for how things get done) used in the project are very often transferable (D'Adderio, 2014; Feldman, 2000). Hence IC has the potential to develop firms' commercialization capabilities, with which firms can independently refine and translate their own abstract ideas into feasible products that meet customer needs (Rothaermel & Boeker, 2008; von Hippel, 1988). To materialize such potential benefits, firms need to invest in exploitation, e.g., design and test new materials and products and incrementally improve their own routines in order to develop new internal commercialization processes.

To materialize such potential benefits, firms also need to invest in exploitation to establish new or adapt the firms' existing manufacturing processes for implementing the production of new products and to adapt internal communication routines for better managing the new commercialization and manufacturing processes (Howard et al., 2016; Nooteboom, 1999). Exploitation investment in internal communication improvement can be especially critical, e.g., Piore (1985) and Kogut & Zander (1992) emphasized that production knowledge is like a language common to a specific part of internal workers, if language does not change with changes in production processes, internal workers can easily make mistakes in their production because they lack the understanding of product specifications.

Refining a manufacturing process until it can become fully operational and achieve high yields will increase firms' exploitation investment (Iansiti & West, 1997) because it requires firms to put effort in building internal communication routines.

Refinement is systematic work that needs interrelated changes in supplier management, product design and other related aspects (Chesbrough & Teece, 1996). To achieve refinement, firms need to invest in communication routines e.g. cross-functional teams that facilitate information sharing and coordinated adjustments throughout the entire new product development process (Chesbrough & Teece, 1996). If a firm fails to do so, the benefit of IC in terms of commercialization skills may not materialize at all. For instance, the manufacturing process of Intel's chip contained more than hundreds of steps and so manufacturing refinement was achieved by investing in forming integration teams with process integrators with extensive background in basic research, applied research and production (Iansiti & West, 1997). Hence, firms have strong incentives to invest in exploitation for having better internal communication routines to reduce the time and costs of firms to bring the new product to the market, and in the case of radically new product, investing in internal communication routines increases the possibilities of firms to determine industrial standards and to gain large market share and acceptance; in other words, it strengthens firms' competitive advantages (Pisano & Wheelwright, 1995).

Exploitation investment may also be made to establish critical databases that are rare, valuable and inimitable. Direct participation in IC allows firms to monitor consumer, suppliers and distributors and to accumulate information of their behaviours. This accumulated information such as consumer expenditures and supplier development is an important source of firm competitive advantages (Widyaningrum, 2015; McAfee & Brynjolfsson, 2012; Lohr, 2012; Kogut & Zander, 1992). We are in an age of big data; there is a clear shift towards data-driven decision-making, which help firms to achieve higher productivity gains than other factors could explain (McAfee & Brynjolfsson, 2012; Lohr, 2012). But critical data are not public goods and have competitive value because it takes time to accumulate and combine them and is expensive to recreate (Kogut & Zander, 1992). Therefore, to materialize benefits of IC, firms may have strong incentives to invest in exploitation by transforming the information they obtained from IC into data that can be transferred and understood by a wide set of employees within the firms, and creating further possibilities of combining them with the firm's own data and resources. The additional benefit is that once a firm transforms the information into data, the information belongs to the organization and will be less likely to be influenced by employee turnover (Widyaningrum, 2015; Kogut & Zander, 1992). Such exploitation investment also reduces costs for training new employees (Garvin et al., 2008; Garvin, 1993). Therefore, firms may desire to invest in exploitation to codify and simplify the information that is accumulated during IC to make it accessible to the wider organization and become more easily deposited within the organization.

Exploitation investment may be further made to enhance the integration of partners' technologies so that they can achieve the co-creation in innovation collaboration. Firms may either invest in exploitation by adapting their specific technologies, skills or resources being exchanged with partners according to the product or technology specification that is provided by partners, or invest in exploitation by establishing knowledge-sharing and cooperation routines that help to develop a common coding system and categorizing information (including products and services) that are shared by partners (Walker et al., 2013). This investment in routines enhances firms' understanding of partners' knowledge through increasing the flow of technological information between collaborating parties at organizational and even personal level (Katz & Kahn, 1966; Walker et al., 2013). It also enhances the analysis and appraisal of partners' knowledge (Kogut & Zander, 1992) and prevents not-invented-here syndrome from happening (Stanczyk-hugiet, et al., 2016), hence facilitating the integration of partners' knowledge. Better integration of partners' knowledge leads to better results of co-creation during IC, e.g., high quality and better function of products, reduced time and risks of commercialization and production that bring more profits to collaborating parties (Luca & Atuahene-Gima, 2007).

Overall, the engagement in IC develops firms' commercialization capabilities and drives firms to invest in exploitation that ensure the implementation of new commercialization and manufacturing processes for successful new products development.

Summarizing the above discussions, we argue that various benefits of the IC process drives participating firms to increase their investment in both exploration and exploitation but may not be to the same extent. There are more mechanisms through which IC can influence exploratory R&D investment. During IC, firms' investment in exploratory R&D activities is facilitated mainly by three learning mechanisms: learning from distant knowledge (learning partners' distant knowledge), vicarious learning (learning partners' experience of serving IC market) and experiential learning (learning through own experience of developing new ideas with commercial use that satisfies the needs of the market) (Howard et al., 2016; Tsang, 2002). Firms' exploitative R&D during IC is however facilitated largely by experiential learning (accumulating of experience of establishing communication routines for knowledge integration that are essential for accomplishing manufacturing). Thus, our hypothesis is:

H1: *Innovation collaboration with external partners increases firms' investment in internal exploration and exploitation, but the impact on exploration is expected to be higher than that on exploitation.*

5.4.3.a External information sourcing and internal exploration and exploitation investment

5.4.3.1.a External information sourcing and exploration investment

A firm's innovation project requires information sourced from within the firm and outside. Performance gap drives firms to search for a new alternative. Search is simple-minded from simple to complex one. If search in the immediate area of the problem cannot provide solutions, firms are likely to move to a more distant search, either conducting distant search internally or externally. We assume that firms prioritize external distant search because external search is more likely to provide solutions to an unsolved problem due to a wide range of external sources and the diverse information from these sources. We identify the differences between firms' internal distant search and external distant search. Both searches can support exploration but they substitute each other, i.e., conducting external distant search reduces investment in internal distant search for exploration. If the existing external information is known to be able to satisfy the firm's need, the less necessary it is for the firm to explore the problem internally via basic or applied research. In other words, if firms can find the distant alternative from the external environment, they will use the external alternative approach directly, instead of doing basic research and designing of new manufacturing process on their own. In summary, the higher the importance information sourced externally, the less investment in own exploration.

Organizational search is problem-directed (Cyert & March, 1964). Firms often need to search for alternative solutions to a problem in innovation. There is a substitute relationship between search alternatives within the firm and search solutions in the environment. Problems arise when firms fail to achieve their aspiration level (March & Simon, 1958). The performance gap between firms' aspiration level and what exists drives firms to search for a new alternative (Feldman & Kanter, 1965; Cyert & March, 1964), and the search will continue until the problem is solved (Cyert & March, 1964). Firms can choose either to conduct distant search internally, e.g., "internal boundary-spanning exploration" or externally, e.g., "radical exploration and external boundary-spanning exploration"(Rosenkopf & Nerkar, 2001). We argue that firms will prioritize external distant search when performance gaps arise because external information is more diverse, and has a higher probability of offering the best solution to a problem (Rosenkopf & Nerkar, 2001). This is consistent with arguments of interdependent evolution of firm-level exploration trajectories, which suggests that technological evolution of a product category is an aggregation of the variation, selection and retention trajectories carried out by communities of organizations in the product category (Rosenkopf & Tushman, 1998; Tushman & Rosenkopf, 1992). In other words, external distant search allows firms' exploration to build upon technologies that exist outside of the firms (Rosenkopf & Nerkar, 2001) and hence firms can discover and integrate external alternatives to fill their performance gaps.

By contrast, internal distant search has its limits. Firstly, when a firm develops expertise in a specific technological area, the variance in its knowledge set is reduced (March, 1991; Fleming, 2001), which increases the difficulties and costs for the firm to find and develop a knowledge that is outside of its technological domain. Secondly, when a problem arises, internal distant search activities depend on the organization's decision routines/rules and the organizational members that are in charge of the search activities (Cyert & March, 1963). While organizations' decision routines are shaped by the firm's past experiences, the organizational members' problem solving strategy and decision-making is also likely determined by their previous experiences and choices (Cyert & March, 1963). So the above internal path-dependency in search and choice-making is unlikely to produce optimal solution to the problem, compared with external distant search.

In summary, the higher the importance of external extracted information for solving a problem (assuming the existing external information is known to be able to satisfy the firm's need[5]), the less necessary it is for the firm to explore the problem internally via basic or applied research. For example, Cosworth company, a producer of high-performance engines for car applications find a technique to deal with problems of porosity in their final product outside its firm, from the nuclear power industry where this technique is used to circulate the liquid sodium coolant served in the fast breeder reactor programme (Tidd et al., 2001). Cosworth adopts an external alternative approach since they find that it can successfully meet their needs of eliminating air during filling and the solidification process of casting. Therefore, firms that consider information sourced externally as more important will reduce investment in their own exploration in order to enjoy the benefits of external information and to avoid redundancy.

[5]In some cases, after extensive search by the firm, external information is found to be unable to satisfy the firm's need to resolve certain problem. For example: Cosworth has searched throughout the world to look for a source of aluminum castings which were cheap enough for volume use and of high enough precision and quality for their product, but they were unable to find anyone suitable. Therefore, they have to go right back to basic research and design their own manufacturing process. They established a small pilot facility and employed a group of metallurgists and engineers with the brief to provide an alternative approach that could meet their needs (Tidd et al., 2001).

H2a: *The higher the average importance of information sourced from all external sources for a firm's innovation projects, the lower the firm's internal exploration investment.*

5.4.3.2a External information sourcing and internal exploitation investment

In this section, we will first analyze the benefits and risks of EIS and then establish how firms use EIS for internal exploitation, which increases a firm's investment in exploitation. Although the availability and advantages of external knowledge increases the appeal of using the market, not all firms use external information with the purpose of accepting what is offered in the external market. Essentially this is because of the risk of a "buy" decision and firms' incentive of beating the market that we shall explain in the following sections. Therefore, we argue that the effects of EIS on firms' internal exploitation investments are not direct and vary significantly depending on whether a firm's innovation is peripheral development oriented or core development oriented.

EIS not only enables firms to externally source problem-driven solutions (that decreases a firm's exploration investment as discussed earlier) but also non-problem driven information. There are two major benefits of obtaining non-problem driven information. First, since external information is relatively more explicit, firms can know who has what, the market price of the information or resources, and whom to contact for acquisition of such information (Kogut & Zander, 1992). In other words, using externally explicit knowledge enables firms to evaluate the costs of adopting what the external market offers. For instance, certain components of a final product (say, Intel's CPU8080) and supplier information are readily available in the market –

the external information may include whom to contact, which the best performing component is, and what the reasonable price is (e.g., Intel has a leading position in CPU development with its 8080 being the most successful and the first general purpose CPU of the world, initially priced at $360 CND in 2015; cpu-world, 2017). This information can be obtained via EIS by the firm at a relatively low cost, e.g., via the free access to Verivox, a German price-comparison website, which provides price information of suppliers in retail markets (Heiligtag et al., 2017). Using EIS, a firm can make decisions by comparing the costs of doing it itself, i.e., increase internal investment of exploitation (in this example developing the equivalent of Intel's CPU8080 by the firm in-house) against using the market, i.e., a "buy" decision (to purchase Intel's CPU8080 from a supplier) that does reduce the firm's internal exploitation investment, since this technology can be obtained without in-house effort. A further example demonstrates how "make" and "buy" decisions may determine the way a firm conducts internal exploitation. Although IBM invested in R&D of a CPU at the same time when Intel was running the project of 8080, with the success of Intel's CPU business, IBM decided to choose Intel's CPU8088 to produce its first Personal Computer because Intel's 8088 is 8-bit support chips that were cheaper than IBM's 16-bit support chips (cpu-world, 2017; Chesbrough & Teece, 1996). IBM's "buy" decision did not lead to increased internal exploitation that would have to be underpinned by the firm's core-development in making successful CPUs but resulted in a faster introduction of its first PC that benefits its peripheral-development.

Second, externally sourced information is very often of larger quantity, compared with information that can be sourced within the firm. For instance, there are many suppliers of external and specialized information, such as Fraunhofer Institute for Production Technology (IPT) - operating about 80 research institutions, with about

12,500 top scientists and engineers in different areas of production, it specializes in developing innovative technologies with practical applications, and its research capacities, facilities and fund has enabled IPT to provide services to worldwide firms (Fraunhofer, 2017; jittc.org., 2017). Mahr Gmbh, a manufacturer of precision measurement instruments, expands its product portfolio by using diverse and large quantity of information from IPT to develop a 3-D measurement device instead of commercialization of new product by itself (Gummer, 2014).

Both of the above benefits (explicit and larger quantity) increase the appeal of using the market by making it easier for firms to evaluate (because of explicitly) and minimize (because of abundance of information and market options) the costs of commercialization (e.g., costs of design and marketing services), production (e.g., costs of new machineries, input materials) and refinement (e.g., costs of obtaining feedback from the market, adjusting costs of existing processes). Since these three areas are typical functions that firms internally invest in to achieve exploitation, the important role of EIS here is to substitute part of a firm's internal exploitation effort in these areas.

These benefits of EIS can be very attractive to firms that prioritize peripheral-development when using EIS, i.e., being peripheral-development oriented. Firms tend to use buy strategy to obtain capabilities and resources that are not related to firms' core strengths to enjoy specialization advantages such as reduction of costs and risks of commercialization, production and refinement of unfamiliar technologies (Veugelers & Cassiman, 1999; Chesbrough & Garman, 2009). Therefore, when firms' technological innovation activities are peripheral development oriented, firms are more likely to relying on EIS as the main input to support their peripheral expansion, reducing a firm's internal exploitation investment relating to the peripheral expansion.

In other words, when a firm is peripheral-development oriented, the higher the importance of information extracted from external sources (EIS), the lower the firm's internal exploitation investment.

In contrast, some firms may prioritize core development when using EIS – knowing what the external market offers but intending to "beat the market" by producing better technologies that lead to the building of the firm's core competence, i.e., being core-development oriented. Firms behaving in such a way may be due to their concerns about the risks of a "buy" decision. There are three main risks. First, firms may lose control over technological and information leakage if they utilize external market to conduct exploitation (Veugelers & Cassiman, 1999). For example, external contractors may learn a firm's knowledge from commercialization, production or refinement process through observation and it is often difficult for the firm to prevent the opportunistic behaviour of contractors (Liebeskind, 1996).

Second, relying on the market to carry out exploitation may not help firms to improve their core strengths and firms risk losing their competitive advantage in the long run since the inputs that a firm obtains through EIS are also available to their competitors (Markides & Williamson, 1994). Moreover, because tacit knowledge is mainly obtained through practical experience in the relevant context (Lam, 2000) and is a critical co-requisite for firms to create new technologies and enter new market (Senker, 1993; Lord & Ranft, 2000; Zhang et al., 2015), relying on EIS, firms are not able to replicate external optimal solution in-house to support the application of acquired external knowledge for expanding their internal exploitation.

Third, because tacit knowledge cannot be substituted by explicit knowledge (Lord & Ranft, 2000; Senker, 1993; Zhang et al., 2015), firms may not have the best opportunity to build capabilities through EIS. Tacit knowledge is important for firms to understand how to do something and how inputs are transformed into outputs (Kogut & Zander, 1992). Without obtaining the tacit component of a knowledge set, the risk of applying external knowledge to conduct firms' own exploitation will be high. For instance, published local market reports and statistics may provide useful information to a non-local firm, but without the direct experience of *how* to deal with local customer preferences, suppliers and government policies, firms are facing a big risk of failure in introducing their products to the local market (Etienne-Benz et al., 1996). In particular, many large companies such as Tesco, IKEA, M&S and Disneyland have experienced significant failures in introducing products to the local markets due to a lack of such first-hand experience about the markets (Heffernan, 2013; Stolba, 2009; RETAILinasai, 2016; Kissane, 2016). Similar failures can also happen when firms enter a new market within their own country because of a lack of experience of addressing sub-national culture differences such as Scottish vs. Welsh in the UK and Basques vs. Catalans in Spain (Kaasa et al, 2014). These suggest the importance of tacit knowledge that EIS cannot provide for firms that are core-development oriented.

Therefore, if a firm's use of EIS is motivated by developing core capabilities to sustain a competitive advantage (over the market), the firm is more like to carry out exploitation in-house through increased internal investment. In other words, while combined with using EIS, the "make" decision ensures better control of a firm's core competence (rare, inimitable technologies, knowledge and process), and enhances the firm's own capability building process (Cassiman & Veugelers, 2007). In such case, a firm tends to use EIS to define the surprises, threats and opportunities of its external environment and also its positions within the environment (Choo, 2001; Sutton, 1988).

Hence, when a firm priorities core development, EIS is mainly used for enhancing its understanding of the external market's offering that serves as input to help the firm develop solutions to outperform the market through increased investment in internal exploitation. Moreover, EIS may contribute to enhancing a firm's control over its internal exploitation. For example, EIS helps a firm to negotiate with the external market, which allows it to better obtain a return that meets expectations (Cyert & March, 1992). The external information can supplement a firm's internal information for making outcomes more reliable, e.g. additional data (changes in market price) to help the firm to avoid uncertainty in internal exploitation activities (EY, 2014). In other words, when a firm is core-development oriented, the higher importance of information extracted from external sources (EIS), the higher the firm's internal exploitation investment.

In summary, the influence of EIS on a firm's internal exploitation is conditional upon a firm's tendency towards core-development or periphery-development. When a firm is core development oriented, EIS enables it to enhance exploitation in-house (commercialization, production and refinement) by providing understandings of the market and strengthening the firm's control over its internal exploitation activities, leading to increased core capabilities to beat or outperform the market. In contrast, when a firm is peripheral development oriented, EIS enables it to reduce the costs and risks of replicating externally available technologies, leading to reduced investment in internal exploitation associated with peripheral development. We have the following two hypotheses:

H2b: *When a firm is core development oriented, the higher the average importance of information sourced from all external sources for a firm's innovation activities (EIS), the higher the internal exploitation investment by the firm.*

H2c: *When a firm is peripheral development oriented, the higher the average importance of information sourced from all external sources for a firm's innovation activities (EIS), the lower the internal exploitation investment.*

5.5.a Results

The results of the random regression model are presented in Table 5.2.a. and Table 5.3.a. Table 5.2.a. provides the results of the influence of firm-specific factors on firms' exploitative R&D investment. Table 5.3.a. provides the results of the influence of firm-specific factors on firms' exploratory R&D investment. In this sub-chapter of the empirical chapter, we will focus on first four models: Model 1-4. Model 1 presents only control variables. Model 2 includes control variables and IC (H1). The first hypothesis examines the relationship between IC and exploratory and exploitative R&D investment. As model 2 indicates, the IC has a positive and statistically significant effect on firms' internal exploitative (beta= .24, p< .001) and exploratory (beta= .28, p< .001) R&D investment, and its impact on exploration is higher than that on exploitation, thus fully supporting H1.

The second hypothesis H2a examines the direct effect of EIS on firm' exploratory R&D investment. As Model 3 in Table 5.3.a. indicates, EIS has a negative and statistically significant (beta= -.68, p< .001) effect on firm's internal exploratory R&D investment. This result provides support to H2a. The results in Model 2 and Model 3 are robust to incorporation of variables for IC and EIS, simultaneously (Model 4), indicating the importance of IC and EIS in influencing firms' investment decisions in internal exploratory R&D activities.

Turning to H2b and 2c, it involves a moderator that captures the changing tendency of a firm from "make" to "buy" on innovation activities. We create this moderator of tendency (make-to-buy) for both product innovation and process innovation. Model 3 in Table 5.2.a. shows that EIS has a negative and statistically significant direct effect (beta= -.47, p< .001) on firm's exploitative internal R&D investment, while make-to-buy strategy of product innovation has a positive and statistically significant (beta= .50, p< .01) effect on the relationship between EIS and exploitative internal R&D investment, which means higher tendency towards buy for product innovation strengthens the negative direct effect of EIS on internal exploitative R&D investment; firms with increased tendency towards buy for product innovation decrease internal exploitative R&D investment. Results for process innovation are different, make-to-buy strategy of process innovation has a negative and statistically significant (beta= -.34, p< .05) effect on the relationship between EIS and internal exploitative R&D investment, which means firms with increased tendency towards buy for process innovation reduce the negative direct effect of EIS on internal exploitative R&D investment. Therefore, what the results show in Model 3 is that H2b and H2c are supported in terms of product innovation but not process innovation.

Although we have not developed a hypothesis for the influence of firm make-to-buy strategy on the relationship between EIS and internal exploratory R&D investment, when we test the moderator effect for firms' internal exploratory R&D investment the result shows that neither make-to-buy strategy of process innovation (beta= -.02, [n.s.]) nor make-to-buy strategy of product innovation (beta= -.22, [n.s.]) has a significant influence on the relationship between EIS and firms' internal exploratory R&D investment. Therefore, in this study, we only present the results for the direct effect of EIS on exploratory R&D investment.

Table 5.2.a. The impact of IC and EIS on exploitative R&D investment

		Exploitative R&D Investment											
		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Mode l1	Model 12
	Firm size	-0.36*(0.16)	-0.35*(0.16)	-0.37*(0.16)	-0.36*(0.16)	-0.36*(0.16)	-0.36*(0.16)	-0.35*(0.16)	-0.36*(0.16)	-0.40 *(0.16)	-0.40*(0.16)	-0.42**(0.16)	-0.41*(0.16)
	Membership of a group of companies	0.30*(0.14)	0.39**(0.14)	0.31* (0.14)	0.38**(0.14)	0.30* (0.14)	0.30* (0.14)	0.30* (0.14)	0.30* (0.14)	0.29* (0.14)	0.29* (0.14)	0.29* (0.14)	0.37** (0.14)
	Collaborate with other companies of its own group	0.71***(0.13)	0.23(0.14)	0.63*** (0.14)	0.23(0.14)	0.71*** (0.13)	0.71***(0.13)	0.71*** (0.13)	0.71***(0.13)	0.71*** (0.13)	0.7 ***(0.13)	0.71***(0.13)	0.23 (0.14)
	Importance of information source: within firm or group	-0.17* (0.07)	-0.16*(0.07)	-0.14*(0.07)	-0.14*(0.07)	-0.17*(0.07)	-0.17* (0.07)	-0.17*(0.07)	-0.17* (0.07)	-0.16* (0.06)	-0.16* (0.07)	-0.16* (0.07)	-0.13* (0.07)
	Firm age	-0.46***(0.10)	-0.41***(0.10)	-0.44***(0.10)	-0.41***(0.10)	-0.46***(0.10)	-0.46***(0.10)	-0.46***(0.10)	-0.47***(0.10)	-0.50***(0.10)	-0.49***(0.11)	-0.51***(0.11)	-0.47***(0.10)
	Number of employees	0.67***(0.06)	0.62***(0.06)	0.66***(0.06)	0.62***(0.06)	0.67***(0.06)	0.67***(0.06)	0.68***(0.06)	0.67***(0.06)	0.68***(0.06)	0.67***(0.06)	0.68***(0.06)	0.61***(0.06)
	Public company	-2.05**(0.62)	-1.76**(0.61)	-1.82**(0.62)	-1.16**(0.61)	-2.08**(0.62)	-2.05**(0.62)	-2.05**(0.62)	-2.09**(0.62)	-2.04**(0.62)	-1.97**(0.62)	-2.01**(0.62)	-1.17*(0.48)
	Private national company	-0.87*(0.43)	-0.38(0.43)	-0.64(0.43)	-0.29(0.43)	-0.91*(0.43)	-0.88*(0.43)	-0.88*(0.43)	-0.94*(0.43)	-0.94*(0.43)	-0.91*(0.43)	-0.95*(0.43)	-0.45(0.43)
	Private multinational company	-0.93*(0.45)	-0.41(0.45)	-0.66(0.45)	-0.30(0.45)	-0.96*(0.45)	-0.94*(0.45)	-0.94*(0.45)	-0.99*(0.45)	-1.01*(0.45)	-0.99*(0.45)	-1.03*(0.45)	-0.45(0.45)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation			-0.11(0.10)	-0.22*(0.10)								-0.22*(0.11)
	Make-to-Buy (process): The degree of external sourcing in process innovation			0.17*(0.08)	0.10(0.08)								0.10(0.08)
	H1: Collaborate with external firms		0.24***(0.03)		0.23*** (0.03)								0.23*** (0.03)
	H2a: External information sourcing			-0.47***(0.08)	-0.32*** (0.08)								-0.32*** (0.08)
	H2b, 2c: EIS × Make-to-Buy (product)			0.50**(0.16)	0.54**(0.16)								0.53**(0.16)
	H2b, 2c: EIS × Make-to-Buy (process)			-0.34* (0.13)	-0.28* (0.13)								-0.28*(0.13)
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					-0.01* (0.00)			-0.01* (0.00)				-0.01** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						-0.00 (0.00)		-0.00 (0.00)				-0.00 (0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							0.00 (0.00)	0.00 (0.00)				0.00(0.00)
Chapter 5c	H6: The level of export									0.11***(0.03)		0.10**(0.03)	0.09**(0.03)
	H7: Geographic market scope										0.20**(0.07)	0.09(0.08)	0.08(0.08)
	Constant	9.25***(0.59)	8.52***(0.60)	10.18*** (0.64)	9.43*** (0.64)	9.36*** (0.60)	9.30*** (0.60)	9.23*** (0.59)	9.44*** (0.60)	9.31*** (0.59)	9.20*** (0.59)	9.28*** (0.59)	9.72*** (0.65)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.061	0.077	0.069	0.081	0.061	0.061	0.061	0.061	0.065	0.063	0.065	0.086
	R2_between	0.064	0.085	0.074	0.089	0.064	0.064	0.064	0.064	0.070	0.067	0.070	0.094
	R2_within	0.002	0.003	0.004	0.005	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.005

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5.3.a. The impact of IC and EIS on exploratory R&D investment

		Exploratory R&D Investment											
		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
	Firm size	0.14(0.17)	0.15(0.17)	0.12(0.17)	0.14(0.17)	0.14(0.17)	0.15(0.17)	0.12(0.17)	0.14(0.17)	0.10(0.17)	0.08(0.17)	0.07(0.17)	0.08(0.17)
	Membership of a group of companies	-0.09(0.16)	0.01(0.16)	-0.08(0.16)	-0.00(0.16)	-0.08(0.16)	-0.09(0.16)	-0.09(0.16)	-0.10(0.15)	-0.09 (0.16)	-0.10(0.16)	-0.10(0.16)	-0.03 (0.15)
	Collaborate with other companies of its own group	0.57***(0.15)	0.03(0.16)	0.47**(0.15)	0.03(0.16)	0.56***(0.15)	0.56***(0.15)	0.57***(0.15)	0.56***(0.15)	0.57***(0.15)	0.57***(0.15)	0.57***(0.15)	0.03 (0.16)
	Importance of information source: within firm or group	-0.12+(0.07)	-0.11(0.07)	-0.07(0.07)	-0.07(0.07)	-0.13+(0.07)	-0.12(0.07)	-0.12+(0.07)	-0.12+(0.07)	-0.12+ (0.07)	-0.12 (0.07)	-0.11 (0.07)	-0.07(0.07)
	Firm age	0.14(0.12)	0.19+(0.12)	0.17(0.12)	0.21+(0.12)	0.16(0.12)	0.16(0.12)	0.15(0.12)	0.19(0.12)	0.10(0.12)	0.09(0.12)	0.08(0.12)	0.19(0.12)
	Number of employees	0.44***(0.07)	0.38***(0.07)	0.42***(0.07)	0.38***(0.07)	0.45***(0.07)	0.45***(0.07)	0.44***(0.07)	0.46***(0.07)	0.45***(0.07)	0.44***(0.07)	0.44***(0.07)	0.39***(0.07)
	Public company	-3.95***(0.69)	-3.63***(0.68)	-3.72***(0.68)	-3.50***(0.68)	-3.82***(0.68)	-3.92***(0.69)	-3.96***(0.69)	-3.77***(0.68)	-3.94***(0.69)	-3.84***(0.69)	-3.86***(0.69)	-3.25***(0.68)
	Private national company	-4.34***(0.48)	-3.80***(0.48)	-4.05***(0.48)	-3.65***(0.48)	-4.19***(0.48)	-4.27***(0.48)	-4.32***(0.48)	-4.07***(0.48)	-4.40***(0.48)	-4.41***(0.48)	-4.43***(0.48)	-3.49***(0.48)
	Private multinational company	-4.31***(0.50)	-3.73***(0.50)	-3.98***(0.50)	-3.55***(0.50)	-4.20***(0.50)	-4.25***(0.50)	-4.28***(0.50)	-4.08***(0.49)	-4.38(0.50)	-4.40***(0.50)	-4.41***(0.50)	-3.45***(0.50)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation												
	Make-to-Buy (process): The degree of external sourcing in process innovation												
	H1: Collaborate with external firms		0.28***(0.03)		0.24*** (0.03)								0.23*** (0.03)
	H2a: External information sourcing			-0.68*** (0.09)	-0.52*** (0.09)								-0.47*** (0.09)
	H2b, 2c: EIS × Make-to-Buy (product)												
	H2b, 2c: EIS × Make-to-Buy (process)												
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					0.03*** (0.00)			0.04*** (0.00)				0.04*** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						0.00*** (0.00)		0.01*** (0.00)				0.01***(0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							-0.01** (0.00)	-0.00 (0.00)				-0.00(0.00)
Chapter 5c	H6: The level of export									0.10**(0.03)		0.05(0.04)	0.04(0.04)
	H7: Geographic market scope										0.29***(0.08)	0.23**(0.09)	0.22*(0.09)
	Constant	9.61(0.66)	8.79***(0.67)	11.09*** (0.69)	10.02*** (0.70)	9.20*** (0.66)	9.26*** (0.67)	9.66*** (0.66)	8.69*** (0.67)	9.66*** (0.66)	9.54*** (0.66)	9.58*** (0.66)	9.04*** (0.70)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.044	0.062	0.059	0.069	0.059	0.049	0.046	0.068	0.046	0.047	0.048	0.091
	R2_between	0.052	0.071	0.071	0.081	0.066	0.056	0.054	0.074	0.054	0.057	0.057	0.103
	R2_within	0.003	0.005	0.003	0.004	0.004	0.003	0.003	0.005	0.003	0.003	0.003	0.006

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The summary of hypotheses that are supported and rejected by the results has been shown in the Table 5.4.a.:

Table 5.4.a. Summary of IC and EIS hypotheses that are supported and rejected by the results

	Hypotheses	Supported	Results
Innovation collaboration	H1	Yes	Table5.2.a. and Table 5.3.a.
External information sourcing	H2a	Yes	Table 5.3.a.
	H2b	Yes for product innovation but not process innovation	Table 5.2.a.
	H2c	Yes for product innovation but not process innovation	Table 5.2.a.

5.6.a Robustness Checks

There are two robust tests. First, we examine the influence of establishing inter-organizational relationships (IC and EIS) with universities and competitors on exploratory and exploitative R&D investment. Second, we use share of exploitative R&D investment instead of absolute values as a dependent variable to examine what firm-specific factor determines the investments in exploitative R&D activities.

We pay specific attentions to two external actors, which are universities and competitors. According to evolutionary economics, Nelson (1996) suggested that universities play an important role in firms' R&D activities and technological progress. They can be seen as a repository of public knowledge of science and technology (Nelson, 1996). They offer firms a number of relationship alternatives to enhance knowledge progress (Santoro & Chakrabarti, 2002) so we can compare the effects of different relationships (EIS and IC) on firms' internal R&D. The other important reason for choosing universities is that the data used in this specific research are drawn from the Spanish business innovation survey. An outstanding feature of the Spanish innovation system is the significant importance of universities and public research bodies in constituting the key source of knowledge (Vega-Jurado et al., 2009). In 2004, they occupied 45% of entire national R&D investment and hired over 76% of researchers in Spain (Vega-Jurado et al., 2009). In line with Chaves, et al., (2012), this study considers universities as having a unique role in training scientists and engineers for industry and on the other hand, though not exclusive, they contribute to production of knowledge and scientific advancement (Chaves, et al., 2012).

Getting connection with competitors, especially in the form of collaboration is a popular phenomenon in today's business world with an increased practical significance (Gnyawali & Park, 2011; Walley, 2007; Hamel et al., 1989). Competing firms have relevant resources, so getting connection with them provides firms with opportunities to obtain and create new knowledge (Quintana-Garcia & Benavides-Velasco, 2004; Ritala et al., 2009). Although it has increased in importance, recent studies have not paid sufficient attention to the effect of firms' relations with competitors on internal investment in exploration and exploitation. As a result, except considering universities, we also include competitors in our study. Moreover, firms may need to deal with competitors in their daily operation but they do not have to get contact with universities frequently and generally do not compete with universities in the product market. Therefore, investigating universities and competitors in the study can help us to examine whether the propositions are true in distinct types of external actors.

We focus on two types of IC: IC with universities (COLABUNI) and IC with competitors (COLABCOMPETITORS) in this study. PITEC provides information on whether the company participated in innovation with universities (competitors) during the past three years. In line with previous studies such as Un and Asakawa (2015) and Belderbos et al. (2004b), each is measured with a dummy variable, it takes value 1 if the company has cooperated with universities (competitors) in any of its innovation activities during the past three years. *Collaboration with other types of partners* is a dummy variable, which takes value 1 if the company has cooperated with other types of partners in any of its innovation activities during the past three years.

The variable *KSUNI* indicates how important information from universities was for the company's innovation activities and *KSCOMPETITORS* indicates how important information from competitors was for the company's innovation activities. *Importance of information source: others (excluded universities, competitors and own)* indicates how important the information from other external sources was for the company's innovation activities**.** These three variables are measured by using the 4-point scale (1=not used; 2=reduced; 3=intermediate; 4=high).

We propose that IC with universities/competitors increases firms' investment in internal exploratory and exploitative R&D activities, but the impact on exploratory R&D investment tends to be higher than that on exploitative R&D investment. Moreover, we expect that sourcing information from universities/competitors decrease firms' exploratory and exploitative R&D investment. Table 5.6.a. shows the random effects results for exploration and exploitation investment. Model 1 and Model 4 show the control variables. Model 2 and Model 5 contain both the main effects and the control variables. These results imply that (1) IC with universities/competitors contributes significantly to exploration and exploitation investment, and the impact on exploratory R&D investment is higher than that on exploitative R&D investment. (2) The more important information sourced from universities for firms' innovation projects is, the less investment in firms' exploration and exploitation. (3) The more important information sourced from competitors is, the less investment in firms' exploitation. These results are robust to incorporation of variables for firms' R&D personnel educational levels and internationalization statuses (Model 3 and Model 6), indicating the importance of IC and EIS in influencing firms' investment decisions in internal exploratory and exploitative R&D activities.

The result is consistent with our major hypotheses that IC is complementary to firms' internal exploratory and exploitative R&D investment, whereas EIS has a substitutive effect on a firm's internal exploratory and exploitative R&D investment.

Moreover, we have tested the influence of IC and EIS on the share of exploitative R&D investment.

Technological development expenditure as an indication of the exploitation investment is defined as the ratio of technological development to current internal expenditure (CIE) on R&D. Given the dependent variable with highly skewed distribution and contains zero values, it is necessary to log it in the regression models by using an inverse hyperbolic sine transformation (IHS) (Di Cintio et al., 2017, p.841). The formula is as follows:

$$The\ share\ of\ exploitative\ R\&D\ Investment$$
$$= \ln\Big(The\ ratio\ of\ technological\ development\ to\ CIE\ on\ R\&D$$
$$+ \sqrt{the\ ratio\ of\ technological\ development\ to\ CIE\ on\ R\&D^2 + 1}\Big)$$

Table 5.7.a. shows the random effects results for the share of exploitative R&D investment. Model 1 shows the control variables. Model 2 contains IC and control variables. Model 3 contains EIS, moderator effects and control variables. Model 4 incorporates IC, EIS, and moderator effect and control variables. These results imply that (1) IC with external partners has a positive and statistically significant effect on the share of R&D investment in exploitative activities. (2) The higher tendency towards buy for product innovation strengthens the negative direct effect of EIS on the share of R&D investment in exploitative activities. However, firms with increased tendency towards buy for process innovation reduce the negative direct effect of EIS on the share of exploitative R&D investment. These results are robust to incorporation of variables for firms' R&D personnel educational levels and internationalization statuses (Model 12). The findings are consistent with what we found in Table 5.2.a., which uses absolute value as dependent variable.

Table 5.6.a. Regression results universities and competitors

	Exploitative R&D investment			Exploratory R&D investment		
	Control	Random Effect	Random Effect	Control	Random Effect	Random Effect
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Firm size	-0.36*(0.16)	-0.36*(0.16)	-0.41*(0.16)	0.14(0.17)	0.16(0.17)	0.10 (0.17)
Membership of a group of companies	0.30*(0.14)	0.35*(0.14)	0.34*(0.14)	-0.09 (0.16)	-0.06(0.15)	-0.09 (0.15)
Collaborate with other companies of its own group	0.71***(0.13)	0.35*(0.14)	0.35*(0.14)	0.57*** (0.15)	0.23(0.15)	0.23 (0.15)
Importance of information source: within firm or group	-0.17*(0.07)	-0.14*(0.07)	-0.13*(0.07)	-0.12*(0.07)	-0.07(0.07)	-0.07(0.07)
Firm age	-0.46***(0.10)	-0.41***(0.10)	-0.47***(0.10)	0.14(0.12)	0.24*(0.12)	0.21+ (0.12)
Number of employees	0.67***(0.06)	0.63***(0.06)	0.63***(0.06)	0.44***(0.07)	0.38***(0.07)	0.39***(0.07)
Public company	-2.05**(0.62)	-1.77**(0.61)	-1.78**(0.61)	-3.95***(0.69)	-3.52***(0.68)	-3.28***(0.68)
Private national company	-0.87*(0.43)	-0.42(0.43)	-0.57(0.43)	-4.34***(0.48)	-3.64***(0.48)	-3.50***(0.47)
Private multinational company	-0.93*(0.45)	-0.43(0.45)	-0.58(0.45)	-4.31***(0.50)	-3.53***(0.50)	-3.45***(0.49)
Research association and other research institutions	..	..	..	..	..	..
Year Dummy	Included	Included	Included	Included	Included	Included
Industry Dummy	Included	Included	Included	Included	Included	Included
Internal R&D researchers with PhD qualification in FTE			-0.01**(0.00)			0.04*** (0.00)
Internal R&D researchers with non-doctorate university qualification in FTE			-0.00 (0.00)			0.01*** (0.00)
Internal R&D researchers with non-university qualifications in FTE			0.00(0.00)			-0.00(0.00)
The level of exporting			0.09**(0.03)			0.05(0.04)
Geographic market scope			0.08(0.08)			0.23**(0.09)
COLABCOMPETITORS		0.31*(0.13)	0.32*(0.13)		0.42**(0.14)	0.41**(0.14)
COLABUI		0.29*(0.13)	0.29*(0.13)		0.97***(0.15)	0.92***(0.15)
Collaboration with other types of partners (dummy)		0.44***(0.10)	0.44***(0.10)		-0.02(0.11)	-0.03(0.11)
KSCOMPETITORS		-0.11*(0.05)	-0.10+(0.05)		0.11+(0.06)	0.10+(0.06)
KSUNI		-0.12*(0.05)	-0.13**(0.05)		-0.34***(0.06)	-0.33***(0.06)
Importance of information source: others		-0.12(0.10)	-0.13(0.10)		-0.32**(0.11)	-0.29**(0.11)
Constant	9.25***(0.59)	9.49***(0.63)	9.76***(0.64)	9.61*** (0.66)	10.26***(0.69)	9.29*** (0.70)
N	13388	13388	13388	13388	13388	13388
R2_overall	0.061	0.076	0.081	0.044	0.076	0.097
R2_between	0.064	0.084	0.090	0.051	0.089	0.109
R2_within	0.002	0.003	0.004	0.003	0.006	0.008

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5.7.a. The influence of IC and EIS on the share of exploitative R&D investment

		The share of exploitative R&D investment											
		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Mode l1	Model 12
	Firm size	-0.15*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.15*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.16**(0.06)	-0.16*(0.06)	-0.16**(0.06)	-0.16**(0.06)
	Membership of a group of companies	0.07(0.06)	0.09(0.06)	0.07(0.06)	0.09(0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.09(0.06)
	Collaborate with other companies of its own group	0.18**(0.05)	0.08(0.06)	0.16*(0.05)	0.08(0.06)	0.18** (0.05)	0.18*** (0.05)	0.18** (0.05)	0.19*** (0.05)	0.18** (0.05)	0.18** (0.05)	0.18** (0.05)	0.08(0.06)
	Importance of information source: within firm or group	-0.03 (0.03)	-0.03 (0.03)	-0.03 (0.03)	-0.03 (0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03 (0.03)
	Firm age	-0.14**(0.04)	-0.13**(0.04)	-0.14**(0.04)	-0.13**(0.04)	-0.14***(0.04)	-0.14**(0.04)	-0.14**(0.04)	-0.15***(0.04)	-0.15***(0.04)	-0.14**(0.04)	-0.15***(0.04)	-0.15***(0.04)
	Number of employees	0.09***(0.02)	0.08***(0.02)	0.09***(0.02)	0.08**(0.02)	0.09***(0.02)	0.09***(0.02)	0.10***(0.02)	0.09***(0.02)	0.10***(0.02)	0.09***(0.02)	0.10***(0.02)	0.08**(0.02)
	Public company	-0.08(0.24)	-0.02(0.24)	-0.04(0.24)	-0.01(0.24)	-0.11(0.24)	-0.09(0.24)	-0.08(0.24)	-0.13(0.24)	-0.08(0.24)	-0.07(0.24)	-0.08(0.24)	-0.03(0.24)
	Private national company	0.33+(0.17)	0.43*(0.17)	0.37*(0.17)	0.44**(0.17)	0.29+(0.17)	0.31+(0.17)	0.32+(0.17)	0.26(0.17)	0.31+(0.17)	0.32+(0.17)	0.31+(0.17)	0.37*(0.17)
	Private multinational company	0.27(0.17)	0.37*(0.18)	0.32+(0.18)	0.39*(0.18)	0.24(0.17)	0.25(0.17)	0.26(0.17)	0.21(0.17)	0.25(0.17)	0.26(0.17)	0.25(0.17)	0.33+(0.18)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation			-0.02(0.04)	-0.04(0.04)								-0.04 (0.04)
	Make-to-Buy (process): The degree of external sourcing in process innovation			0.07*(0.03)	0.05+(0.03)								0.05(0.03)
	H1: Collaborate with external firms		0.05***(0.01)		0.05*** (0.01)								0.05***(0.01）
	H2a: External information sourcing			-0.07*(0.03)	-0.04 (0.03)								0.05(0.03)
	H2b, 2c: EIS × Make-to-Buy (product)			0.21**(0.06)	0.22***(0.06)								0.22***(0.06)
	H2b, 2c: EIS × Make-to-Buy (process)			-0.12* (0.05)	-0.10 *(0.05)								-0.11*(0.05)
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					-0.01*** (0.00)			-0.01*** (0.00)				-0.01*** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						-0.00** (0.00)		-0.00 ***(0.00)				0.00(0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							0.00+(0.00)	0.00 (0.00)				0.00(0.00)
Chapter 5c	H6: The level of export									0.02*(0.01)		0.03+(0.01)	0.02+(0.01)
	H7: Geographic market scope										0.02(0.03)	-0.00(0.03)	-0.01(0.03)
	Constant	3.54***(0.23)	3.39***(0.23)	3.63*** (0.25)	3.48*** (0.25)	3.63*** (0.23)	3.62*** (0.23)	3.53*** (0.23)	3.74*** (0.24)	3.55*** (0.23)	3.53*** (0.23)	3.55*** (0.23)	3.73***(0.26)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.015	0.019	0.017	0.020	0.019	0.016	0.016	0.021	0.016	0.015	0.016	0.028
	R2_between	0.017	0.022	0.018	0.022	0.020	0.017	0.018	0.021	0.019	0.017	0.019	0.030
	R2_within	0.003	0.003	0.004	0.005	0.003	0.003	0.003	0.004	0.002	0.003	0.002	0.006

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.7.a Discussion

By drawing on the literature of evolutionary economics, open innovation and organizational learning, this study investigates the relationship between EIS and IC respectively with firms' internal exploratory and exploitative R&D investment. The results show that IC and EIS affect firms' internal investment in exploratory and exploitative R&D differently. We find that IC is mainly complementary to firms' internal exploratory R&D. Firms tend to increase more investment in exploratory R&D than exploitative R&D during the IC. However, EIS has a substitutive effect on a firm's internal exploratory R&D investment. Furthermore, we find that the influence of EIS on a firm's internal exploitative R&D investment is conditional upon a firm's tendency towards core-development (by using a "make" strategy to beat the market through internal exploitation efforts) or periphery-development (by using a "buy" strategy to let the market implement the exploitation for it).

5.7.1.a Theoretical implications

Evolutionary economics and open innovation literature point to the importance of external ideas for firms' innovation activities (Chaves et al., 2012). Early studies of evolutionary economics adopt Willamson's economics of transaction costs theory to explain firms' choice between internal and external R&D (Laursen & Salter, 2006). They found a substitution effect. Later on, studies in this area found a complementary relationship between them (Mowery & Rosenberg, 1989). Current studies in open innovation explain the complementarities or substitution effect between external knowledge and internal R&D by focusing on firm-specific characteristics such as organizational structure (Lichtenthaler, 2011) and qualified personnel (Monteiro et al., 2017). However, they remained relatively silent on the impact of forms of inter-organizational relationships such as EIS and IC on firm's two types of internal R&D: exploration and exploitation. Our study extends current thinking by revealing that the variation in firms' exploration and exploitation investment is influenced by the way of firms acquiring external knowledge (formal inter-organizational relationship vs. informal inter-organizational relationship). We stress on organizational learning theory by arguing that IC facilitates firms' exploratory R&D investment through developing the experiential learning capabilities of the firms, and facilities firms' exploitative R&D investment by building the commercialization capabilities of the firm. We suggest that EIS reduces firms' exploratory R&D investment by providing solutions to a firm's unsolved problems through external distant search.

We also contribute to prior studies by revealing that the exploratory and exploitative R&D investment decisions can be better understood by a moderating effect of a firm development tendency. Although the availability and explicitness of external knowledge increases the appeal of using the market, not all firms use external information with the purpose of accepting what is offered in the external market due to the risk of "buy" decision such as losing control of core competence and failing to obtain tacit knowledge through EIS. A firm's tendency to use "make" strategy in order to "beat the market" by conducting the product innovation by itself with the expectation that it offers better alternatives, and this process aims at building its core-capability, thus reduces the negative relationship between EIS and firm's exploitation investment. A firm's tendency to use "buy" strategy in order to take advantage of what the market offers by letting the market do it for the firm with the expectation that the market's offering helps the firm expand its product range quickly (peripheral development) with "just fine" inputs, thus it strengthens the negative relationship between EIS and firm's exploitative R&D investment. However, the situation is different for process innovation. In the PITEC survey, process innovation is defined as "innovation aimed at achieving greater flexibility and the improvement in quality and security such as automatic tracking of shipments and transport systems connection" (PITEC survey, 2010, p.18). The process innovation is more internal and tacit to the firm than product innovation (Un & Asakawa, 2015). According to the knowledge-based view, tacit knowledge is difficult to be understood by people outside of the firm (Kogut and Zander, 1993). Therefore, when a firm has a tendency to use "buy" strategy, the high importance of information sourced from markets for a firm's innovation activities means the firm needs to make more efforts on integration of external production methods in their own production activities, thus reducing the negative relationship between EIS and the firm's exploitation investment. This finding is in line with Un and Asakawa (2015), which supports that the empirical research of product innovation does not always apply to process innovation. Our study enhances researchers' understanding on how firms make decisions in exploration and exploitation when they sourcing information externally.

5.7.2.a Management and policy implications

Our findings also have critical managerial implications. They show that collaborating with external partners can increase firms' investment in exploratory and exploitative R&D activities because innovation collaboration facilitates learning in organizations. However, innovation collaboration does not have the same level of impact on exploratory and exploitative R&D investment. This finding suggests that if a manager or policy maker wants firms to increase their exploratory R&D spending, innovation collaboration is likely to be the most effective measure. Moreover, we find that EIS reduces firms' exploratory R&D investment because EIS can help firms to find new solutions from the market for problems that they have not experienced before. We suggest that managers could adopt EIS to shun away from substantial and risky sunk R&D investment when dealing with tough innovation problems. Since we find firms' development orientations influences firms' exploitative R&D investment, we suggest that managers should understand the development orientation of their firms before they design measures for facilitating exploitative R&D investment. Only when the firm has a goal of developing core competence, the EIS is an effective measure for firms to facilitate their exploitative R&D investment. Our findings support the view of Schartinger et al. (2002) that IC and EIS are used for opposite needs.

5.7.3.a Limitations and directions for future research

Due to data constraints, at this stage of this study, we were unable to investigate the effect of EIS and IC on firms' exploration and exploitation investment at a global level. Sourcing information worldwide and collaborating with foreign partners may generate different effects on the organizational learning compared with domestic ones. Future research could focus on international EIS and international IC and compare results with our research to find out similarities and differences. Second, this study depends on secondary data. Although we could acquire all necessary information about variables from the PITEC survey, which continuously collect data from 2003-2011 for 12000 firms from 14 main industry sectors, future researchers could collect first-hand data to generate insights on other firm-specific factors such as merger and acquisitions and governance structures, and then use learning mechanisms introduced in this study to explain their relationship with firms' internal exploration and exploitation investment.

Chapter 5b Educational Level of R&D Personnel

Abstract

Unlike prior studies that found a positive relationship between education level and firms' R&D investment, we show that education stimulates a firm's exploratory R&D investment but reduces exploitative R&D investment. Moreover, it is only the high level of education, such as university degrees, that influences a firm's R&D investment. Researchers with non-university degrees (e.g. with technical qualifications) do not have a significant effect on a firm's exploratory and exploitative R&D investment. This study generates novel insights on how the variance in firms' exploration and exploitation investment can be explained by R&D personnel of firms. Our findings have implications for research as well as for managers and policy makers concerned with the supply of individuals' education to balance firms' exploration and exploitation.

5.1.b Introduction

Firms need to invest in both exploratory and exploitative R&D investment to sustain current competitiveness while achieving long-term success. Exploration and exploitation compete for scarce resources (March, 1991). The order of consideration of investment depends on the part of the organization in which the decision is being made, indicating that firm level of exploration and exploitation investment to a large extent originate in organizational division of labour in decision-making (Cyert & March, 1992). However, only few studies have paid attention to individual-level effects on firms' exploration and exploitation investment (Zacher et al., 2014). In addition, the existing research merely focuses on the higher levels of decision makers such as managers (Mom et al., 2007) and entrepreneurs (Adomako et al., 2017;

Lynskey, 2016; Tuncdogan et al., 2015; Hmieleski & Baron, 2008; Ganotakis, 2012). We argue that more attention should be paid to the education level of firm R&D personnel, because exploration (basic research and applied research) and exploitation (technological development) are current internal R&D activities of firms. Paying attention to researchers dedicated to internal R&D activities within firms can enhance the understanding of firms' investment in exploration and exploitation (Sauermann & Cohen, 2010). Researchers with different educational levels may consider different things as important and have distinct definitions of problems facing the organization (Allen & Katz, 1992). Their past experience (network benefits and confidence in exploratory-related activities) influences the ability and acceptance of learning new knowledge (willingness to take a risk). In other words, R&D personnel constructs a firm's innovative climate and openness to technological innovation (Hosseini et al., 2003) and influences a firm's ability to process new information and knowledge (Toner, 2011; Nelson & Phelps, 1966). Therefore, the educational level of R&D personnel can affect a firm's focus on organizational learning and result in differences in firms' exploratory and exploitative R&D investment.

Some empirical studies on human resource management (HRM) and organizational learning found that high levels of education such as PhD and undergraduate degrees (general human capital) encourage the exploratory learning of a firm (Diaz-Fernandez et al, 2017; Ganotakis, 2012). High levels of education enhance employees' communication, social and learning abilities (Avermaete et al., 2004). These abilities enable firms to search and scan environments for information about changes, identify viable business opportunities and search for distant knowledge for possible alternatives that facilitate a firm's exploratory learning (Marvel & Lumpkin, 2007; Boeker & Karichalil, 2002).

Existing empirical findings do not always confirm that high levels of educational qualification facilitate firms' exploratory learning. These studies report that high level of specialization and strong academic tendency may impede researchers' understanding of the dynamics and needs of the market (Toole & Czarnitzki, 2009). For example, Ucbasaran et al., (2008) found that entrepreneurs with high levels of education lead to inertia in firms' explorative learning, because these entrepreneurs tend to think that their education is sufficient to provide all the information needed to achieve their organizational goal. This attitude encourages firms to scan and concentrate their search activities within their current knowledge base, rather than searching for distant or new information that has not been accessed previously (Cooper et al., 1994; Fiet, 2002). From this point of view, the high educational qualification of entrepreneurs tends to decrease firms' alertness to environmental changes and may have a preference towards exploitative learning, such as learning knowledge from routines that performed well in the current or/and past (Ucbassaran et al., 2008).

The mixed results prompt the need to better understand how the level of education affects the organizational learning. We propose that the variance in firms' exploratory and exploitative R&D investment can be explained by firms' R&D personnel education level, because different levels contain different capabilities for firms' exploratory and exploitative learning. We argue that a firm that has a higher proportion of internal R&D researchers with doctorate qualifications in FTE tends to make different investment decisions in exploration and exploitation compared with a firm with higher proportion of non-doctorate university qualifications or non-university qualifications in FTE.

There are some contributions of this study. Much of the literature in organizational learning focuses on education of higher level of decision makers such as managers and entrepreneurs (Adomako et al., 2017; Lynskey, 2016; Tuncdogan et al., 2015; Hmieleski & Baron, 2008; Ganotakis, 2012). We extend prior research by emphasizing the R&D personnel of firms. We find that a higher proportion of internal R&D researchers with doctorate qualifications increases firms' exploratory R&D investment but decreases firms' exploitative R&D investment. Second, prior studies in human capital literature suggested that an employee's intelligence, motivation and discipline can be assessed by educational level (Ucbasaran et al., 2008). Employees with high level of education are very likely to be trusted in decision-making. These studies found that education contributes to more efficient decision-making (Griliches, 2000). Our research classified education into several levels, and it not only provides evidence of a significant influence between higher educated R&D researchers (PhDs and masters) and firms' decision making in exploratory and exploitative R&D investment, but also makes a contribution to prior studies by showing evidence of an insignificant relation between lower educated R&D researchers (non-university degrees) and firms' decision marking in exploratory and exploitative R&D investment. This study helps researchers and managers to understand the learning capabilities of researchers of different education levels. To address this issue, firms and policymakers can design better education, training and reward systems for their R&D personnel in order to promote organizational learning (Hatch & Dyer, 2004; Diaz-Fernandez et al., 2017).

5.2.b Literature Review

5.2.1.b Education as a determinant of firm-level R&D investment

Educational qualification of the labour force is one of the crucial determinants of firms' R&D activities (Allen & Katz, 1992; Jain & Murray, 1984). Knowledge and skills are often acquired through education, which produce formal qualifications in terms of doctorate, degrees and diplomas (OECD, 1995). The relationship between education and firm-level R&D investment was examined in previous studies (Lynskey, 2016; Roach and Sauermann, 2010; Scherer and Huh, 1992). They found that educational qualification often has a positive relationship with R&D investment levels (Herrera et al., 2010; Del Canto & Gonzalez, 1999). High educational levels, especially doctorate degrees, can be assumed to help promote the recognition and management of firms' relevant external knowledge flows (Lynskey, 2016; OECD, 2008; Stuart and Ding, 2006; Bercowitz and Feldman, 2008; Baba et al., 2010). Employees with higher education will enhance firms' adaptability to environmental changes (Lundvall & Nielsen, 1999) and facilitate firms' innovation (Coronado et al., 2008; McGuirk et al., 2015; Lynskey, 2016). Since R&D is often considered as an important input to innovation and the level of R&D investment by firms often presents a proxy of innovative activity (Griliches, 1990), the educational level of employees is positively related to firms' R&D investment.

The prior empirical research in organizational learning literature did not relate firms' different R&D investment to firms' exploratory learning or exploitative learning. Our study proposes that each level of educational qualification may result in different types of organizational learning, and hence cause a variance in firms' exploratory and exploitative R&D investment. Research emphasizing individual educational qualification related to firms' organizational learning mainly use scales to identify two dimensions of organizational learning (Diaz-Fernandez et al., 2017), which motivates us to examine the issue at different types of R&D investment.

5.3.b Hypotheses Development

There exists a dual nature of PhD education, which can be described as "process" and "product" (Lee et al., 2010). "Process" refers to the view that a PhD provides professional research training to develop independent researchers. The training can enhance one's ability to conduct independent research, which is a general skill. A thesis as the final "product" of the PhD education has been used to assess the abilities of graduates to make original and frontier of knowledge to their specific disciplines. Hence, a PhD graduate is specialized in his/her research area and also has transferable and general skills such as learning ability, communication and social abilities (Teixeira & Tavares-Lehmann, 2014; Lee et al., 2010; Avermaete et al., 2004). PhDs' specialized knowledge and general skills help a firm to recognize or create opportunities in the environment (Marvel & Lumpkin, 2007; Shane, 2003; Arenius & De Clercq, 2005; Witt, 1998).

PhDs' high learning ability enables a firm to pursue the perceived attractive opportunities and experiment the possible alternatives that can enhance decision-making (Davidsson & Honig, 2003). Moreover, PhDs on average possess a higher level of self-confidence, creativity and openness to new knowledge (Hitt & Tyler, 1991; Wally & Baum, 1994). Therefore, the internal R&D researchers with PhD degrees are very likely to motivate a firm to set up new research projects so as to pursue business opportunities new to the firm or/and to the market. As a result, researchers with PhD degrees will increase firms' investment in experimental and original work (basic research and applied research) to construct abstract ideas that meet the opportunities they perceive in the market. For instance, an increased demand for electrified, networked and intelligent vehicles provides great business opportunities for the IT industry (Debord, 2017). IT companies with large proportions of PhDs in R&D are more likely to be the industry pioneers, because PhD researchers not only can help firms to be the first group of firms that recognize these emerged opportunities but also encourage firms to take the risks and engage in scientific experiments for constructing technological ideas, such as in-car information technologies and self-driving solutions that meet the opportunities.

PhDs' communication and social abilities help firms to search and manage external knowledge flow (OECD, 2008), and hence increase exploratory learning of the firms. Upon entering industrial employment, PhDs continue to make connections, both formal and informal, to researchers both within and outside of their research areas and professions (Ponomariov & Boardman, 2010). These connections (e.g. established through attendance at professional conference and memberships in professional societies or publishing) facilitate both explicit and tacit knowledge flow (Ponomariov & Boardman, 2010; Cockburn & Henderson, 1998; Sauermann & Stephan, 2009). Firms can have access to scientific information from connections established by their PhDs (Adler & Kwon, 2002; Fischer & Pollock, 2004) and incorporate this scientific knowledge into the firm's knowledge base through PhDs' guidance (Herrera & Nieto, 2013; Cruz-Castro & Sanz-Menendez, 2005; Zellner, 2003; Almeida & Kogut, 1999). The broad scientific knowledge base helps firms to analytically approach scientific problems (Ponomariov & Boardman, 2010) and overcome a particular knowledge barrier during the scientific experimentation (Almeida et al., 2011). Firms with a higher proportion of internal R&D researchers with PhD degrees tend to experience small risks in exploration and thus are more likely to invest in exploration.

Cyert and March (1992) argued that search bias reflects special training or experience of different units of the organization. PhDs are trained for research. Doing the path-breaking research and publishing research results are long seen as critical to PhDs (Stephan & Levin, 1992; Stern, 2004). Prior studies found that higher education employees, especially PhDs, often desire intellectual challenges and like to select more technological significant projects (Diaz-Fernandez et al., 2017; Banker et al., 2008). They are mainly responsible for achieving the adequate and proportionate share of the publication and patent output in firms (Sauermann and Cohen, 2010). Because of these goals, PhD researchers are more likely to consider that developing firms' competitive advantages through long-term capabilities is much more important than through developing short-term capabilities. Therefore, firms with a large percentage of PhD researchers are more likely to increase investment in exploration.

Moreover, PhDs increase firms' possibilities to get high returns from basic research (Smith et al., 2005; Ucbasaran et al., 2008) that encourage firms to invest in exploration. Prior studies identified a positive relationship between education and firm innovation (Bhide, 2000) and growth (Wilbon, 2000; Almus & Nerlinger, 1999). PhD researchers in firms are often considered as a stamp of research quality (Corolleur et al., 2004). The highest education helps PhDs to improve their cognitive processing and problem-solving abilities (Kimberly & Evanisko, 1981; Hitt & Tyler, 1991; Wally & Baum, 1994; Ucbasaran et al., 2008). They can propose distant solutions to the problems by using imagination combined with techniques such as analogies and associations (Ray & Myers, 1986) and can accurately predict outcomes, manage time and resources as well as monitor results (Smith et al., 2005). Moreover, because of their strong learning abilities, they can accompany the development of technology at all stages, which helps to bridge the gap between different types of R&D activities and hence contributes to reducing the risk of a failure of innovation project (Herrera & Nieto, 2013). Therefore, firms with a large proportion of PhD researchers are more likely to increase exploratory R&D investment, because possessing PhD researchers increases firms' expectation of returns from basic research.

PhD researchers reduce the costs of production and refinement of new products (exploitative R&D investment), because their wide range of skills enable firms to develop a road map for all design, engineering and manufacturing activities. They help firms to select technologies that can be effectively integrated into a new product, and therefore reduce the costs and time of manufacturing and refining the new product (avoid costs of scrap and rework) (Iansiti & West, 1997).

According to the attention theory, even though PhDs may have the ability to recognize various problems in both firms' experimentation and production processes, only few of problems can get sufficient attention due to time limits (Ocasio, 1997). Individuals adapt their attention rules based on previous experience (Cyert & March, 1992). They learn to attend to some issues and ignore others to which they are generally not able to provide satisfactory solutions (Cyert & March, 1992). PhDs' university experience increases their confidence in doing experimentation and original work, which facilitates their perception and search activities towards exploratory R&D activities and hence hinders perception and search activates towards exploitative R&D activities.

***H3**: A higher proportion of internal R&D researchers with doctorate qualifications in FTE increase firms' exploratory R&D investment but decrease firms' exploitative R&D investment.*

Although graduates are also highly-educated workforce, the academic training they receive at university differs significantly from what is designed for PhDs. The process of PhD study has often been considered as a journey of individual learning (Lee et al., 2010), whereas undergraduate and master programmes focus more on collaborative learning (Britton, et al., 2017). Teamwork is an essential outcome of non-doctorate university study (Schech et al., 2017). Therefore, researchers with non-doctorate university degrees are better at identifying skill-integration problems. They facilitate firms' knowledge integration through improving firms' team level of learning (Grant, 1996). They allow firms to collectively interpret and combine individuals' knowledge to attain a shared understanding (Bontis et al., 2002). Each member of the teams has been encouraged to explore issues from alternative perspectives, articulating their options to others and taking coordinated action to achieve a common goal (Lin & Sanders, 2017). Diverse perspectives, enriched interpretations and coordination are important enablers for exploratory learning (Gupta et al., 2007; Shipton et al., 2017), so we expect that a firm's the proportion of internal R&D researchers with non-doctorate university qualification is positively related to its exploratory R&D investment.

Moreover, as higher education develops students' expert intuition, entrepreneurial intuition and time management skills (a specific deadline for each task) (Bates, 1990), researchers who hold qualifications at undergraduate and master levels often have in-depth knowledge of their specific subject areas, such as engineering or architecture, as well as knowledge of business practices, such as managerial and marketing skills. With entrepreneurial intuitions, highly-educated researchers are able to implement and effectively introduce technologically complex and radically new products to a market (Crossan et al., 1999; Leonard-Barton & Kraus, 1985). They facilitate firms to invest in exploitation to exploit firms' existing technological innovation so that firms can reduce new products' time to market.

In summary, in line with Lundvall & Johnson (1994), we expect that graduates not only have abilities to invent a new technology but also have abilities to implement the new technology. They facilitate firms' exploratory learning and exploitative learning, resulting in an increase in firms' exploration and exploitation investment.

H4: *A higher proportion of internal R&D researchers with non-doctorate university qualifications in FTE increase firms' exploratory R&D investment and exploitative R&D investment.*

Education contributes to individuals' cognitive capability and influences their working methods (Østergaard, et al., 2011; Bantel & Jackson, 1989). Researchers with non-university degrees (Diplomas; technical architects and engineers, specific professional training and secondary school) are often specialized in a knowledge domain. The knowledge and skills they learnt are "less transferable and have a narrower scope of applicability" (McGuirk et al., (2015), p.967), and hence researchers with non-university degrees are believed to be poor at exploratory learning (Diaz-Fernandez et al., 2017; Kang & Snell, 2009).

The non-university education aims at developing students' expert intuition (accepting old patterns). The expert intuition encourages researchers to utilize experience from previous innovation projects to approach and solve problems (Lin & Sanders, 2017). Therefore, they are likely to search solutions along their existing technological trajectories and use existing ways of doing things (Iansiti & West, 1997; Ganotakis, 2012). Kang & Snell (2009) found that researchers with non-university degrees are likely to be confined to a particular perspective (Kang & Snell, 2009) and are less willing to use knowledge outside of their domains (Dougherty, 1992). They tend to hinder a firm's exploratory learning. The new knowledge they learnt is an extension of what they understand already, rather than being completely new (Diaz-Fernandez et al., 2017; Ray & Myers, 1986). As exploitation is about implementation and production and is mainly related to path dependence, routinisation and current technologies and markets (Brown & Eisenhardt, 1998), researchers with non-university degrees contribute to a firm's exploitative learning (Diaz-Fernandez et al., 2017). They are likely to facilitate firms to invest in exploitation such as refinement of technology and production, while hindering firms' investment in exploration.

***H5:** A higher proportion of internal R&D researchers with non-university qualifications in FTE increase firms' exploitative R&D investment, but decrease firms' exploratory R&D investment.*

5.4.b Results

Results on the effect of researchers' educational level on firms' exploratory and exploitative R&D investment

To test the effect of researchers' educational level on firms' exploitative and exploratory R&D investment, Model 5-7 in Table 5.1.b. and 5.2.b. introduce three measures of researchers' educational level, successively. The first hypothesis of this sub-chapter of empirical chapters (H3) involves the role of internal R&D researchers with PhD qualification in FTE. As the Model 5 indicates, this measure has a negative and statistically significant (beta= -.01, $p < .01$) effect on firms' exploitative R&D investment while having a positive and statistically significant (beta= .03, $p < .001$) effect on firms' exploratory R&D investment, thus fully supporting H3, showing that a higher proportion of internal R&D researchers with doctorate qualifications in FTE increase firms' exploratory R&D investment but decrease firms' exploitative R&D investment.

Turning to the second hypothesis (H4), it involves the role of internal R&D researchers with non-doctorate university qualification in FTE. The Model 6 shows that this measure has a negative and statistically insignificant (beta= -.00, not significant [n.s.]) effect on exploitative R&D investment, while generating a positive and statistically significant (beta= .00, p< .001) effect on firms' exploratory R&D investment. These results provide only partial support to H4, showing that only firms' exploratory R&D investment increases as the proportion of internal full-time researchers with non-doctorate university degree.

H5 involves the role of internal R&D researchers with non-university qualification in FTE. Model 7 shows that this measure has a positive and statistically insignificant (beta= .00, n.s.) effect on exploitative R&D investment, while generating a negative and statistically significant (beta= .01, p< .01) effect on firms' exploratory R&D investment. These results provide partial support to H5, showing that the proportion of internal R&D researchers with non-university qualifications in FTE only can determine firms' exploitative R&D investment.

When we include all measures of educational level simultaneously in Model 8, only results for PhD qualification and non-doctorate university qualification remain qualitatively the same. The results for non-university qualification shows that this measure has an insignificant effect on both exploratory (beta= -.00, n.s.) and exploitative R&D investment (beta= .00, n.s.), indicating that firms' exploratory and exploitative R&D investment are significantly influenced by the proportion of internal highly-educated researchers (PhDs and other university degrees) in FTE, rather than lower-educated researchers (non-university degrees) in FTE. These results are robust to inclusion of variables for inter-organizational relationships and internationalization statuses (Model 12), thus H5 is rejected in Model 8 and Model 12.

In conclusion, firms' internal researchers with PhD qualification in FTE can generate effect on firms' exploratory and exploitative R&D investment. The highest education facilitates firms' exploratory R&D investment but reduces firms' exploitative R&D investment. Firms' internal researchers with non-doctorate university qualification in FTE contribute to the increase in firms' exploratory R&D investment. Firms' internal researchers with non-university degrees do not influence on firms' exploratory and exploitative R&D investment. Our results suggest that only the proportion of internal R&D researchers with high level of education critically influence a firm's R&D investment decision. Education does not facilitate all types of R&D investment. It only promotes firms' exploration investment and may hinder a firm's exploitation investment.

Table 5.1.b. The impact of R&D personnel's educational level on exploitative R&D investment

		Exploitative R&D Investment											
		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Mode l1	Model 12
	Firm size	-0.36*(0.16)	-0.35*(0.16)	-0.37*(0.16)	-0.36*(0.16)	-0.36*(0.16)	-0.36*(0.16)	-0.35*(0.16)	-0.36*(0.16)	-0.40 *(0.16)	-0.40*(0.16)	-0.42**(0.16)	-0.41*(0.16)
	Membership of a group of companies	0.30*(0.14)	0.39**(0.14)	0.31* (0.14)	0.38**(0.14)	0.30* (0.14)	0.30* (0.14)	0.30* (0.14)	0.30* (0.14)	0.29* (0.14)	0.29* (0.14)	0.29* (0.14)	0.37** (0.14)
	Collaborate with other companies of its own group	0.71***(0.13)	0.23(0.14)	0.63*** (0.14)	0.23(0.14)	0.71*** (0.13)	0.71***(0.13)	0.71*** (0.13)	0.71***(0.13)	0.71*** (0.13)	0.7 ***(0.13)	0.71***(0.13)	0.23 (0.14)
	Importance of information source: within firm or group	-0.17* (0.07)	-0.16*(0.07)	-0.14*(0.07)	-0.14*(0.07)	-0.17*(0.07)	-0.17* (0.07)	-0.17*(0.07)	-0.17* (0.07)	-0.16* (0.06)	-0.16* (0.07)	-0.16* (0.07)	-0.13* (0.07)
	Firm age	-0.46***(0.10)	-0.41***(0.10)	-0.44***(0.10)	-0.41***(0.10)	-0.46***(0.10)	-0.46***(0.10)	-0.46***(0.10)	-0.47***(0.10)	-0.50***(0.10)	-0.49***(0.11)	-0.51***(0.11)	-0.47***(0.10)
	Number of employees	0.67***(0.06)	0.62***(0.06)	0.66***(0.06)	0.62***(0.06)	0.67***(0.06)	0.67***(0.06)	0.68***(0.06)	0.67***(0.06)	0.68***(0.06)	0.67***(0.06)	0.68***(0.06)	0.61***(0.06)
	Public company	-2.05**(0.62)	-1.76**(0.61)	-1.82**(0.62)	-1.16**(0.61)	-2.08**(0.62)	-2.05**(0.62)	-2.05**(0.62)	-2.09**(0.62)	-2.04**(0.62)	-1.97**(0.62)	-2.01**(0.62)	-1.17*(0.48)
	Private national company	-0.87*(0.43)	-0.38(0.43)	-0.64(0.43)	-0.29(0.43)	-0.91*(0.43)	-0.88*(0.43)	-0.88*(0.43)	-0.94*(0.43)	-0.94*(0.43)	-0.91*(0.43)	-0.95*(0.43)	-0.45(0.43)
	Private multinational company	-0.93*(0.45)	-0.41(0.45)	-0.66(0.45)	-0.30(0.45)	-0.96*(0.45)	-0.94*(0.45)	-0.94*(0.45)	-0.99*(0.45)	-1.01*(0.45)	-0.99*(0.45)	-1.03*(0.45)	-0.45(0.45)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation			-0.11(0.10)	-0.22*(0.10)								-0.22*(0.11)
	Make-to-Buy (process): The degree of external sourcing in process innovation			0.17*(0.08)	0.10(0.08)								0.10(0.08)
	H1: Collaborate with external firms		0.24***(0.03)		0.23*** (0.03)								0.23*** (0.03)
	H2a: External information sourcing			-0.47***(0.08)	-0.32*** (0.08)								-0.32*** (0.08)
	H2b, 2c: EIS × Make-to-Buy (product)			0.50**(0.16)	0.54**(0.16)								0.53**(0.16)
	H2b, 2c: EIS × Make-to-Buy (process)			-0.34* (0.13)	-0.28* (0.13)								-0.28*(0.13)
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					-0.01* (0.00)			-0.01* (0.00)				-0.01** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						-0.00 (0.00)		-0.00 (0.00)				-0.00 (0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							0.00 (0.00)	0.00 (0.00)				0.00(0.00)
Chapter 5c	H6: The level of export									0.11***(0.03)		0.10**(0.03)	0.09**(0.03)
	H7: Geographic market scope										0.20**(0.07)	0.09(0.08)	0.08(0.08)
	Constant	9.25***(0.59)	8.52***(0.60)	10.18*** (0.64)	9.43*** (0.64)	9.36*** (0.60)	9.30*** (0.60)	9.23*** (0.59)	9.44*** (0.60)	9.31*** (0.59)	9.20*** (0.59)	9.28*** (0.59)	9.72*** (0.65)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.061	0.077	0.069	0.081	0.061	0.061	0.061	0.061	0.065	0.063	0.065	0.086
	R2_between	0.064	0.085	0.074	0.089	0.064	0.064	0.064	0.064	0.070	0.067	0.070	0.094
	R2_within	0.002	0.003	0.004	0.005	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.005

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5.2.b. The impact of R&D personnel's educational level on exploratory R&D investment

Exploratory R&D Investment

		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
	Firm size	0.14(0.17)	0.15(0.17)	0.12(0.17)	0.14(0.17)	0.14(0.17)	0.15(0.17)	0.12(0.17)	0.14(0.17)	0.10(0.17)	0.08(0.17)	0.07(0.17)	0.08(0.17)
	Membership of a group of companies	-0.09(0.16)	0.01(0.16)	-0.08(0.16)	-0.00(0.16)	-0.08(0.16)	-0.09(0.16)	-0.09(0.16)	-0.10(0.15)	-0.09 (0.16)	-0.10(0.16)	-0.10(0.16)	-0.03 (0.15)
	Collaborate with other companies of its own group	0.57***(0.15)	0.03(0.16)	0.47**(0.15)	0.03(0.16)	0.56***(0.15)	0.56***(0.15)	0.57***(0.15)	0.56***(0.15)	0.57***(0.15)	0.57***(0.15)	0.57***(0.15)	0.03 (0.16)
	Importance of information source: within firm or group	-0.12+(0.07)	-0.11(0.07)	-0.07(0.07)	-0.07(0.07)	-0.13+(0.07)	-0.12(0.07)	-0.12+(0.07)	-0.12+(0.07)	-0.12+ (0.07)	-0.12 (0.07)	-0.11 (0.07)	-0.07(0.07)
	Firm age	0.14(0.12)	0.19+(0.12)	0.17(0.12)	0.21+(0.12)	0.16(0.12)	0.16(0.12)	0.15(0.12)	0.19(0.12)	0.10(0.12)	0.09(0.12)	0.08(0.12)	0.19(0.12)
	Number of employees	0.44***(0.07)	0.38***(0.07)	0.42***(0.07)	0.38***(0.07)	0.45***(0.07)	0.45***(0.07)	0.44***(0.07)	0.46***(0.07)	0.45***(0.07)	0.44***(0.07)	0.44***(0.07)	0.39***(0.07)
	Public company	-3.95***(0.69)	-3.63***(0.68)	-3.72***(0.68)	-3.50***(0.68)	-3.82***(0.68)	-3.92***(0.69)	-3.96***(0.69)	-3.77***(0.68)	-3.94***(0.69)	-3.84***(0.69)	-3.86***(0.69)	-3.25***(0.68)
	Private national company	-4.34***(0.48)	-3.80***(0.48)	-4.05***(0.48)	-3.65***(0.48)	-4.19***(0.48)	-4.27***(0.48)	-4.32***(0.48)	-4.07***(0.48)	-4.40***(0.48)	-4.41***(0.48)	-4.43***(0.48)	-3.49***(0.48)
	Private multinational company	-4.31***(0.50)	-3.73***(0.50)	-3.98***(0.50)	-3.55***(0.50)	-4.20***(0.50)	-4.25***(0.50)	-4.28***(0.50)	-4.08***(0.49)	-4.38(0.50)	-4.40***(0.50)	-4.41***(0.50)	-3.45***(0.50)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation												
	Make-to-Buy (process): The degree of external sourcing in process innovation												
	H1: Collaborate with external firms		0.28***(0.03)		0.24*** (0.03)								0.23*** (0.03)
	H2a: External information sourcing			-0.68*** (0.09)	-0.52*** (0.09)								-0.47*** (0.09)
	H2b, 2c: EIS × Make-to-Buy (product)												
	H2b, 2c: EIS × Make-to-Buy (process)												
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					0.03*** (0.00)			0.04*** (0.00)				0.04*** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						0.00*** (0.00)		0.01*** (0.00)				0.01***(0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							-0.01** (0.00)	-0.00 (0.00)				-0.00(0.00)
Chapter 5c	H6: The level of export									0.10**(0.03)		0.05(0.04)	0.04(0.04)
	H7: Geographic market scope										0.29***(0.08)	0.23**(0.09)	0.22*(0.09)
	Constant	9.61(0.66)	8.79***(0.67)	11.09*** (0.69)	10.02*** (0.70)	9.20*** (0.66)	9.26*** (0.67)	9.66*** (0.66)	8.69*** (0.67)	9.66*** (0.66)	9.54*** (0.66)	9.58*** (0.66)	9.04*** (0.70)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.044	0.062	0.059	0.069	0.059	0.049	0.046	0.068	0.046	0.047	0.048	0.091
	R2_between	0.052	0.071	0.071	0.081	0.066	0.056	0.054	0.074	0.054	0.057	0.057	0.103
	R2_within	0.003	0.005	0.003	0.004	0.004	0.003	0.003	0.005	0.003	0.003	0.003	0.006

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.5.b Robustness Checks

We test the influence of firms' R&D personnel educational level on the share of exploitative R&D investment in order to understand whether firms' R&D personnel education level determines firms' investment in exploitative R&D activities.

Table 5.3.b. shows the random effects results for the share of exploitative R&D investment. Model 1 shows the control variables. Models 5-7 include variables for education level successively. Model 8 contains all variables for education level, simultaneously. We introduce all variables for firm-specific factors in Model 12.

Model 5 indicates that the internal R&D researchers with PhD qualification in FTE has a negative and statistically significant effect on the share of exploitative (beta= .01, p< .001) R&D investment. These results are robust to incorporation of the variable for non-doctorate university qualification and non-university qualification and also variables for other firm-specific factors (Models 8 and 12), indicating the importance of internal R&D researchers with PhD qualification in influencing firms' investment in internal exploitative R&D activities. The internal R&D researchers with non-doctorate university qualification in FTE has a negative and significant effect (beta= .00, p< .01) on the share of exploitative R&D investment (Model 6). These results are robust to incorporation of the variable for PhD qualification and non-university qualification (Models 8), but it is insignificant in Model 12, indicating that when other firm-specific factors are controlled, the proportion of internal R&D researchers with non-doctorate university qualification do not determine firms' investment in exploitative R&D activities. The internal R&D researchers with non-university qualification in FTE has insignificant effect on the share of exploitative R&D investment in Model 7, 8 and 12, highlighting that the proportion of internal R&D researchers with non-university qualification do not determine firms' investment in exploitative R&D activities. The findings are consistent with what we found in Table 5.1.b., which uses absolute value as a dependent variable.

Table 5.3.b. The influence of R&D personnel educational level on the share of exploitative R&D investment

		The share of exploitative R&D investment											
		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Mode l1	Model 12
	Firm size	-0.15*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.15*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.16**(0.06)	-0.16*(0.06)	-0.16**(0.06)	-0.16**(0.06)
	Membership of a group of companies	0.07(0.06)	0.09(0.06)	0.07(0.06)	0.09(0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.09(0.06)
	Collaborate with other companies of its own group	0.18**(0.05)	0.08(0.06)	0.16*(0.05)	0.08(0.06)	0.18** (0.05)	0.18*** (0.05)	0.18** (0.05)	0.19*** (0.05)	0.18** (0.05)	0.18** (0.05)	0.18** (0.05)	0.08(0.06)
	Importance of information source: within firm or group	-0.03 (0.03)	-0.03 (0.03)	-0.03 (0.03)	-0.03 (0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03 (0.03)
	Firm age	-0.14**(0.04)	-0.13**(0.04)	-0.14**(0.04)	-0.13**(0.04)	-0.14***(0.04)	-0.14**(0.04)	-0.14**(0.04)	-0.15***(0.04)	-0.15***(0.04)	-0.14**(0.04)	-0.15***(0.04)	-0.15***(0.04)
	Number of employees	0.09***(0.02)	0.08***(0.02)	0.09***(0.02)	0.08**(0.02)	0.09***(0.02)	0.09***(0.02)	0.10***(0.02)	0.09***(0.02)	0.10***(0.02)	0.09***(0.02)	0.10***(0.02)	0.08**(0.02)
	Public company	-0.08(0.24)	-0.02(0.24)	-0.04(0.24)	-0.01(0.24)	-0.11(0.24)	-0.09(0.24)	-0.08(0.24)	-0.13(0.24)	-0.08(0.24)	-0.07(0.24)	-0.08(0.24)	-0.03(0.24)
	Private national company	0.33+(0.17)	0.43*(0.17)	0.37*(0.17)	0.44**(0.17)	0.29+(0.17)	0.31+(0.17)	0.32+(0.17)	0.26(0.17)	0.31+(0.17)	0.32+(0.17)	0.31+(0.17)	0.37*(0.17)
	Private multinational company	0.27(0.17)	0.37*(0.18)	0.32+(0.18)	0.39*(0.18)	0.24(0.17)	0.25(0.17)	0.26(0.17)	0.21(0.17)	0.25(0.17)	0.26(0.17)	0.25(0.17)	0.33+(0.18)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation			-0.02(0.04)	-0.04(0.04)								-0.04 (0.04)
	Make-to-Buy (process): The degree of external sourcing in process innovation			0.07*(0.03)	0.05+(0.03)								0.05(0.03)
	H1: Collaborate with external firms		0.05***(0.01)		0.05*** (0.01)								0.05***(0.01）
	H2a: External information sourcing			-0.07*(0.03)	-0.04 (0.03)								0.05(0.03)
	H2b, 2c: EIS × Make-to-Buy (product)			0.21**(0.06)	0.22***(0.06)								0.22***(0.06)
	H2b, 2c: EIS × Make-to-Buy (process)			-0.12* (0.05)	-0.10 *(0.05)								-0.11*(0.05)
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					-0.01*** (0.00)			-0.01*** (0.00)				-0.01*** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						-0.00** (0.00)		-0.00 ***(0.00)				0.00(0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							0.00+(0.00)	0.00 (0.00)				0.00(0.00)
Chapter 5c	H6: The level of export									0.02*(0.01)		0.03+(0.01)	0.02+(0.01)
	H7: Geographic market scope										0.02(0.03)	-0.00(0.03)	-0.01(0.03)
	Constant	3.54***(0.23)	3.39***(0.23)	3.63*** (0.25)	3.48*** (0.25)	3.63*** (0.23)	3.62*** (0.23)	3.53*** (0.23)	3.74*** (0.24)	3.55*** (0.23)	3.53*** (0.23)	3.55*** (0.23)	3.73***(0.26)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.015	0.019	0.017	0.020	0.019	0.016	0.016	0.021	0.016	0.015	0.016	0.028
	R2_between	0.017	0.022	0.018	0.022	0.020	0.017	0.018	0.021	0.019	0.017	0.019	0.030
	R2_within	0.003	0.003	0.004	0.005	0.003	0.003	0.003	0.004	0.002	0.003	0.002	0.006

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.6.b Discussion

Although the effects of characteristics such as organizational structure, size and age in influencing exploration and exploitation has been well established in the previous research (Jansen et al., 2006; Csaszar, 2013; Beckman et al., 2004; Lavie et al., 2010), they have not paid sufficient attention to how education - a source of search patterns, learning, communication and risk preferences - influences an organization's exploration and exploitation. Much of this literature focused on higher-level of decision makers such as managers and entrepreneurs (Adomako et al., 2017; Lynskey, 2016; Tuncdogan et al., 2015; Hmieleski & Baron, 2008; Ganotakis, 2012). This study extends the organizational learning literature by examining how educational qualifications of internal R&D researchers of a firm influence the firm's exploratory and exploitative R&D investment.

This study also contributes to current thinking on firm-level exploration and exploitation by revealing that the highest-educated internal R&D researchers drive variations in firms' exploratory and exploitative R&D investment. We find that a higher proportion of internal R&D researchers with doctorate qualifications in FTE increase firms' exploratory R&D investment but decrease firms' exploitative R&D investment. Doctorate education develops PhDs' abilities of identifying, creating and pursuing external business opportunities and finding new and radical solutions by distant search (Marvel & Lumpkin, 2007; Davidsson & Honig, 2003). PhDs tend to result in a learning advantage due to accumulation of superior managerial capabilities (Mithas & Krishnan, 2008), and they are comfortable with risk-taking, which is one of important elements of exploratory R&D investment (Wang & Ahmed, 2004). On the other hand, according to organizational learning and attention-based theory, PhDs' experience during the doctorate study makes them focus on exploratory learning that facilitates their perception and search activities towards exploratory R&D activities and hinder perception and search activates towards other R&D activities (Ocasio, 1997), which results in an increase in exploratory R&D investment and a decrease in exploitative R&D investment.

Our results indicate that a higher proportion of internal R&D researchers with non-university qualifications (diplomas, specific professional training and secondary school) who work on R&D have an insignificant effect on firms' exploratory and exploitative R&D investment. There are two potential reasons that can explain these results. First, researchers with non-university degree do not usually have the same power in R&D investment decisions. Power is derived from reputation and trust (Cyert & March, 1992). Firms tend to give highly-educated researchers considerable freedom and enormous resources in creating concepts of the new generation of products because of PhD researchers' on-going network with universities and research institutions and strong abilities to learn and process new information (Iansiti & West, 1997). In contrast, researchers with non-university degree are not able to win the same trust from firms on R&D decisions due to a lack of management and commercialization skills and ability to understand the market.

Prior studies found that if technical-focused researchers are fully responsible for making organizational decisions, firms' performance tends to decrease due to mere concentration on technical-based issues (West & Noel, 2009). Innovation often needs knowledge and skills beyond the technical level such as project management skills, commercial skills and problem-solving capability to ensure effective completion of the project (Ganotakis, 2012). Tabrizi & Walleigh (1997) found that if firms purely rely on technical engineers to develop innovation projects, they tend to face a delay in product definition process, whereas if the innovation project team is composed of market strategists and technical counterparts, the innovation team tends to obtain the trust and authority needed to make decisions that would not easily be overturned. A trustworthy team can make decisions without the need to resolve conflicts among the coalition (Cyert & March, 1992). However, if a team does not have sufficient credibility in accessing trade-offs, this tends to increase the costs of decision-making such as second-guessing by others (Tabrizi & Walleigh, 1997). As a result, researchers with non-university degrees may not be able to influence firms' decisions in exploratory and exploitative R&D investment as technical researchers lack management and commercial skills.

Researchers with non-university qualifications (technical specialists) are more likely to make decisions on the basis of a concept of appropriateness generated by experiential learning. Therefore, they tend to persist in using their prior experience to interpret a new technology (Barley, 1988; Levitt & March, 1988). Experiential learning makes technical specialists commit to a particular set of technologies and procedures; therefore, they are likely to make mistakes when environmental conditions change (Cyert & March, 1992).

The second reason is that researchers with lower education levels may not be motivated to engage in firms' investment decisions in R&D. Monetary incentives and goal setting are two important factors in that they can be used as motivational techniques to help employees to achieve better performance (Wright, 1994). There is anecdotal evidence that researchers with lower education levels usually receive lower pay than those with higher education levels (Mithas & Krishnan, 2008). Since employers tend to evaluate an applicant's intelligence, motivation and discipline based on his/her educational qualification (Ucbasaran et al., 2008), lower-educated researchers are less likely to be assigned to tasks related to radical changes and innovation within the organization. They do not usually have same chance to gain access to needed resources for experimentation as highly-educated researchers. Moreover, researchers with lower education levels do not have the same promotion opportunities as researchers with higher education levels (Wright, 1988). Conducting exploration is not likely to increase their promotion opportunities because each group (coalition) within a firm has its own goals (Cyert & March, 1992; Wright, 1994) but it may increase the unnecessary risk as exploration involves high level of uncertainties (March, 1991).

Researchers with non-doctorate university degrees (graduates, architects and engineers) tend to possess both expert intuition and problem-solving capabilities (Bates, 1990). We assume that a higher proportion of internal R&D researchers with non-doctorate university qualifications in FTE increase firms' exploratory and exploitative R&D investment. However, the findings indicate that researchers with non-doctorate university qualifications have a significant and positive effect on exploratory R&D investment but do not have a significant effect on firms' exploitative R&D investment. This is probably because problem-solving capabilities and superior managerial capabilities are more valuable than expert intuition when considering innovation (Dougherty, 1992). Researchers with non-doctorate university degrees can provide entirely new solutions to solve a complex problem in ways that others cannot by using their rich cognitive maps (Crossan et al., 1999). Therefore, firms are more likely to exploit highly-educated researchers to facilitate exploratory learning rather than allocating them to production process for exploitative learning.

The prior empirical research in organizational learning literature did not relate firms' different R&D investment to firms' exploration or exploitation. March (1991) argued that a firm's choice in exploration and exploitation is found in their decisions about alternative investments. Mudambi and Swift (2014) found that a significant change in firm-level R&D expenditure is an indicator of transitions between exploration and exploitation. In line with March (1991) and Mudambi and Swift (2014), we suggest that exploration and exploitation relate to different types of firm-level R&D investment. Having the data of firms' exploratory and exploitative R&D investments allows us to compare the effect of different education levels of internal R&D researchers on organizational learning. In addition, there are only few empirical studies on Spanish firms' R&D investment (Del Canto & Gonzalez, 1999). Much of these studies are conducted at sector level and only focus on the largest Spanish firms (Del Canto & Gonzalez, 1999). Our sample group contains all major industry sectors and includes all Spanish firms that conducted and correctly recorded R&D investment.

Our findings also contribute to research on the balance of exploration and exploitation (e.g. Auh & Menguc, 2005) by specifying the influence of the education on search patterns. A firm's competitive position would be at risk if the environment in which they participating is radically changing (Chan & Cui, 2016). Studies on organizational learning suggested that in a turbulent environment, firms need to be receptive to diverse ideas and react by adapting their learning process (Posen & Levinthal, 2012; Lavie & Rosenkopf, 2006; March, 1991). According to our research, it is clear that firms can hire PhD researchers and exploit their search bias to develop new competitive advantages and to survive in a changing environment, because PhDs can help firms to question current problem solutions, and to actively understand the environment and search from distant and a wide range of sources.

Our research emphasizes the importance of high education in exploration due to the needs of the management skills and problem solving skills for exploratory R&D. This study implies that R&D researchers who already possess a high degree as a threshold are more likely to have skills necessary for exploration. However, it does not mean that on-the-job training not having functions of its own. For example, if firms help researchers with non-university degrees to develop new skills such as management skills and problem solving skills that will increase their openness to unfamiliar knowledge and ideas (Kang & Snell, 2009). After the on-the-job training, these technical specialists (non-university degrees) can also become firms' important competitive advantages, because first, they not only have practical experience in production processes but also have abilities to search external new knowledge and expand the firm's knowledge domains. In other words, they contribute to both firms' exploratory and exploitative learning. Second, according to resource-based view, firms' competitors cannot deploy the human capital to the same firm-specific use as it is a firm-specific, intangible and socially complex resource (Klein et al., 1978; Mahoney & Pandian, 1992).

It is difficult for managers to identify employee skills and deploy them to their most productive R&D tasks (exploratory vs. exploitative) to enhance firms' performance (Hatch & Dyer, 2004). This study helps researchers and managers to understand the learning capabilities of different educational levels of researchers. To study this issue, firms and policymakers can promote organizational learning by better allocating their R&D personnel to R&D activities that best exploit learning capabilities of their R&D personnel (Hatch & Dyer, 2004; Diaz-Fernandez et al., 2017).

The findings are subject to several limitations. First, we discuss the influence of power on firms' exploratory and exploitative R&D investment. Leadership determines the distribution of power and autonomies of a firm (Gordon, 2010). Since we do not have data on leaders' behaviour, we are not able to compare its influence with the influence of researchers' education level in this study. Future research should examine the effect of researchers' education levels and leaders' behaviours, such as leader opening behaviour (encouraging employees to take risks and search for distant solutions) vs. leader closing behaviour (developing routines and encouraging employees to pursue rules) (Zacher et al., 2014) on exploratory and exploitative R&D investment at same time in a single study. This small step would improve our understanding of how leaders' behaviours and researchers' education levels interact to shape a firm's exploratory and exploitative R&D investment decisions. The second limitation concerns the generalizability of empirical results of this study. We test our hypotheses by focusing on a single European country. Future studies may test these hypotheses in other developed or developing countries in order to examine whether the implication of educational qualification are similar or not in other contexts.

Chapter 5c Export and Geographic Scope

Abstract

Research investigating the relationship between internationalization and firm-level internal R&D investment in exploration and exploitation, has used views in organizational learning theory. We develop two hypotheses that relate the level of exporting activities and the scope of firms' geographic markets to firm exploratory and exploitative R&D investment. Using a panel data of Spanish firms during the 2006 - 2011 period, we find that the level of exporting activities has a significant and positive relationship with firm exploitative R&D investment, whereas geographic markets scope has a significant and positive link with firm exploratory R&D investment. Our research proves the positive influence of internationalization on organizational learning, and contributes to the balance of exploration and exploitation literature by specifying the level of exporting and geographic market scope that lead organizations toward exploitation or/and exploration.

5.1.c Introduction

Prior studies investigated the antecedents of internationalization of firms (Kiss et al., 2017; Barron et al., 2016) and the effect of internationalization on firm performance such as profitability, productivity and innovation (Schwens et al., 2017; Lu & Beamish, 2001; Lileeva & Trefler, 2010; Castellani, 2002; Salomon & Shaver, 2005; Love & Ganotakis, 2013; Golovko & Valentini, 2014). Yet, to date, only few studies brought the fields of internationalization and organizational learning together and investigated the effect of internationalization on firm's investment in organizational learning (Hotho et al., 2015). Moreover, they did not assess the core concepts of organizational learning such as characteristics of knowledge (tacitness and complexity or novelty) and exploration and exploitation (Hotho et al., 2015). We suggest more attention should be paid to explore how knowledge and learning is generated in the internationalization of firms and the effect of internationalization on firms' two types of internal R&D investments: exploratory and exploitative. We carefully control the effect of other potential sources of learning and knowledge that affect firms' internal R&D investment such as EIS and IC with external partners. Our results show that the variance in exploratory and exploitative R&D investments among firms can be explained by the level of firms' exporting activities and geographic markets scope. That is, firms with a high level of exporting activities are more likely to invest in exploitative R&D, and firms with a broader geographic market scope are more likely to invest in exploratory R&D. It indicates that organizational learning increasingly happens in organizations that engage in internationalization.

Our research contributes to the organizational learning literature by enriching the understanding of determinants of firm's investment in organizational learning. The literature of learning by exporting and geographic scope suggest that firms gain international competitiveness and better performance through internationalization due to internationalization facilitating role in learning (Castellani, 2002; Salomon & Shaver, 2005; Goerzen & Beamish, 2003). The literature identifies a number of mechanisms through which internationalization facilitates learning, e.g. buyer-seller relationship and referents (Coe & Helpman, 1995; Geletkanycz & Hambrick, 1997). Our research finds support for the learning by exporting and geographic scope literature that there is significant impact of internationalization on firm's learning and knowledge. It sheds new light on this literature by highlighting the importance of investment in learning to materialize the benefits of internationalization. Since R&D investment is an important input to fostering a source of sustained competitive advantage (Banker et al., 2008), the finding of this research demonstrates that internationalization contributes to a firm's competitive advantage. Furthermore, by explaining how exporting and geographic scope of a firm facilitate a firm's investment in different types of activities of organizational learning (exploratory R&D vs. exploitative R&D), this research helps policy makers and managers to understand the learning processes in firms' internationalization. It allows them to design better measures to enhance firm-level exploration and/or exploitation investment.

5.2.c Literature Review

This section summarizes the main theoretical and empirical contributions of related literature that can help understand the relationship between internationalization statuses and firms' two types of internal R&D investment: exploratory and exploitative. Section 6.2.1 and section 6.2.2 help explain how the learning occurs during two kinds of internationalization statuses. In section 6.2.3 and 6.2.4 we review the prior studies on the relationship between export and geographic market scope respectively with firms' internal R&D investment.

5.2.1.c Learning-by-exporting

Prior research examining the benefits from trade and openness found a positive relationship between exporting and performance by using macroeconomic data (Grossman & Helpman, 1991a, 1991b). Exporting facilitates knowledge and information exchange from other countries, resulting in an outward shift of domestic productivity frontier (Salomon & Shaver, 2005). This effect has been summarized as "learning-by-exporting". Recent studies have gone to the micro level, studying learning-by-exporting effect at the level of the firm (Love & Ganotakis, 2013; Bai et al., 2017). "Learning by exporting at firm level often refers to the mechanism thereby firms enhance their performance such as productivity and overall competitive position after engaging export market" (Bai et al., 2017, p.123). There are two main reasons why exporters may benefit from their exposure to foreign markets. First, the increased market size allows exploitation of economies of scale and larger size of innovation rents (Aghion et al., 2017; Castellani, 2002). Second, export induces knowledge spillovers, such as learning about technological expertise through the buyer-seller relationship (Egan & Mody, 1992; Coe & Helpman, 1995). However, empirical studies provide rather mixed evidence. Some studies found no evidence of firm level learning-by-exporting effect (Wagner, 2007; Clerides et al., 1998), while others provide evidence of positive learning effects (Keller, 2009; De Loecker, 2013; Manjon et al., 2013; Castellani, 2002). The mixed results may be explained by how they capture the learning by exporting effect. Some empirical studies on benefits of exporting such as Salomon and Shaver (2005) and Love and Ganotakis (2013) argued that at firm level learning by exporting is less likely to have a direct effect on firm performance, especially productivity, because productivity differs greatly even among firms from similar industries (Goddard et al., 2006) and is easily influenced by other factors that are unrelated to exporting such as learning from external information sources. Moreover, R&D investment is an important element that induces better performance when firms internationalized through export, which emphasized the exporting – R&D investment – performance (e.g. productivity) link (De Loeckera, 2013; Damijan et al., 2008). Export allows firms to learn from foreign competitors and customers (De Loeckera, 2013). This learning occurs during exporting can induce productivity gains when firms invest in R&D activities such as conducting new experiments and upgrading product quality (De Loeckera, 2013). Therefore, some research on learning by exporting suggested using an alternative dependent variable, R&D investment or innovation, which has a relatively more direct link with firms' learning outcome, to look for the evidence of learning by exporting (Love & Ganotakis, 2013; Aw et al., 2008; Lileeva & Trefler, 2007; Girma et al., 2008; Aghion et al., 2017; Bratti & Felice, 2012).

According to organizational learning, exporting is an accumulation process of knowledge and learning (Yeoh, 2004). International expansion can result in multiple learning mechanisms such as experiential learning and distant search taking place within the firm (Casillas & Moreno-Menendez, 2014; Belderbos et al., 2011) that allow firms to work on learning activities that aim at developing knowledge along an existing trajectory and knowledge along an entirely new trajectory. Therefore, exporting tends to have a direct effect on firms' investment in exploratory and exploitative R&D. Previous studies on benefits from exporting using R&D investment or innovation performance as the dependent variable did not capture the effect of exporting on firms' two types of learning: exploratory and exploitative. We would like to extend these previous studies by using exploratory and exploitative R&D investment as dependent variables to study the learning by exporting effect, because first, they embody firms' post-export efforts on different types of learning; second, they help researchers and managers to understand how learning by exporting influences the balance of exploration and exploitation at the level of the firm.

5.2.2.c Geographic market scope

Geographic market scope refers to the geographic scope of locations or markets where a firm sells its goods or services. It indicates the international extent of a firm's business (Delios & Beamish, 1999). Firms operating in a broader geographic scope are very likely to experience the benefits of learning and flexibility (Goerzen & Beamish, 2003). Prior studies have shown that a broader geographic market offers firms with more referents (industry peers) and diverse information cues that can help firms to take advantage of environmental opportunities (Geletkanycz & Hambrick, 1997). As a result, firms doing business in international geographic markets can augment their firm-specific advantage by exploring international markets' location-specific advantage and new strategic resources. Therefore, they can acquire and develop greater technological capabilities and more ample knowledge structure than firms only doing business in a national geographic market will enjoy (Barkema & Vermeulen, 1998; Contractor et al., 2003; Lu & Beamish, 2004). Moreover, many studies focused on flexibility of firms having a broader geographic scope (Allen & Pantzalis, 1996; Tang & Tikoo, 1999). There are two central arguments in these studies. First is that the broader geographic scope, the more profit firms can obtain by exploiting their firm-specific advantages (Kim et al., 2015); second is that firms having geographic market in international scope can "lower the risk of R&D by avoiding business cycles and fluctuations specific to a single market or region" (Kafouros et al., 2008, p.67).

5.2.3.c The level of exporting and R&D investment

Since we focus on the effect of exporting on firms' two types of internal R&D investment: exploratory and exploitative, we will review the empirical evidence on the relationship between export and firms' internal R&D investment. Aw et al. (2008) using firm-level data for electronics manufacturers in Taiwan found that exporting has a positive effect on firms' incentives to invest in R&D because bigger export markets brings higher profits to current R&D investment. Participation in export market allows the firm to spread the fixed costs of R&D over a wider output base and thus stimulates firms to invest in R&D. Girma et al. (2008) investigated the link between exporting and firm R&D using firm level data for Republic of Ireland and

Great Britain. They found that exporting increases R&D for Irish firms because firms need to invest in new technology to compete in export markets, but they did not find significant learning-by-exporting effect for British firms. This probably because British exporters are self-selected to the export markets (Girma et al., 2008). They have strong R&D capability and good absorptive capacity before they enter the export markets (Girma et al., 2008). Using a dataset of Spanish manufacturing firms, Manez et al. (2015) found that exporting would significantly increase the likelihood of firms to engage in R&D due to scale effects, increased competition and the knowledge flows from international customers. Neves et al. (2016) provided support for Manez et al. (2015)'s study. Using a data for Portuguese firms, they also found evidence that entering export markets would raise the probability of conducting R&D activities. They suggested that this positive effect that comes mainly from a larger export market brings more returns to R&D, which is consistent with the arguments of prior studies of the learning by exporting effect.

5.2.4.c The level of geographic market scope and R&D investment

The international markets as a large platform for learning mechanisms such as experiential learning and vicarious learning, leading to an increase in focal firms' incentives to invest in R&D. Firms learn from and aspire to R&D of others from international markets (Mol & Birkinshaw, 2009). The wider a firm's geographic scope, the more technologies the firm can discover through experiential learning and vicarious learning (observation and interaction) (Kim et al., 2015), which tends to result in an increase in the firm's R&D activities for introducing new knowledge. For instance, after facing a competition in the U.S. market, Toyota searched and discovered a technology from U.S. supermarket industry, which inspired Toyota to conduct R&D to develop a lean production system (Udagawa, 1995).

Moreover, a firm with economic transactions in international markets can access a richer pool of external knowledge and more valuable reference groups than a firm having economic transactions only in national market (Mol & Birkinshaw, 2009). For example, a small Leicestershire-based train maintenance equipment (TME) producer might view its reference group as other small Leicestershire TME producers, as all TME producers within the EU, or as all TME producers across the world, and it is very likely that the last reference groups will provide a more diversified technologies, as well as a higher performance benchmark. One of the important aims of R&D is to increase a firm's ability to absorb new knowledge created by others (Cohen & Levinthal, 1990). Therefore, a wider geographic scope increases the opportunity of a firm to gain large returns from its R&D due to the richness of the pool of external knowledge and higher performance benchmark provided by other firms in international markets (Levinthal & March, 1993). It seems that a larger geographic market scope will have a positive effect on firms' R&D investment. However, most empirical studies have paid attention to the effect of geographic market scope on firms' performance such as return on assets, return on equity and sales revenues (Delios & Beamish, 1999; Wiersema & Bowen, 2011). They remain relatively silent on the impact of the geographic market scope on firms' R&D investment. In the next section we will develop two hypotheses to explore the relationship between a firm's geographic market scope and its investment in exploratory and exploitative R&D.

5.3.c Hypotheses

5.3.1.c The level of exporting, exploratory R&D investment, exploitative R&D investment

Firms that export products or services to the international market can learn and develop knowledge through experiential learning and vicarious learning (Hotho et al., 2015). Firms need to invest in organizational learning, especially exploitation, in order to take advantage of knowledge and maximize benefits that are obtained from exporting. For instance, being involved in exporting tends to expedite a firm to invest in improving its efficiency of production in order to benefit from increased production volumes caused by exporting (Klepper, 1996). Interaction with buyers in export markets enables exporters to learn valuable marketing and production information, such as customer preferences, buyers' manufacturing processes, quality and delivery standard and competing products (Salomon & Shaver, 2005). Firms tend to incorporate these knowledge and information into their production function (Salomon & Shaver, 2005). They complemented such information and knowledge by investing in refining production process (exploitation) (Egan & Mody, 1992). In summary, firms with a high level of exporting have strong incentives to invest in exploitation because such investment allows them to materialize the potential benefits that are provided by buyers, and even to learn more than these buyers provide directly.

Price, quality and delivery are three criteria that exporters must meet when selling in the international market (Egan & Mody, 1992). These three minimum requirements are very likely to facilitate firms to invest in exploitation rather than exploration. On the one hand, firms that invest in exploitation such as investing in refining manufacturing processes and commercializing processes can avoid product return costs, overmuch inspections costs and service costs, because of the enhanced product quality, the lower wastes and the more reliable delivery standards (Egan & Mody, 1992). On the other hand, if firms conduct exploration, the price of the product will rise sharply and the delivery time will be uncertain because the consequences of exploration are often unpredictable (March, 1991). Therefore, firms with a high level of exporting tend to concentrate on developing its competitive advantage by investing in exploitation to enhance production efficiency.

Exporting allows participators to improve their technological base, but such an enhanced technological base may be not sufficient to increase firms' exploration capacity. There are two reasons. First, although buyers tend to send technological expertise to exporters to help exporters to get the product out, "they are willing to teach exporters only the minimum information required in product design and production" (Egan & Mody, 1992, p.328) and will not actively transfer valuable tacit information to exporters because they want to prevent exporters from bypassing them in the distribution channel or even accessing to the market as competitors (Egan & Mody, 1992). It is very difficult for exporters to obtain and understand buyers' tacit, novel and complex technological knowledge. Firms need more interaction modes of international expansion to obtain innovative technological knowledge from buyers. Second, although exporting increases possibilities of participators to access information and resources in export markets, according to the central argument of the asset-seeking FDI research, exporters cannot obtain tacit knowledge embedded in export markets because exporters do not locate proximally to destination country firms (Salomon & Shaver, 2005). In other words, it is difficult for an exporter to benefit from location externalities because exporting does not require the exporter to build a physical presence in the destination countries (Siotis, 1999; Kogut & Chang, 1991). As a result, although exporting improves participators technological base, it does not offer sufficient knowledge to stimulate participators to invest in exploration.

H6: *The level of exporting activities of firms will have a significant positive effect on firms' exploitative R&D investment but an insignificant effect on exploratory R&D investment.*

5.3.2.c Geographic market scope, exploratory R&D investment, exploitative R&D investment

Firms operating in a wider geographic market scope tend to face a large number of competitors, so they are more likely to set a higher standard for their own products or services and invest in exploratory R&D investment to develop competitive advantages. Firms can build competitive advantages by implementing a differentiation strategy, which aims at providing customers a unique product or service (Aulakh et al., 2000). The differentiation strategy can be achieved through a brand image, a cutting-edge technology, customer service or innovative products (Miller & Friesen, 1986). Investing in exploratory R&D activities allows firms to differentiate themselves along multiple aspects: brand image, technology and innovative products. For instance, Gordon Murray Design successfully gained a reputation by unveiling a concept city car with features of energy-efficiency in 2010 (Hull, 2016). Their concept ideas provide a unique experience to customers and stimulate their competitors to rethink the way they conceive a car (Oliver, 2008). The good brand image makes demand price-inelastic which helps the company to set entry barriers for newcomers, leading to higher sales margins for the company (Aulakh et al., 2000). Therefore, firms competing in a wider geographic market scope (international markets) have strong incentives to invest in exploration to differentiate themselves from competition and obtain higher profit margins.

Exploratory R&D contains high risk and costs, but as we have mentioned, successful exploratory R&D makes a firm outstanding from its competitors. If the results of successful exploratory R&D such as new technologies and new scientific and product ideas can be easily accessed by a firm's competitors, the firm tends to choose to exploit others' explorations rather to conduct thier own exploratory R&D due to the high risks and costs associated with exploratory R&D (Levinthal & March, 1993). Geographic scope increases an exploratory R&D investment by helping the firm build barriers to imitation. The greater level of market frictions and heterogeneity of international markets increases interaction between causal ambiguity and uniqueness that helps prevent the firm's innovative knowledge from outflowing to other firms (Kim, 2013). As a result, geographic scope enables a firm to capture a larger proportion of economic returns from exploratory R&D, thus, it stimulates a firm to invest in exploratory R&D.

Since international markets involve different legitimacy, local knowledge and relationships, firms with economic transactions in a broader market scope tend to experience much higher market frictions such as uncertainty and information asymmetry than those having economic transactions only in national markets (Mahoney & Qian, 2013). Moreover, country differences increase the chances for firms to obtain heterogeneous knowledge (Williamson, 2000). These two attributes increase the degree of causal ambiguity and uniqueness of knowledge obtained from international markets (Kim, 2013). The higher level of causal ambiguity for the knowledge obtained from international markets increases potential imitators' difficulties in understanding the sources of superior performance (Johanson & Vahlne, 2009). Obtaining local-specialized knowledge across countries through experiential and vicarious learning enables firms to attain more unique combinations of knowledge (e.g. combining others' knowledge to create new and original scientific ideas) (Kogut & Zander, 1992). Other countries' local-specialized knowledge tends to have mutual dependence with firms' internal specialized knowledge (Teece, 1986). Therefore, it is difficult for imitators to take the cospecialized knowledge "out of context without losing much of its value" (Malmberg et al., 1996, p.92). Acquiring knowledge from a broader geographic scope enables a firm to prevent its competitors from duplicating and utilizing the newly developed exploratory knowledge. In other words, this firm can exclusively capture the value created through its new exploratory R&D activities, and the outcomes of the new exploratory R&D can become the firm's competitive advantages (Kim, 2016). Therefore, geographic scope tends to have a positive relationship with firms' exploratory R&D investment.

Firms operating in broad geographic markets have stronger abilities to source valuable knowledge for exploration. They can obtain knowledge of which geographic market knows what and which geographic market is best at doing what. Firms can identify and coordinate knowledge assets across geographically dispersed locations. This knowledge stimulates firms to invest in exploration to build competitive advantage.

According to the resource-based theory, "a firm can gain from continued international expansion as long as its proprietary assets are still valuable, rare, inimitable, and non-substitutable" (Goerzen & Beamish, 2003, p.1291). As a result, the broader a firm's geographic market scope, the more benefits the firm can gain from exploiting its exiting core competence, firm-specific advantages (Goerzen & Beamish, 2003). Therefore, a firm operating in a larger geographic scope has strong incentives to refine their existing knowledge in order to exploit the benefits of internationalization.

Moreover, each country has its unique context, so customer demands in international markets may differ from those in a firm's home country. Firms operating in international markets need to respond to new local demands, which results in substantial exploitation investment (e.g. a high level of refinement investment due to communication costs increased) (Westney, 1993; Kogut & Zander, 1993). Exploitation is a systematic work, which means refining existing production processes requires interrelated changes in product design, supplier management and other related aspects (Chesbrough & Teece, 1996). Therefore, the host countries' diverse customer demands, social context and languages are very likely to increase the misunderstanding in the firm's production and refinement processes (Buckley & Casson, 1976). This misunderstanding can happen between the firm and local customers (misunderstanding local customers' product requirement), as well as between the firm's different production units of the organization (the purchasing department may misunderstand the needs of new materials of product design department). It seems that firms operating in international markets tend to report a high investment in exploitation due to the increased communication costs (Kogut & Zander, 1993).

H7: *Geographic scope will have a positive relationship with firms' exploratory and exploitative R&D investment.*

5.4.c Results

Table 5.2.c. and Table 5.3.c. present the results for hypotheses relating to internationalization statuses (H6-H7). First, we introduce control variables in Model 1. Second, we enter the variables for internationalization statuses (level of exporting and geographic market scope) in Models 9-10 successively. Third, we include all variables for internationalization statuses simultaneously in Model 11. Fourth, we

incorporate all variables for inter-organizational relationships, the R&D personnel educational level and internationalization statuses, and control variables in Model 12.

Results on the effect of a firm's level of export on its exploratory and exploitative R&D investment

H6 examines the relationship between a firm's level of exporting and its exploratory and exploitative R&D investment. Model 9 indicates that the level of exporting has a positive and statistically significant effect on both firms' exploitative (beta= .11, p< .001) and exploratory R&D investment (beta= .10, p<.01). Although its influence on exploratory R&D investment is significant in Model 9, it is insignificant in Models 11-12. Therefore, H6 receives support in Models 11-12, showing that when other firm-specific factors are controlled, a higher level of exporting of a firm stimulates the firm to invest in exploitative R&D activities but not exploratory R&D activities. In other words, only a firm's exploitative R&D investment increases with the level of exporting of the firm.

Results on the effect of a firm's geographic market scopes on its exploratory and exploitative R&D investment

H7 examines the effect of a firms' geographic market scope on exploratory and exploitative R&D investment. Model 10 shows that a firm's geographic market scope has a positive and statistically significant effect on both exploitative (beta= .02, p< .01) and exploratory R&D investment (beta= .29, p< .001). Although its influence on exploitative R&D investment is significant in Model 10, it is insignificant in Models 11-12. These results provide only partial support to H7, showing that when other firm-specific factors are controlled, a broader geographic market scope of a firm stimulates the firm to invest in exploratory R&D but not exploitative R&D. It is an important determinant of firms' internal exploratory R&D investment. In other words, only a firm's internal exploratory R&D investment increases with its geographic market scope.

Table 5.2.c. The impact of exporting and geographic market scope on exploitative R&D investment

		Exploitative R&D Investment											
		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Mode l1	Model 12
	Firm size	-0.36*(0.16)	-0.35*(0.16)	-0.37*(0.16)	-0.36*(0.16)	-0.36*(0.16)	-0.36*(0.16)	-0.35*(0.16)	-0.36*(0.16)	-0.40 *(0.16)	-0.40*(0.16)	-0.42**(0.16)	-0.41*(0.16)
	Membership of a group of companies	0.30*(0.14)	0.39**(0.14)	0.31* (0.14)	0.38**(0.14)	0.30* (0.14)	0.30* (0.14)	0.30* (0.14)	0.30* (0.14)	0.29* (0.14)	0.29* (0.14)	0.29* (0.14)	0.37** (0.14)
	Collaborate with other companies of its own group	0.71***(0.13)	0.23(0.14)	0.63*** (0.14)	0.23(0.14)	0.71*** (0.13)	0.71***(0.13)	0.71*** (0.13)	0.71***(0.13)	0.71*** (0.13)	0.7 ***(0.13)	0.71***(0.13)	0.23 (0.14)
	Importance of information source: within firm or group	-0.17* (0.07)	-0.16*(0.07)	-0.14*(0.07)	-0.14*(0.07)	-0.17*(0.07)	-0.17* (0.07)	-0.17*(0.07)	-0.17* (0.07)	-0.16* (0.06)	-0.16* (0.07)	-0.16* (0.07)	-0.13* (0.07)
	Firm age	-0.46***(0.10)	-0.41***(0.10)	-0.44***(0.10)	-0.41***(0.10)	-0.46***(0.10)	-0.46***(0.10)	-0.46***(0.10)	-0.47***(0.10)	-0.50***(0.10)	-0.49***(0.11)	-0.51***(0.11)	-0.47***(0.10)
	Number of employees	0.67***(0.06)	0.62***(0.06)	0.66***(0.06)	0.62***(0.06)	0.67***(0.06)	0.67***(0.06)	0.68***(0.06)	0.67***(0.06)	0.68***(0.06)	0.67***(0.06)	0.68***(0.06)	0.61***(0.06)
	Public company	-2.05**(0.62)	-1.76**(0.61)	-1.82**(0.62)	-1.16**(0.61)	-2.08**(0.62)	-2.05**(0.62)	-2.05**(0.62)	-2.09**(0.62)	-2.04**(0.62)	-1.97**(0.62)	-2.01**(0.62)	-1.17*(0.48)
	Private national company	-0.87*(0.43)	-0.38(0.43)	-0.64(0.43)	-0.29(0.43)	-0.91*(0.43)	-0.88*(0.43)	-0.88*(0.43)	-0.94*(0.43)	-0.94*(0.43)	-0.91*(0.43)	-0.95*(0.43)	-0.45(0.43)
	Private multinational company	-0.93*(0.45)	-0.41(0.45)	-0.66(0.45)	-0.30(0.45)	-0.96*(0.45)	-0.94*(0.45)	-0.94*(0.45)	-0.99*(0.45)	-1.01*(0.45)	-0.99*(0.45)	-1.03*(0.45)	-0.45(0.45)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation			-0.11(0.10)	-0.22*(0.10)								-0.22*(0.11)
	Make-to-Buy (process): The degree of external sourcing in process innovation			0.17*(0.08)	0.10(0.08)								0.10(0.08)
	H1: Collaborate with external firms		0.24***(0.03)		0.23*** (0.03)								0.23*** (0.03)
	H2a: External information sourcing			-0.47***(0.08)	-0.32*** (0.08)								-0.32*** (0.08)
	H2b, 2c: EIS × Make-to-Buy (product)			0.50**(0.16)	0.54**(0.16)								0.53**(0.16)
	H2b, 2c: EIS × Make-to-Buy (process)			-0.34* (0.13)	-0.28* (0.13)								-0.28*(0.13)
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					-0.01* (0.00)			-0.01* (0.00)				-0.01** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						-0.00 (0.00)		-0.00 (0.00)				-0.00 (0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							0.00 (0.00)	0.00 (0.00)				0.00(0.00)
Chapter 5c	H6: The level of export									0.11***(0.03)		0.10**(0.03)	0.09**(0.03)
	H7: Geographic market scope										0.20**(0.07)	0.09(0.08)	0.08(0.08)
	Constant	9.25***(0.59)	8.52***(0.60)	10.18*** (0.64)	9.43*** (0.64)	9.36*** (0.60)	9.30*** (0.60)	9.23*** (0.59)	9.44*** (0.60)	9.31*** (0.59)	9.20*** (0.59)	9.28*** (0.59)	9.72*** (0.65)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.061	0.077	0.069	0.081	0.061	0.061	0.061	0.061	0.065	0.063	0.065	0.086
	R2_between	0.064	0.085	0.074	0.089	0.064	0.064	0.064	0.064	0.070	0.067	0.070	0.094
	R2_within	0.002	0.003	0.004	0.005	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.005

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5.3.c. The impact of exporting and geographic market scope on exploratory R&D investment

		Exploratory R&D Investment											
		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
	Firm size	0.14(0.17)	0.15(0.17)	0.12(0.17)	0.14(0.17)	0.14(0.17)	0.15(0.17)	0.12(0.17)	0.14(0.17)	0.10(0.17)	0.08(0.17)	0.07(0.17)	0.08(0.17)
	Membership of a group of companies	-0.09(0.16)	0.01(0.16)	-0.08(0.16)	-0.00(0.16)	-0.08(0.16)	-0.09(0.16)	-0.09(0.16)	-0.10(0.15)	-0.09 (0.16)	-0.10(0.16)	-0.10(0.16)	-0.03 (0.15)
	Collaborate with other companies of its own group	0.57***(0.15)	0.03(0.16)	0.47**(0.15)	0.03(0.16)	0.56***(0.15)	0.56***(0.15)	0.57***(0.15)	0.56***(0.15)	0.57***(0.15)	0.57***(0.15)	0.57***(0.15)	0.03 (0.16)
	Importance of information source: within firm or group	-0.12+(0.07)	-0.11(0.07)	-0.07(0.07)	-0.07(0.07)	-0.13+(0.07)	-0.12(0.07)	-0.12+(0.07)	-0.12+(0.07)	-0.12+ (0.07)	-0.12 (0.07)	-0.11 (0.07)	-0.07(0.07)
	Firm age	0.14(0.12)	0.19+(0.12)	0.17(0.12)	0.21+(0.12)	0.16(0.12)	0.16(0.12)	0.15(0.12)	0.19(0.12)	0.10(0.12)	0.09(0.12)	0.08(0.12)	0.19(0.12)
	Number of employees	0.44***(0.07)	0.38***(0.07)	0.42***(0.07)	0.38***(0.07)	0.45***(0.07)	0.45***(0.07)	0.44***(0.07)	0.46***(0.07)	0.45***(0.07)	0.44***(0.07)	0.44***(0.07)	0.39***(0.07)
	Public company	-3.95***(0.69)	-3.63***(0.68)	-3.72***(0.68)	-3.50***(0.68)	-3.82***(0.68)	-3.92***(0.69)	-3.96***(0.69)	-3.77***(0.68)	-3.94***(0.69)	-3.84***(0.69)	-3.86***(0.69)	-3.25***(0.68)
	Private national company	-4.34***(0.48)	-3.80***(0.48)	-4.05***(0.48)	-3.65***(0.48)	-4.19***(0.48)	-4.27***(0.48)	-4.32***(0.48)	-4.07***(0.48)	-4.40***(0.48)	-4.41***(0.48)	-4.43***(0.48)	-3.49***(0.48)
	Private multinational company	-4.31***(0.50)	-3.73***(0.50)	-3.98***(0.50)	-3.55***(0.50)	-4.20***(0.50)	-4.25***(0.50)	-4.28***(0.50)	-4.08***(0.49)	-4.38(0.50)	-4.40***(0.50)	-4.41***(0.50)	-3.45***(0.50)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation												
	Make-to-Buy (process): The degree of external sourcing in process innovation												
	H1: Collaborate with external firms		0.28***(0.03)		0.24*** (0.03)								0.23*** (0.03)
	H2a: External information sourcing			-0.68*** (0.09)	-0.52*** (0.09)								-0.47*** (0.09)
	H2b, 2c: EIS × Make-to-Buy (product)												
	H2b, 2c: EIS × Make-to-Buy (process)												
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					0.03*** (0.00)			0.04*** (0.00)				0.04*** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						0.00*** (0.00)		0.01*** (0.00)				0.01***(0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							-0.01** (0.00)	-0.00 (0.00)				-0.00(0.00)
Chapter 5c	H6: The level of export									0.10**(0.03)		0.05(0.04)	0.04(0.04)
	H7: Geographic market scope										0.29***(0.08)	0.23**(0.09)	0.22*(0.09)
	Constant	9.61(0.66)	8.79***(0.67)	11.09*** (0.69)	10.02*** (0.70)	9.20*** (0.66)	9.26*** (0.67)	9.66*** (0.66)	8.69*** (0.67)	9.66*** (0.66)	9.54*** (0.66)	9.58*** (0.66)	9.04*** (0.70)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.044	0.062	0.059	0.069	0.059	0.049	0.046	0.068	0.046	0.047	0.048	0.091
	R2_between	0.052	0.071	0.071	0.081	0.066	0.056	0.054	0.074	0.054	0.057	0.057	0.103
	R2_within	0.003	0.005	0.003	0.004	0.004	0.003	0.003	0.005	0.003	0.003	0.003	0.006

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

R

5.5.c Robustness Checks

We test the influence of the level of exporting and geographic market scope on the share of exploitative R&D investment in order to understand whether firms' internationalization statuses determine firms' investment in exploitative R&D activities.

Table 5.4.c. shows the random effects results for the share of exploitative R&D investment. Model 1 shows the control variables. Models 9-10 includes variables for internationalization statuses successively. Model 11 contains all variables for internationalization statuses. We introduce all variables for firm-specific factors in Model 12.

Model 9 indicates that the level of exporting has a positive and statistically significant effect on the share of exploitative R&D investment (beta= .02, $p < .05$). These results are robust to incorporation of the variable for geographic market scope and also variables for other firm-specific factors (Models 11-12), indicating the importance of the level of exporting in influencing firms' investment in internal exploitative R&D activities. Model 10 shows that geographic market scope has an insignificant effect (beta= .02, n.s.) on the share of exploitative R&D investment. These results are robust to incorporation of the variable for the level of exporting and also variables for other firm-specific factors (Models 11-12), highlighting that geographic market scope does not determine firms' investment in exploitative R&D activities. The findings are consistent with what we found in Table 5.2.c, which uses absolute value as a dependent variable.

Table 5.4.c. The influence of exporting and geographic market scope on the share of exploitative R&D investment

		The share of exploitative R&D investment											
		Control	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect	Random Effect
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Mode l1	Model 12
	Firm size	-0.15*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.15*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.15*(0.06)	-0.16*(0.06)	-0.16**(0.06)	-0.16*(0.06)	-0.16**(0.06)	-0.16**(0.06)
	Membership of a group of companies	0.07(0.06)	0.09(0.06)	0.07(0.06)	0.09(0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.07 (0.06)	0.09(0.06)
	Collaborate with other companies of its own group	0.18**(0.05)	0.08(0.06)	0.16*(0.05)	0.08(0.06)	0.18** (0.05)	0.18*** (0.05)	0.18** (0.05)	0.19*** (0.05)	0.18** (0.05)	0.18** (0.05)	0.18** (0.05)	0.08(0.06)
	Importance of information source: within firm or group	-0.03 (0.03)	-0.03 (0.03)	-0.03 (0.03)	-0.03 (0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03(0.03)	-0.03 (0.03)
	Firm age	-0.14**(0.04)	-0.13**(0.04)	-0.14**(0.04)	-0.13**(0.04)	-0.14***(0.04)	-0.14**(0.04)	-0.14**(0.04)	-0.15***(0.04)	-0.15***(0.04)	-0.14**(0.04)	-0.15***(0.04)	-0.15***(0.04)
	Number of employees	0.09***(0.02)	0.08***(0.02)	0.09***(0.02)	0.08**(0.02)	0.09***(0.02)	0.09***(0.02)	0.10***(0.02)	0.09***(0.02)	0.10***(0.02)	0.09***(0.02)	0.10***(0.02)	0.08**(0.02)
	Public company	-0.08(0.24)	-0.02(0.24)	-0.04(0.24)	-0.01(0.24)	-0.11(0.24)	-0.09(0.24)	-0.08(0.24)	-0.13(0.24)	-0.08(0.24)	-0.07(0.24)	-0.08(0.24)	-0.03(0.24)
	Private national company	0.33+(0.17)	0.43*(0.17)	0.37*(0.17)	0.44**(0.17)	0.29+(0.17)	0.31+(0.17)	0.32+(0.17)	0.26(0.17)	0.31+(0.17)	0.32+(0.17)	0.31+(0.17)	0.37*(0.17)
	Private multinational company	0.27(0.17)	0.37*(0.18)	0.32+(0.18)	0.39*(0.18)	0.24(0.17)	0.25(0.17)	0.26(0.17)	0.21(0.17)	0.25(0.17)	0.26(0.17)	0.25(0.17)	0.33+(0.18)
	Research association and other research institutions	..	..	..	..	..	..	..	..	..	..	..	..
	Year Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
	Industry Dummy	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Chapter 5a	Make-to-Buy (product): The degree of external sourcing in product innovation			-0.02(0.04)	-0.04(0.04)								-0.04 (0.04)
	Make-to-Buy (process): The degree of external sourcing in process innovation			0.07*(0.03)	0.05+(0.03)								0.05(0.03)
	H1: Collaborate with external firms		0.05***(0.01)		0.05*** (0.01)								0.05***(0.01）
	H2a: External information sourcing			-0.07*(0.03)	-0.04 (0.03)								0.05(0.03)
	H2b, 2c: EIS × Make-to-Buy (product)			0.21**(0.06)	0.22***(0.06)								0.22***(0.06)
	H2b, 2c: EIS × Make-to-Buy (process)			-0.12* (0.05)	-0.10 *(0.05)								-0.11*(0.05)
Chapter 5b	H3: Internal R&D researchers with PhD qualification in FTE					-0.01*** (0.00)			-0.01*** (0.00)				-0.01*** (0.00)
	H4: Internal R&D researchers with non-doctorate university qualification in FTE						-0.00** (0.00)		-0.00 ***(0.00)				0.00(0.00)
	H5: Internal R&D researchers with non-university qualifications in FTE							0.00+(0.00)	0.00 (0.00)				0.00(0.00)
Chapter 5c	H6: The level of export									0.02*(0.01)		0.03+(0.01)	0.02+(0.01)
	H7: Geographic market scope										0.02(0.03)	-0.00(0.03)	-0.01(0.03)
	Constant	3.54***(0.23)	3.39***(0.23)	3.63*** (0.25)	3.48*** (0.25)	3.63*** (0.23)	3.62*** (0.23)	3.53*** (0.23)	3.74*** (0.24)	3.55*** (0.23)	3.53*** (0.23)	3.55*** (0.23)	3.73***(0.26)
	N	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388	13388
	R2_overall	0.015	0.019	0.017	0.020	0.019	0.016	0.016	0.021	0.016	0.015	0.016	0.028
	R2_between	0.017	0.022	0.018	0.022	0.020	0.017	0.018	0.021	0.019	0.017	0.019	0.030
	R2_within	0.003	0.003	0.004	0.005	0.003	0.003	0.003	0.004	0.002	0.003	0.002	0.006

t statistics in parentheses + p<0.1, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.6.c Discussion

While past studies recognized the positive influence of internationalization on organizational learning (Love & Ganotakis, 2013; Kafouros et al., 2008; Goerzen & Beamish, 2003; Castellani, 2002), they often focus extensively on the impact of internationalization such as productivity and innovation performance (Castellani, 2002; Kafouros et al., 2008). This study contributes to internationalization and organizational learning literature by investigating the impact of internationalization on firms' investment in activities of organizational learning (exploration and exploitation). We examine two different internationalization statuses: exporting and having geographic markets in international scope, respectively. Initially, the study reviews prior research that explained how learning and knowledge occur in two internationalization statuses through experiential learning and vicarious learning (Casillas & Moreno-Menendez, 2014; Kim et al., 2015). Then, it illustrates the specific benefits of exporting and geographic scope and highlights the importance of investing in learning (exploration and exploitation) to materialize the benefits of internationalization and to build competitive advantage. We demonstrate that internationalization has a positive impact on firms' decisions to invest in activities of organizational learning. Furthermore, we find different internationalization statuses stimulate firms' investment in different activities of organizational learning.

The findings extend prior studies on the effect of internationalization and firms' R&D investment by suggesting that although organizational learning increasingly happens in organizations that engage in internationalization (Yeoh, 2004; Mol & Birkinshaw, 2009), different internationalization statuses promote firms' investment in different types of organizational learning. We find that exporting has a positive effect on exploitative R&D investment, while generating an insignificant effect on exploratory R&D investment. The geographic market scope has a positive effect on exploration, while generating an insignificant effect on exploitation. The implication for theory is that future studies on determinants of a firm's investment decisions in organizational learning (exploratory learning and exploitative learning) should consider the firm's internationalization activities. The other implication of our findings is that it highlights the importance of physical presence in obtaining tacit knowledge and pursuing specific advantages of local markets as pointed out by Salomon and Shaver (2005) and Kogut and Chang (1991). Our results shed light on prior studies by showing that although exporting enhances exporters technological base, it does not provide sufficient knowledge to stimulate exporters' investment in exploration. The information and knowledge exchanged through exporting increases firms' exploitative capacity but may not be able to increase firms' exploratory capacity. According to Egan and Mody (1992), buyers are more likely to transfer minimum and production-related knowledge to their exporters to get the product out. Thus, it is difficult for exporters to learn tacit and novel knowledge from buyers but firms with export activities can maximize the benefits of learning that is created by exporting through investing in complementary production function to successfully achieve the primary goals of exporting (price, quality and delivery), and consequently deepen relationships with buyers (Egan & Mody, 1992). The increased investment in firms' exploitation we find during exporting supports our arguments. Therefore, we suggest that firms with high level of exporting are very likely to invest in exploitation so as to absorb the increased exploitative capacity and to use this opportunity to upgrade their own plant and develop competitive advantages.

Prior study suggested that a broader geographic market scope may generate two main effects on firms: (1) stimulating firms to exploit their firm-specific advantages and/or (2) exploring location-specific advantages embedded in each market (Kim et al., 2015). Our results indicate that the geographic market scope facilitates organizational learning and new resource exploration, but do not support the exploitation benefit. This is probably because firm-specific advantages are not absolute strengths (Wernerfelt & Karnani, 1987). The firm-specific advantages may vary according to the country where the firm entered, for example, if a firm's strength is not superior enough to compete with local firms, the firm cannot benefit from exploiting firm-specific advantage in that country (Kim et al., 2015). Therefore, firms operating in broader geographic markets tend to augment their firm-specific advantage by using local knowledge and resources to develop specific technologies that are unique to their customers. They invest in exploration to materialize the benefits of new strategic resources and location-specific advantages that are obtained from international markets and to successfully compete against competitors from different countries.

In summary, we suggest that exporting promotes firms' invest in exploitative R&D by increasing firms' incentives of absorbing production and marketing information of others in the export market (Salomon & Shaver, 2005; Egan & Mody, 1992) and by enabling firms to exploit their firm-specific advantages in export markets (Kim et al., 2015). While having transactions in broader geographic markets promotes firms' investments in exploratory R&D activities (1) by increasing the incentives of firms to differentiate themselves from competitors (Aulakh et al., 2000), (2) by enabling firms to access new strategic resources and pursuit of location-specific advantages embedded in different geographic markets; and (3) by helping firms build barriers to imitation (Kim, 2013; 2016). Therefore, our research enhances the understanding regarding characteristics of knowledge and learning that occurs during firms' different internationalization statuses (the level of exporting and geographic scope) and their influence on firms' investment decisions in two major activities of organizational learning: exploratory and exploitative R&D. It provides a richer understanding of the influence of the level of exporting and geographic scope on firms' exploratory and exploitative R&D investment, and helps policy makers to design measures to promote firms' exploitative learning and exploratory learning.

The study remains some limitations, which offer avenues for future research. First, our study does not examine the environmental conditions where a firm is operating. The host countries' different context may influence a firm's ability of exploitation of their firm-specific advantages and exploration of location-specific advantages (Kim et al., 2015). Second, this study measures the geographic market scope by using a scale (0= no international market; 1= enter markets of other EU and EFTA countries or all remaining countries 2= enter markets of other EU and EFTA countries and all remaining countries). We do not account the number of international markets that a firm has. A firm with multiple foreign markets may have a different investment strategy on exploration and exploitation compared with firms that only have a single foreign market, because they tend to face different levels of competitive pressures from international markets (Kostova & Zaheer, 1999; Hitt et al., 1994; Hitt et al., 2006). Despite these limitations, we believe our study helps researchers to better understand firms' investment decisions in exploration and exploitation.

This study uses data from Spain. Future studies could re-estimate the model using data from developing countries to generalize the results. Since the importance of investing in exploration and exploitation to materialize the benefits of internationalization, future studies can emphasize the geographic scope -R&D

investment (learning) -firm performance link to examine whether the R&D is a missing mechanism through which the geographic scope improves firm performance. Furthermore, given an insignificant relationship between exporting and firms' exploration investment, it seems that exporting alone is insufficient to predict firms' exploration investment. Future researchers can introduce a moderator such as country-level environmental conditions or firm size to examine when and where exporting stimulates firms to invest in exploration. Likewise, considering an insignificant relationship between a firm's geographic market scope and firms' exploitation, future researchers could examine possible moderators between geographic scope and exploitation investment.

Chapter 6 Conclusion

This thesis aims to investigate the effect of firm-specific factors on exploratory and exploitative R&D investment decisions of firms. It looks closer at some key firm specific determinants of internal exploration and exploitation investment. It builds on organizational learning theory to explain how a firm's inter-organizational relationships, the education of R&D personnel and internationalization influence its decisions on investing in internal exploratory and exploitative R&D. In the empirical literature, there are mixed results regarding effects of inter-organizational relationships –i.e., positive (e.g., Cassiman and Veugelers, 2006), or negative (e.g., Laursen and Salter, 2006). By using panel data of Spanish firms from 2003 to 2011, this thesis demonstrates that the reason for previously mixed results may be a lack of consideration of the forms of inter-organizational relationships. IC as a formal inter-organizational relationship not only drives firms to increase investment in creation of new knowledge through science experiment and applied research (exploratory R&D), but also stimulates firms to invest in improvement of existing knowledge through production (exploitative R&D). In other words, there is a positive effect of IC on internal exploratory and exploitative R&D investment. In contrast, EIS as an informal inter-organizational relationship has mostly a negative effect on internal exploratory and exploitative R&D investment of firms because of the appeal of market in facilitating exploratory and exploitative R&D of firms. An increased level of EIS allows firms to search for new alternatives/solutions in the environment, which tends to substitute the internal distant search for exploration. In addition, this research find that the effect of EIS on internal exploitative R&D investment is moderated by the development tendency of firms. Firms with a tendency towards core-capability development will increase investment in exploitative R&D, whereas firms with a tendency towards periphery-development will reduce investment in exploitative R&D.

The thesis then demonstrates why the education of R&D personnel of firms matters in explaining firms' investment decisions in exploration and exploitation. Much of the literature in HRM and organizational learning focuses on education of the higher level of decision makers such as managers and entrepreneurs (Adomako et al., 2017; Lynskey, 2016; Tuncdogan et al., 2015; Hmieleski & Baron, 2008; Ganotakis, 2012). We are intrigued by the question of how the education of R&D personnel of firms (researchers who are dedicated to internal R&D activities within firms) influences firms' decisions to invest in exploratory and exploitative R&D. This thesis addresses the question by comparing the influence of different educational levels of researchers on firms' exploratory and exploitative R&D investment. Building on organizational learning theory, the thesis argues that researchers with different education levels tend to consider different things as important and have distinct definitions of a problem facing the organization, because their past experience influences the ability and acceptance of learning new knowledge (Cyert & March, 1992). Therefore, the bias in different educational levels of researchers can affect a firm's focus on organizational learning and result in differences in firms' exploratory and exploitative R&D investment. Our analysis of 5939 Spanish firms reveals that a higher proportion of researchers with doctorate qualifications in FTE increase firms' exploratory R&D investment, but decrease firms' exploitative R&D investment. A higher proportion of researchers with non-doctorate university qualifications in FTE increase firms' exploratory R&D investment, but has an insignificant effect on firms' exploitative R&D investment. A higher proportion of lower educated researchers (non-university degrees) in FTE has an insignificant effect on firms' R&D investment.

This thesis presents a third determinant of internal exploration and exploitation investment – firms' internationalization status: firms internationalized through export and the geographic market scope that firms have businesses and services. Prior research indicated that internationalization stimulates organizational learning through a number of mechanisms such as vicarious learning (e.g. buyer-seller relationships and reference groups) (Salomon & Shaver, 2005; Geletkanycz & Hambrick, 1997) and the direct experience of serving international markets (experiential learning) (Kim et al., 2015; World Bank, 1997), and therefore results in a better performance in productivity (Castellani, 2002; Bai et al., 2017), or innovation (Love & Ganotakis, 2013; Kafouros et al., 2008). Studies on learning by exporting suggested that investment in R&D induces better performance when firms internationalized through export, which emphasized the exporting - R&D investment (learning) - performance link (De Loeckera, 2013; Damijan et al., 2008). The results of prior empirical studies supported the positive relationship between exporting and R&D investment (Aw et al., 2008; Girma et al., 2008; Manez et al., 2015; Neves et al., 2016). Extending these previous studies, this thesis demonstrates that exporting does not facilitate investment in all types of activities of organizational learning. A higher level of exporting only increases firms' investment in exploitative R&D and has an insignificant effect on firms' exploratory R&D investment. Geographic scope scholars mainly focused on investigating the relationship between firms' geographic scope and firm performance such as return on assets and sales revenues (Delios & Beamish, 1999; Wiersema & Bowen, 2011). However, they remained silent on the importance of investing in organizational learning when firms serving the international markets. Extending the prior research, this thesis brings the fields of geographic scope and organizational learning together and empirically tests the influence of geographic scope on organizational learning. The results show that the geographic scope facilitates firms to invest in exploratory R&D, but has an insignificant effect on firms' exploitative R&D investment.

6.1 Contributions of the Research

This thesis provides important insights for researchers to understand better how firms' make internal exploratory and exploitative R&D investment decisions. So far, firm-specific factors that determine firms' internal exploration and exploitation investment have remained largely unaddressed. With this thesis, we contribute to a better understanding of the determinant of firms' investment decisions in internal exploration and exploitation by investigating the influence of inter-organizational relationships, the education of R&D personnel and internationalization on internal exploration and exploitation investment of firms. Many previous studies considered R&D investment as a homogeneous construct when studying the determinants of organizational learning (Spithoven & Teirlinck, 2010; Kafouros et al., 2008). Empirically, this research shows that the influence of a determinant on exploratory R&D investment is different from its influence on exploitative R&D investment; the determinants of exploratory R&D investment also differ from the determinants of exploitative R&D investment. These findings stress that future research needs to be careful in extrapolating conclusions from analysis that studies a specific type of R&D investment into studies that analyze overall R&D investment or into studies that analyze another type of R&D investment.

Our findings of inter-organizational relationships reveal that IC contributes to firms' competitive advantage. Moreover, our results of IC and EIS support the view of Schartinger et al. (2002) that IC and EIS are used for opposite needs. In addition, we complement prior studies on the relationship between external knowledge and internal

R&D investment by suggesting a moderating effect. We argue that the influence of EIS on exploitative R&D investment differs according to core and periphery development tendency, because it influences firms' needs of control on their internal exploitation (Veugelers & Cassiman, 1999; Audretsch et al., 1996). When a firm is core-development oriented, aiming at developing goods and services in-house to outperform other similar-type products or services currently in market, it has strong incentives to control over its internal exploitation activities (Dutta & Weiss, 1997). Firms with core development-orientation are more likely to use the information sourced externally to better understand the market. Therefore, we argue that when a firm is core-development oriented, the higher the importance of information sourced from external sources for a firm's innovation activities, the higher the internal exploitation investment by the firm. When a firm is peripheral-development oriented, aiming at developing goods or services externally to bring them to market quicker, it has strong incentives to reduce the costs and risks of replicating externally available technologies (Audretsch et al., 1996). Therefore, we argue that when a firm is peripheral-development oriented, the higher the importance of information sourced from external sources for a firm's innovation activities, the lower the internal exploitation investment by the firm. The result contributes to prior studies by showing that a firm's development tendencies in product innovation moderate the effects of EIS on firms' investment decisions in internal exploitation. Future studies in this area could examine both direct and moderating effects of other firm-specific factors on internal exploratory and exploitative R&D investment of firms.

While the extant research on HRM and innovation suggested that high level of education stimulates firms' R&D investment, we extend such understanding and argue that higher educational level does not increase all types of R&D investment.

Our results contribute to studies in these literatures by showing that a higher proportion of doctorate holders turned out to stimulate internal exploration investment, but in contrast, it reduces firms' investment in internal exploitation. The findings also contribute to organizational learning literature by considering education as a source of organizations' search patterns and learning. PhDs increase firms' abilities of finding alternative solutions through distant search (Marvel & Lumpkin, 2007; Davidsson & Honig, 2003) and enhance firms' abilities of learning (Mithas & Krishnan, 2008). They often have a desire for more technological significant projects and thrive on intellectual challenges (Diaz-Fernandez et al., 2017; Banker et al., 2008). Their search bias facilitates firms' exploratory learning but hinders firms' exploitative learning and hence results in an increase in firms' internal exploratory R&D investment and a decrease in internal exploitative R&D investment. This would offer insights on the investment decisions of exploration and exploitation in firms. Moreover, the effect of researchers with non-university qualifications on firms' internal exploration and exploitation investment has not been investigated before, but is nevertheless important because it helps to be aware of the risks of lacking of high-educated researchers in internal R&D. The results of this research contribute to prior studies on HRM and organizational learning by indicating that non-university researchers do not contribute to enhance firms' competitive advantages. They have an insignificant influence on firms' exploration and exploitation investment.

The result of this thesis confirms the argument of prior research (Love & Ganotakis, 2013; Kafouros et al., 2008; Goerzen & Beamish, 2003; Castellani, 2002) that organizational learning increasingly happens in organizations that engage in internationalization (Yeoh, 2004; Mol & Birkinshaw, 2009). It reveals that internationalization contributes to a firm's competitive advantages. Our finding makes some contributions to prior research. It suggests that two internationalization statuses have different influences on the types of R&D investment. The level of exporting is positively related only to firms' exploitative R&D investment, whereas the geographic scope is positively related only to firms' exploratory R&D investment.

Since export does not require a physical presence, it is difficult for exporters to learn tacit and novel knowledge from other actors such as competitors and buyers of export markets. Egan and Mody (1992) suggested that buyers are more likely to transfer minimum and production-related knowledge to their exporters to get the product out. By this token, the information and knowledge exchanged through exporting increases firms' exploitative capacity but may not be able to increase firms' exploratory capacity. We suggest that firms with a high level of exporting should invest in internal exploitation to benefit from the increased exploitative capacity. The increased investment in firms' exploitation that we find during exporting supports these arguments. This finding contributes to both learning by exporting and organizational learning literatures by highlighting the level of exporting stimulates firms to enhance presence of competitive advantage through investing in exploitative R&D. The results of geographic scope provide us with evidence that geographic scope is an important determinant for exploration but not for exploitation. This may be a result of intense competition in international markets. This can cause firms to augment their firm-specific advantages by using local knowledge and resources to develop specific technologies, products or services that are unique to their customers. Investing in exploration allows firms to materialize the benefits of new strategic resources and location-specific advantages that are obtained from international markets and to successfully compete against competitors from different countries.

The findings of the thesis offer some guidelines for policy makers and managers in formulating internal exploratory and exploitative R&D investment strategy. For example, the results highlight that firm-specific factors play an important role in shaping firms' investment decisions in internal exploration and exploitation. Managers need to examine firms' inter-organizational relationships, the educational level of R&D personnel and internationalization, particularly, IC, EIS, the proportions of doctoral/university/non-university degree researchers, the level of export and geographic scope before they can decide a proper internal exploration and exploitation investment strategy for their firms.

Our finding shows that firms that acquire knowledge from the external environment by relying on EIS are able to reduce their investment in both exploration and exploitation but may have to face the risk of losing competitive advantages. Due to the differences between IC and EIS (Hitt et al., 2005; Tsang, 2002; Veugelers & Cassiman, 1999), we argue that firms should outsource activities that are outside the domain of firms' core competence, while collaborating with external actors in realms that are at the centre of defining their organizations or that are crucial for developing competitive advantage. Moreover, since EIS has some benefits (allows firms to obtain explicit and large quantity of information) (Chesbrough & Teece, 1996), firms that desire to beat and outperform the market have strong incentives to invest in exploitative R&D to exploit the information obtained through EIS. Managers can benefit from these arguments. Managers could consider adopting EIS to either shun away from substantial and risky sunk R&D investment when dealing with unfamiliar innovation problems, or increase investment in exploitation to enhance core capabilities with the goal of beating and outperforming the market. In addition, we suggest that managers should use IC to gain long-term benefits for their firms, since

IC provides opportunities for firms to develop and enhance internal capabilities and exploit them for new applications.

The increased investment in exploration and the decreased investment in exploitation that we find in firms with higher proportion of doctorate researchers indicate doctorate researchers expose firms to some new alternatives to existing solutions for problems, encourage firms to take risk, and try these alternatives to see what fits the firm best. This provides an interesting implication for practice. Since firms with a large proportion of university-educated researchers are able to entertain and process new knowledge better than firms with a large proportion of nonuniversity-educated researchers (Hosseini et al., 2003; Toner, 2011), managers can consider hiring PhDs to develop new competitive advantage. In a turbulent environment, firms need to be receptive to diverse ideas. PhDs can help firms to question current problem solutions, to actively understand the environment and search for alternatives and ideas along an entirely new knowledge trajectory from a wide range of sources. To study the education of R&D personnel, firms and policymakers can promote organizational learning by better allocating their researchers to R&D activities that best exploit their researchers' learning capabilities (Hatch & Dyer, 2004; Diaz-Fernandez et al., 2017).

The thesis demonstrates the positive influence of internationalization on firms' investment in learning. Therefore, managers need to consider the importance of internationalization in developing firms' competitive advantages, and should take into account the function of exploratory and exploitative R&D in absorbing and exploiting knowledge that learnt through internationalization. Moreover, by distinguishing investment in different types of learning, this thesis helps policy makers and managers to understand the learning processes in firms' internationalization, so they can design better measures to enhance firm-level exploration and/or exploitation as well as to further improve the balance of exploration and exploitation at the level of the firm.

6.2 Limitation and Future Studies

The research has several limitations that should be considered in future studies. First, due to data constraints, at this stage of this study, we are unable to investigate the effect of EIS and IC on firms' exploration and exploitation investment at a global level. However, sourcing knowledge worldwide and collaborating with foreign partners may generate different effects on the organizational learning compared with domestic ones. Future research could focus on international EIS and international IC and compared results with our research to find out the similarities and differences. Second, this thesis measures geographic scope by using a scale. We do not account for the number of international markets that a firm entered. A firm with multiple foreign markets may have a different investment strategy on exploration and exploitation compared with firms that only have a single foreign market because they tend to face different levels of competitive pressures from international markets (Kostova & Zaheer, 1999; Hitt et al., 1994; Hitt et al., 2006). Third, this present study does not examine the environmental conditions where a firm is operating. The host countries' different context may influence a firm's incentives to exploit their firm-specific advantages and take advantage of location-specific advantages (Kim et al., 2015). Fourth, we discuss the influence of power on firms' exploratory and exploitative R&D investment. Leadership determines the distribution of power and autonomies of an organization. Since we do not have data on leaders' behaviours, we are not able to compare its influence with the influence of employees' education level in this study. Future research can examine the effect of employees' education levels and leaders' behaviours such as leader opening behaviour (encouraging employees to take risks and search for distant solutions) versus leader closing behaviour (developing routines and encouraging employees to pursue rules) on firms' exploratory and exploitative R&D investment at same time in a single study. This would improve understanding on leaders' behaviours and employees' education level and how they interact to shape an organization' exploratory and exploitative R&D investment decisions. Due to the importance of investing in exploration and exploitation to materialize the benefits of internationalization, future studies can emphasize the geographic scope - R&D investment (learning) - firm performance link to examine whether the R&D is a missing mechanism through which the geographic scope improves firm performance.

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