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National framework conditions, technological regimes and knowledge dynamics:

A multilevel analysis of international innovation collaboration

by

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Abstract: The behavior of a firm to engage in international innovation collaborations is characterized by complex relations that are identified at more than one level. However, less has been done to understand multilevel interactions and the effects of the national framework conditions. In this respect, this study elaborates a comprehensive set of country and firm-level variables, including the properties of technological regimes, to shed light on the diversifying nature of collaboration patterns. We relax the emphasis on firm-specific capabilities and lay the ground for country-level effects to appear within the context of multilevel modeling. We find that firms embedded in an environment with less developed research infrastructure tend to collaborate more through international collaboration linkages. Knowledge dynamics are highly influential to define the international collaboration patterns of firms. Furthermore, the findings point out the importance of different levels in innovation studies while introducing the three-level hierarchical model as a novelty for the analysis of cooperation on innovation.

Keywords: international innovation collaboration, national framework conditions, technological regimes, multilevel analysis.

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1 Introduction

Internationalization of innovation activities is an old phenomenon which has started with the commercialization of new products and processes in international markets (Archibugi & Michie, 1995) and, followed by the research collaboration activities of firms beyond their national boundaries (Howells, 1990) and the relocation of R&D facilities in other countries (Cantwell & Piscitello, 2005; Cantwell & Piscitello, 2007). In the early 2000's, following the globalization of production and manufacturing, global production networks and global value chains have been extensively studied (Ernst, 2009; Dedrick et al., 2010; Timmer et al., 2014; Coe et al., 2004) and recently, there has been growing interest in global innovation networks as a new wave of globalization of innovation activities (Barnard & Chaminade, 2017; Cooke, 2013). In line with the surge of global innovation networks, substantial attention in the literature has been given to the role played by global sources of knowledge to trigger the competitiveness of firms and regions (Moodysson et al., 2008; Chaminade & Plechero, 2015).

Globalization has reached beyond the markets for goods and finance, and extended into the markets for technology and knowledge production while triggering the mobility of knowledge in both organizational and geographical terms (Ernst, 2009). Therefore, the integration into collaboration linkages has turned into a key factor for competitiveness and growth where any single firm cannot stand isolated from relevant technological developments in the new global economic landscape (Ebersberger & Herstad, 2013). Moreover, innovation activities are becoming increasingly distributed across territorial economies and networks versus being located in individual firms (Herstad et al., 2014). Engagement in international collaboration linkages is conducive to lead to innovation with higher degrees of novelty by enabling companies to connect new pools of knowledge externally compared to similar knowledge transferred through local and regional linkages (Plechero & Chaminade, 2016). Moreover, it enables the direct transfer of knowledge even across large distances where the strategic importance of partner institution can dampen the sensitivity of collaboration to geographical proximity (Laursen et al., 2011). Similarly, through the transfer of knowledge which is not available domestically, international collaboration linkages create opportunities to follow the changes in the global environment, to catch up global trends and to cope with the lock-in forces driven by outdated production systems, technologies and markets (Grillitsch et al., 2015).

Accordingly, several studies point out the role of involvement in global innovation and knowledge collaborations as a crucial factor for regional development where external ties facilitate the development of new growth paths (Trippl et al., 2017; Isaksen & Trippl, 2014). Within that stream of literature, several studies investigated the interaction between regional innovation systems (RIS) and different types of global interaction to understand how regions are connected with a variety of geographical markets and technological sources of knowledge (Martin & Moodysson, 2013; Tödtling et al., 2011; Sotarauta et al., 2011).

Given the aforementioned importance of international collaboration in innovation activities to substantially induce the innovativeness and economic performance of firms and regions, it is of crucial importance to investigate what type of factors underpin or constrain the involvement of companies in international innovation collaboration. However, to the best of author's knowledge, less has been done to analyze the differentiation at firm-level in international cooperation processes across countries while considering the national context in which firms are embedded. Most of the studies have been confined to one single country and just a few have relied on a small number of national datasets (Dachs et al., 2008; Abramovsky et al., 2009), thus, offered limited evidence regarding the effects of varying institutional contexts on firms' behavior. Moreover, empirical research on collaboration in innovation activities mainly has adopted a framework limited to one single level, and thus, been ill-equipped to understand specific differences between varying contexts in a proper and concise way. As regards innovation collaboration, relations are identified at more than one level and complex where higher-levels such as industries and countries pose effects that are accountable for outcomes at firm-level (Srholec, 2011). Here, multilevel modeling provides insight to distinguish what types of differences at higher levels matters and how they impact firms' involvement in international collaboration linkages.

Accordingly, the most important differentiation of our study is the analysis of the firm-level diversification in international innovation collaboration across countries within the framework of multilevel analysis and the inclusion of the theory of technological regimes. It is aimed to analyze multilevel interactions in a comprehensive way. Hence, this study is established on two building blocks; national framework conditions and the dimensions of technological regimes. In short, this study investigates the impacts of the national framework conditions and the dimensions of technological regimes as the sources of differentiation that condition the collaboration behavior of firms in innovation activities. To get a broader understanding of which extent they matter, firms are treated as being embedded in the national contexts using multilevel hierarchical modeling. By doing so, we make a contribution to the literature on the determinants of a firm's decision to engage in international collaboration.

Within this respect, Srholec (2015) has been the one to investigate different institutional contexts by using multilevel modeling. However, while making a pioneering and significant contribution to our knowledge, his study offers a limited set of firm-level and country-level predictors and, more importantly, gives no attention to the properties of technological regimes which are indicated to be the key drivers of firm-level differentiation (Herstad et al., 2014). Herstad et al. (2014) delivered one of the most prominent recent attempts to understand the characteristics of firms that influence the pattern of collaboration and the geography of partner selection by connecting the theories of technological regimes (Breschi & Malerba, 1997; Breschi et al., 2000; Castellacci, 2007) and advancements in industrial knowledge development (Asheim & Coenen, 2005; Asheim, 2007; Martin, 2013; Jensen et al., 2007). Based on their analysis, they found that analytical knowledge base, lower degrees of cumulativeness in knowledge development, appropriability conditions and technological opportunities are positively associated with the degree of engagement in international innovation collaboration. Yet, as a drawback, Herstad et al. (2014)'s analysis was solely conducted using national data from one single economy and neglected the cross-country differentiation of firms' behavior to participate in foreign innovation collaborations in line with national framework conditions.

The motivation of this study is built on several notions. First, the specificities of national innovation systems (Lundvall, 1992) are likely to guide the patterns of innovation collaboration. The challenges and opportunities presented by foreign collaborative linkages drive the awareness and importance of implementing strategies and policies to source knowledge externally, still in increasing importance. However, while firms are under direct effect of these challenges and opportunities to transform themselves, national-level policies keep their importance as being immediate forms of intervention to shape innovation behavior in business life (Herstad et al., 2010). Moreover, the approach of innovation systems puts emphasis on the national borders to separate different systems between each other and, describe the interdependencies of actors in a particular country (Fagerberg, 2004).

Second, the economic environment, the size of the economy and institutions vary across countries (Leiponen & Drejer, 2007; Beaudry & Schiffauerova, 2009), accordingly, these distinctive characteristics of economies may be the sources of differentiation to access global knowledge pools. Here, Fernhaber et al. (2014) put forward evidence for the role played by the location of firms to determine the needs to internationalize and the availability of local resources. In that line, Grillitsch and Chaminade (2018) argue that the institutional differences can draw barriers and challenges for firms to internationalize their knowledge sourcing processes where firms need to enhance their capabilities to overcome the complexity of different institutional settings to be able to successfully engage in global innovation collaborations. In fact, institutions can postulate contradicting effects given the notion of cognitive proximity that denotes to the actors which carry a similar type of knowledge. Here, institutional similarities, which translate into relational proximity can facilitate the transfer of knowledge (Grillitsch et al., 2015). However, the increased cognitive distance between actors hypes the complexity of knowledge transfer while also enhancing the degree of novelty and the learning potential among actors (Boschma, 2005; Nooteboom et al., 2007).

Finally, in the literature, the technological environment, which is conditioned by opportunity and appropriability conditions, is described as a major factor to assign the intensity of innovation (Breschi et al., 2000) and interwoven with the degree of involvement in international innovation collaboration (Herstad et al., 2014). Therefore, it is significant to reveal that the relationship pattern shown by Herstad et al. (2014) is not specific to one country rather a general phenomenon. Moreover, it is of crucial importance to analyze how the properties of technological regimes act under different national framework conditions. However, empirical studies have not far questioned whether firms differ in their global involvement patterns to source knowledge in varying contexts, given the key characteristics of technological regimes. Hence, different national settings require an examination to be able to make a comparison regarding the involvement behaviors of firms in distinct environments.

Accordingly, in order to capture the specificities driven by the national framework conditions and institutional environment, one should discuss the role of national contexts to impact the engagement patterns of firms into global knowledge sources while referring to the interdependencies between firm-level strategies and the available resources at the local surroundings. Thus, in this paper, our point of departure is the underappreciation of the context-specificity of firm characteristics linked to national boundaries as the source of differentiation. Building upon these lines, the main contribution of this paper lies in the inclusion of the matters of different national contexts and the properties of technological regimes to enhance our understanding on international collaboration involvement for innovation activities in a broader perspective.

This thesis is divided into six main sections. Chapter 2 reviews the existing literature in the field. Chapter 3 describes the data and the variables used in the analysis. Further, Chapter 4 explains the methodology relied on which is, in that case, the multilevel modeling. Chapter 5 presents the results and offers a discussion of the main findings of the analysis, and Chapter 6 concludes.

1.1 Scope and Delimitations

The analysis is confined to some selected countries of Europe depending on the data available to generate consistent variables for the purpose defined within the framework of this study. Therefore, some advanced economies of Europe such as Finland, Denmark, and Sweden as well as the developed and developing countries of other world regions are not considered in the analysis, which notion limits the scope of the study to draw extensive and general conclusions for the rest. However, the results are in the manner of encouraging to conduct further research with large micro datasets to find out to which extent the inferences are applicable to a broader set of countries.

2 Theory

The purpose of this section is to present the national framework conditions and the technological regime concept as a distinguishing factor to influence the behavior of firms to participate in international innovation collaboration.

2.1 Literature Review

It is widely accepted that innovation has turned into an increasingly complex, open and interactive phenomenon given its diversifying nature between sectors and knowledge bases and, the increased number of knowledge sources and inputs utilized by institutions and firms where the division of labor and the interdependence among actors have been more complicated (Tödtling et al., 2011; Asheim et al., 2005; Asheim, 2007). Innovation processes evolved substantially over the last decade relying more and more on external sources of innovation like universities, consortia, and government labs. Moreover, R&D collaboration has enhanced with the involvement of foreign and domestic rivals (Powell & Grodal, 2005).

In this respect, to be able to successfully innovate, firms are required to source knowledge from a variety of sources and actors distributed across various spatial scales and, combine it with their internal knowledge and competences (Tödtling et al., 2006; Tödtling et al., 2011), which notion is the main purpose of the collaborative linkages (Fey & Birkinshaw, 2005). Here, innovation and knowledge collaborations as being the external sources of knowledge and innovation have been regarded as fundamental to overcome the long-term lock-in problems (Bathelt et al., 2004). Therefore, cooperation with other firms and institutions has been increasingly pointed out as the prevalent mode of technology development (Srholec, 2015).

The geographical scale in which the focal firm collaborate is shaped as a result of the evolution of firm-level characteristics and strategies under several external forces. These forces even can be contradictory to each other such as centrifugal and centripetal forces which refer to the centralization of linkages within the context of uncertainties, stickiness of knowledge and technological complexity; and the increased connectedness to abroad business contexts driven by market differentiation and geographically distributed technological development, respectively (Herstad et al., 2014; Cantwell, 1995). The balance between these two forces has been changed by the increased integration of emerging economies into the global economy which has created new centripetal forces to centralize the research activities in the country of origin and the need for access to heterogeneous scientific and technological resources dispersed globally (Sachwald, 2008).

It is of crucial importance for firms to be updated with relevant technological advances concerning competitiveness and growth. In that sense, in the current global economy where the locus of innovation has shifted towards territorial economies and the distributed networks rather than firms, any single firm cannot live being isolated from external knowledge sources (Ebersberger & Herstad, 2013). Cooperation arrangements act as a facilitator to access external knowledge sources while pooling the complementary resources of the partners, distributing cost and risk between them and increasing the division of labor for innovation activities (Srholec, 2015). Some of these external sources are tradable and can be purchased through market transactions. However, others are embodied in people and organizations, thus, hard to absorb by means of markets, instead, need the interactive learning between users and producers in order to be transferred efficiently (Maskell & Malmberg, 1999b). At this point, international collaborative linkages carry importance in line with their capacity to transfer embodied, tacit and evolving knowledge across long distances (Herstad et al., 2014). Therefore, involvement in international collaboration has been increasingly regarded as a key factor for knowledge exchange and generation (Martin et al., 2018).

The drivers, outcomes, and dynamics of the new global configuration of innovation activities have been widely debated in the literature by a growing number of studies. Within this respect, to our knowledge, engagement in international collaboration is positively correlated with a variety of firm-specific characteristics like firm size, research and development intensity, export activities, the education level of the labor force and foreign ownership (Ebersberger & Herstad, 2013). International collaboration is organizationally demanding (Narula, 2002) and the utilization from innovation networks is highly dependent on the absorptive capacity of firms (Chaminade & Plechero, 2015; Barnard & Chaminade, 2017). Furthermore, engagement in cooperation for innovation activities can be tending to inertia owing to high marginal costs of shifting between network configurations. Here, firms need to be aware of the consequences for their selection of collaboration partners where there is a trade-off between the risk of misunderstanding and the opportunity of novelty which are shaped under the notions of absorptive capacity and cognitive distance (Nooteboom et al., 2007). The internal knowledge accumulation of firms can shape the knowledge distribution pattern within a knowledge network regardless of the geographical proximity and the density of business networks (Giuliani, 2006). However, this kind of studies while widely discussing the determinants of international collaboration patterns of firms, offer no explanation for the national contexts that firms are embedded in and how these contexts draw upon the firm characteristics.

Another strand of the literature focused on the conditions of regional innovation systems to identify certain regions according to their behaviors to source knowledge externally. In this respect, Martin et al. (2018) highlight the geographical advantage of firms in organizationally thick and diversified RIS to access globally distributed knowledge. Furthermore, in addition to the complementary role of innovation collaborations (Fitjar & Rodríguez-Pose, 2013), companies in organizationally thin and peripheral RIS may tend to collaborate more in broader geographical scales to compensate for the lack of local knowledge spillovers (Grillitsch & Nilsson, 2015; Chaminade & Plechero, 2015). However, the need for knowledge flows from global sources in the periphery is determined by the low attractiveness and insufficient local resources to internationalize (Herstad & Ebersberger, 2015) and therefore, is highly depended on firm size and absorptive capacity (Grillitsch & Nilsson, 2015). Here, Herstad (2018) states that the local conditions as the bases for internationalization substantially differ in their incentives and resources available to local firms.

Recently, Herstad et al. (2014) draw on the theory of technological regimes and studies on industrial knowledge development to understand the behavioral differentiation of firms to engage in international collaboration. This paper follows the lines of Herstad et al. (2014) by relying on technological regime literature to distinguish firm-level characteristics. However, our main aim is to conduct analysis across countries by investigating the unexplained cross-country heterogeneity that drives the collaboration patterns of firms beyond firm-level predictors. Therefore, this study adopts the notion of that national context and institutions matter to shape the tendency and manner of firms to cooperate in their innovation activities. In sum, this study combines firm characteristics in the form of technological regimes and nests them in national conditions.

Dachs et al. (2008) investigated the differences in cooperative behavior of innovating firms within the contexts of Austria and Finland where they found a higher propensity to involve in innovation collaboration linkages for Austrian firms. They ascribed these differences in firm behavior to the underlying national conditions in which they are rooted deeply. Abramovsky et al. (2009) (cited in Srholec, 2015), using the CIS3 data that belongs to a broader range of countries, highlighted that Spain differs from France, Germany and United Kingdom in its cooperation behavior on innovation. Here, according to their empirical findings, countries postulate intriguing differences especially for the impact of R&D intensity, appropriability, constraints, and scale.

Recently, Srholec (2015) relied on a larger dataset of twelve countries using CIS4 to compare the innovation cooperation across countries in a multi-level model. He combined firm and country-level data by distinguishing domestic, foreign and mixed cooperation behaviors. Based on his results, national framework conditions matter especially to cooperate with foreign partners where several country-level differences are capable to explain the variation in foreign cooperation. Moreover, firms located in countries with less developed research infrastructure are likely to be linked to foreign cooperation due to suffering the lack of relevant partners at home.

2.2 National Framework Conditions

Taking into consideration the highly distributed character of innovation collaboration, space can seem an insignificant part of that global system. Nevertheless, the relationship between space and innovation activities is much more complicated given the notion that some regions perform better than others under the conditions of the globalization of the world economy. Here, several concepts such as territorial production systems, regional innovation networks, and innovative milieu seek answers to understand the role played by distinct regional contexts analyzing local supply-side characteristics of regions (Simmie, 2003).

With reference to a certain time and space, knowledge has the context-specific nature where without considering this context, it turns into information (Nonaka et al., 2000). Here, the growing body of learning regions puts emphasis on tacit knowledge and the importance of being co-located to innovate and explains the geography of innovative activity based on social interactions (Asheim, 1996). Moreover, innovation systems highlight the notion of collective learning in which local actors interact by means of systemic relations (Asheim & Gertler, 2005). Additionally, innovation system literature implies that the local level is the initial phase where the innovative capacity of firms is shaped, and economic processes are coordinated and managed (Chaminade & Vang, 2008; Gu, 2006). In that line, the unequal involvement to global knowledge flows across regions and the existence of some places as powerhouses or knowledge hubs in global innovation networks (Chaminade & Plechero, 2015) support the argument on the key role played by the local.

This study, by referring to the cruciality of the local conditions shaped under the context-specific national institutions, takes into account the cross-country differentiation in which boundaries refer to a shared culture, history, language, social and political institutions (Lundvall, 1992; Nelson, 1993). Here, the concept of national innovation systems (NIS) defines the boundaries of an innovation system as being equal to country's geographical borders and highlights the role played by nation-states in innovation activities (Breschi & Malerba, 1997). In other words, national differences and boundaries are major factors that bring national innovation systems into being. The NIS approach focuses on the understanding of how a variety of actors embedded in innovation processes such as firms, universities, governmental institutions, and research institutes operate and interact with each other (Nelson, 1993). Therefore, organizations and institutions are regarded as substantial components of innovation systems (Högselius, 2005).

Country borders reveal discontinuities in geographic spaces given the abrupt changes in institutions, regulations, laws and even culture (Beugelsdijk & Mudambi, 2014). Therefore, if one considers companies which possess required competencies for innovation processes, the major factor would be their capabilities to successfully deal with institutional barriers and social networks in the way of creating a widened search space for information and knowledge and, thus, for the engagement in global international collaboration linkages (Grillitsch & Chaminade, 2018). Moreover, to be able to interact and communicate with potential external partners, firms are required to understand the diversifying nature of institutional settings where linkages through global pipelines are conditioned on the cognitive distance between partners (Bathelt et al., 2004).

The literature on innovation systems extensively investigated national conditions that influence the interactive learning and, thus innovation (Lundvall, 1992; Nelson, 1993). In that strand of literature, historical, political and institutional factors have been regarded as context-specific capabilities which evolve in line with the path-dependent national trajectories and, in turn, distinguish the innovative behavior of micro-level actors like firms. Therefore, the ability of firms to reach the external sources of knowledge is perceived as crucial to catch up with the frontier and recent technological advancements. At this point, it is also important to throw a hint on that the international business does not diminish the role played by regional or national innovation systems (Srholec, 2009).

Furthermore, innovation processes reach beyond the notion of research and development where technological capabilities of a nation are under the impact of the set of institutions but not confined to the ones that are related to innovation (Nelson, 1993). In that sense, innovation system of a nation needs to be delineated on the basis of industrial and technological capabilities as well as, to some extent, institutions, political process, the quality of governance, research infrastructure, workforce and so on (Fagerberg, 2004). Institutions regulate the relations between people and groups of people as well as between organizations. On that ground, the institutional setting of a country defines and manages the pattern and the content of the interaction and communication related to innovation processes. Additionally, it takes a very long time to occur changes in the institutional setting (Edquist & Johnson, 1996).

Departing from that point, this paper while distinguishing the distinct capabilities and innovative performances of companies, acknowledges the crucial role played by several institutions and organizations within the framework of national conditions to shape the innovative activities and collaboration patterns of firms. Here, one can fairly state that firms' participation in foreign collaborative linkages is contingent on the national environment and the institutional structure of a country's national system. Therefore, our baseline hypothesis refers to the country-level differences to be influential on the behavior of firms to engage in international collaboration:

Hypothesis 1. Firms' behavior to engage in international collaboration varies under different national framework conditions.

The provision of knowledge inputs constitutes a crucial component of innovation systems where it can be understood in the body of two different processes. The first one refers to the continuity of research and development activities to sustain the generation of new knowledge whereas the second one relates to the provision of human capital and competence building to provide the production and the reproduction of relevant skills to be able to use them in innovation and R&D processes (Chaminade & Edquist, 2006). A well-functioning innovation system with denser networks of cooperation between partners makes it easier to access knowledge produced elsewhere in the system (Srholec, 2015) and is highly dependent on the research infrastructure and educational inputs to be efficiently operating. In that line, advanced framework conditions like research and educational infrastructures underpin firms to develop cooperation linkages with partners in the same environment. However, this type of understanding is only capable to explain the patterns of domestic cooperation but falls short to give an explanation for the tendencies of firms to cooperate abroad (Srholec, 2015).

Nevertheless, Barnard and Chaminade (2017) investigate the cross-border interactions of multinational companies (MNCs) and shed light on the diversifying behavior of MNCs in advanced economies and the emerging MNCs regarding their motives to participate in global innovation networks. In this respect, the emerging MNCs show a tendency to use collaborative ties for their motives to access additional capabilities rather than the exploitation of additional capabilities where they aim to compensate for the limited local resources. Despite the notion of that firms tend to collaborate with partners in proximity in order to decrease the costs and to get rid of venturing abroad, in the case of the absence of relevant domestic partners with complementary resources in the country's national innovation system, it is quite reasonable for firms to participate in foreign collaborations to reach knowledge that is not available domestically. In this respect, firms operating in less developed research infrastructure are prone to establish collaborative linkage abroad in comparison to firms embedded in well-developed national innovation systems due to weak access to knowledge (Srholec, 2015). This notion takes us to our second hypothesis which is:

Hypothesis 2. The quality of research infrastructure is negatively associated with firms' behavior to engage in international collaboration.

Education which stands as a crucial framework condition for the supply of qualified labor force feeds the basis of national innovation systems towards increased technological capabilities. Here, the educational system of a nation not only takes a role in the provision of labor but also defines their attitudes towards technical advance (Nelson, 1993). Moreover, the search for new knowledge is conditioned by local knowledge pools and the availability of the relevant expertise in terms of human capital which is capable to provide knowledge related to the idiosyncratic needs of firms (Breschi & Malerba, 1997). In that sense, the provision of the qualified workforce increases the density of interactions between local actors and restricts the search space given the abundance of local knowledge spillovers. Accordingly, we expect a negative impact of education on international collaboration due to its contribution to strengthen the structure of national innovation system and underpin the development of well-functioning research environment through human capital. On the other hand, it may be hard to interpret the sole impact of education since it is highly influential on the quality of research infrastructure which undertakes some portion of the impact related to education. Overall, this follows us our third hypothesis:

Hypothesis 3. Education is negatively associated with firms' behavior to engage in international collaboration.

Since the system approach is considered within the framework of political and administrative borders (Fagerberg, 2004), such factors are likely to be crucial to understand the tendency of firms to innovate and collaborate. The research and educational infrastructure in a national system cannot be analyzed separately from the control of broader institutions that refer to the governance which affects the environment in which firms operate and the way of how they conduct their businesses (Goedhuys & Srholec, 2015). Relations between government agencies and companies and, the impact of technology policies on innovations point out the effects of governance on learning and innovation processes. Moreover, the governance dimension of national framework conditions controls and manages the allocation of resources to universities, research institutes, and other actors as well as to the activities related to research and development cooperation and innovation networking (Edquist & Johnson, 1996). Governments put policies into regulation that plan infrastructure, incentives, and other related framework conditions to foster innovation (Goedhuys & Srholec, 2009). In this respect, the tendency of firms to collaborate for innovation activities is shaped under the influence of certain policy measures. Here, we expect good governance to develop favorable conditions for the further development of international collaboration:

Hypothesis 4. The quality of governance is positively associated with firms' behavior to engage in international collaboration.

Finally, we consider two more dimensions, namely ease of doing business and openness, to delineate the spatial dynamics in terms of the variety of relevant collaboration partners domestically and the intensity of outward trade linkages, respectively. Accordingly, we expect both measures to draw contradicting effects on the firms' behavior to participate in international collaboration. The dimension of ease of doing business serves to enhance the variety of relevant collaboration partners within national borders, thus, increases the possibility to establish domestic ties favoring an environment with dense local knowledge spillovers:

Hypothesis 5. Ease of doing business is negatively associated with firms' behavior to engage in international collaboration.

Nevertheless, openness denotes to the intensity of economic transactions with foreign countries beyond the country's geography, history, and economic structure. In this respect, more dense interactions with foreign companies, or in other words high degree of involvement in global economic system through trade, investment, and other means, open new avenues to establish collaborative linkages (Srholec, 2015) while reinforcing the capabilities of firms to successfully deal with institutional barriers:

Hypothesis 6. Openness is positively associated with firms' behavior to engage in international collaboration.

Knowledge related to innovation activities can be sourced at various spatial levels such as local, national or international. By considering distinct country conditions, this study also acknowledges the importance of national contexts to shape the behavior of the focal firm to interact through local and global linkages. Here, from a broader perspective, the paper adopts a framework in which firms are also under the influence of national innovation systems and institutional structure. Therefore, the analysis is useful to deliver more robust insights to understand the inter-firm differentiation of international involvement in comparison to the analysis which is confined to one small single economy.

As mentioned, Srholec (2015) studied diversifying cooperation behavior in innovation processes across countries within the framework of multilevel modeling. However, his study underestimates a variety of industrial characteristics related to the knowledge and technology nature of respective sectors in which firms operate. Therefore, this thesis aims to provide a fine-tuned analysis to pool micro and macro datasets. We take a further step in the understanding of firms' tendencies to participate in international collaborations by linking it to industry-level knowledge and technology characteristics which are well-articulated in the notion of technological regimes.

2.3 The Dimensions of Technological Regimes

The notion of technological regimes has rooted in the works of Nelson and Winter (1982) and Winter (1984). The term of "technological regimes" is used to define some regularities which are created by technological and commercial incentives as well as constraints experienced by firms where firms in the same technological regime perform similar patterns in the organization of innovation activities.

In the literature on technological regimes, behavioral differentiation is considered to be driven by the nature of knowledge and the key economic properties. Here, the nature of knowledge is defined by the notions of the specificity and cumulativeness. Additionally, appropriability and opportunity conditions are considered as the crucial determinants of behavioral differentiation which, respectively, capture the right of firms to have proprietary knowledge within certain boundaries and the efforts required to turn innovations into sales (Ebersberger & Herstad, 2011; Herstad et al., 2014). In the literature, several scholars put forward evidence for the dimensions of technological regimes as being the most relevant factors that affect the market dynamics and innovation compared to the firm size and demand (Breschi et al., 2000; Gort & Klepper, 1982; Cohen & Levin, 1989).

Nevertheless, Herstad et al. (2014) and Leiponen and Drejer (2007) highlight that the literature mainly has put effort to understand the differentiation among industries neglecting the heterogeneity at firm-scale. Therefore, following the trails of Leiponen and Drejer (2007) and Herstad et al. (2014), this study relies on micro-level data. The independent variables used in our analysis reflect core competences of firms and their organizational behaviors as well as the properties of the environment in which they act such as the diversity of markets and technological conditions (Herstad et al., 2014). Firms in the same environment may tend to adopt different strategies given the ruggedness of the conditions. For that reason, innovation collaboration behavior of firm may follow different trajectories (Leiponen & Drejer, 2007). Here, the adoption of micro-level data enables us to reflect the firm-specific characteristics to the results.

The notion of technological regimes that is conceptualized by the nature of technology and knowledge is mainly defined as the combination of four fundamental factors; the properties of the internal knowledge base, the cumulativeness of knowledge development, appropriability of innovations and technological opportunities (Malerba & Orsenigo, 1997; Malerba & Orsenigo, 1990; Breschi & Malerba, 1997).

2.3.1 The properties of the internal knowledge base

Knowledge is the key driver of innovation (Howells, 2002) where both creation and transfer of knowledge are crucial to foster a learning process through which the competitive advantage of firms, industries, and regions is generated (Boschma, 2005) Given the notion of learning economy, competition between firms is substantially shaped by the production, acquisition, and distribution of knowledge and to some extent, this notion is true for all industries (Gertler & Levitte, 2005).

The most well-known knowledge classification is the taxonomy of knowledge as “codified” and “tacit” which has been grounded by the seminal work of Polanyi (1967). According to this classification, the creation and transfer of tacit knowledge across the network of innovators are more sensitive to proximity and personal relations, thus, hard to observe and complex in comparison to the codified knowledge which is less space-bounded, easy to articulate and observable (Bathelt et al., 2004). Moreover, tacit knowledge needs direct experience and face-to-face interaction for a successful knowledge transfer given its context-specific nature. Hence, tacit knowledge is regarded as “spatially sticky” and “embodied in the geography" (Howells, 2002; Martin & Moodysson, 2013). Dimensions of knowledge gain importance during the search process of companies to identify relevant partners (Herstad et al., 2014). Tacit and codified nature of knowledge act together and influence each other to guide the innovation and knowledge creation processes which, in turn, become more complex (Liu et al., 2013). However, geographical proximity is "neither a necessary nor sufficient condition" for interactive learning and innovation (Boschma, 2005). Furthermore, a variety of geographical scales such as global, national and regional/local possess a different role for innovation, learning and, the creation of knowledge (Asheim & Isaksen, 2002).

It is well-common to describe knowledge bases with reference to R&D intensity, accumulated R&D and technological profiles of firms which can be easily drawn upon the patent data (Herstad et al., 2014; Castellacci & Zheng, 2010). However, for their innovation processes, firms externally source knowledge from a variety of sources such as suppliers and clients, universities, R&D institutes, competitors, consultants, etc. where all refer to specific kinds of scientific and applied knowledge (Grillitsch et al., 2015; Tödtling et al., 2006). Hence, this type of assessment is not capable to identify the intrinsic qualities of the learning process where only firms with scientific inputs and systematic R&D are likely to rely on science-technology innovation (Herstad et al., 2014; Jensen et al., 2007). Here, the differentiated knowledge base captures a broad-based view beyond the limits of the narrow, supply-side, linear innovation model (Martin & Moodysson, 2011; Lundvall, 2007) covering the experience-based knowledge and non-R&D forms of learning (Herstad et al., 2014).

An *analytical knowledge base* (scientific-based) refers to the economic activities based on scientific knowledge in which codification and rational processes are crucial (Asheim et al., 2011). Basic research is located at the core of analytical knowledge base (Grillitsch et al., 2019). Additionally, innovation is built on the application of scientific principles and methods where the development of products and processes is operated systematically. Firms with analytical knowledge base mainly have in-house research and development (R&D) departments and exploit knowledge substantially from universities and research organizations. The knowledge transfer is less sensitive to distance-decay effects (Asheim et al., 2005; Coenen & Moodysson, 2009; Asheim & Gertler, 2005).

Contrary, *synthetic knowledge base* (engineering-based) dominates the industries with innovation processes developed on the application or novel combinations of existing knowledge and mainly non-scientific sources, often in response to specific problems raised by clients and suppliers (Zukauskaite & Moodysson, 2016). Innovation considerably takes place in the form of applied research and, process and product development (Asheim & Gertler, 2005). New knowledge generation is an inductive process of testing, experimentation, simulation and practical work where it is created through learning by doing, using and interacting (Asheim & Coenen, 2006; Coenen & Moodysson, 2009; Martin & Moodysson, 2011; Liu et al., 2013). Firms that rely on synthetic knowledge base broadly perform interactions with partners in proximity. Due to being in a cross-disciplinary nature and the system-embeddedness of knowledge, partner search is more complex for synthetic knowledge base (Herstad et al., 2014). A synthetic knowledge base is regarded as being negatively associated with global innovation linkages due to the reliance on face-to-face interaction and the experience gained through learning-by-doing, using and interacting (DUI).

2.3.2 The cumulativeness of knowledge development

The condition of cumulativeness simply defines the situation where new knowledge development is highly dependent on the previous rounds of innovation processes in which firms rely on the accumulated knowledge and technology (Herstad et al., 2014). Therefore, knowledge development and innovation activities of today lay the ground for the subsequent innovations of tomorrow while continuously improving the original innovation. Thus, it represents the persistence of innovation activities and increasing returns (Breschi et al., 2000). By referring to the firm-level cumulativeness, Breschi and Malerba (1997) relate the continuity of innovations to the size of a firm as well as the presence of research infrastructure. Another important dimension of cumulativeness is that it represents the distribution degree of valuable knowledge inputs across various actors and territorial contexts or a limited number of firms within a value chain. Cumulativeness also entails system embeddedness and complexity which can lead to lock-in by limiting the collaboration partners with the existing ones (Herstad et al., 2014). Cumulativeness of knowledge also shows interdependencies with the notion of knowledge bases where firms that rely on synthetic knowledge base are likely to undergo a higher degree of cumulativeness given the reliance on existing knowledge for the development of new knowledge.

2.3.3 Appropriability of innovations

Profits from innovation are determined by three main factors; appropriability regime, complementary assets and the existence of a dominant paradigm or vice versa (Dosi et al., 2006) Therefore, appropriability conditions draw the possibilities for protecting innovations from imitation and the generation of profits from innovation activities (Breschi et al., 2000; Malerba & Orsenigo, 1997) Two basic conditions can be defined to summarize the appropriability conditions; the level and the means of appropriability. Level refers to the ranking of the appropriability conditions. High appropriability indicates the presence of conditions to protect innovations while low appropriability refers to an economic environment with prevalent knowledge spillovers (Levin et al., 1987). On the other hand, means of appropriability encompass the formal means of protection such as patent and copyright as well as informal means of protection like secrecy, lead times, costs and time required for duplication, learning, sales and the control of complementary assets (Dosi et al., 2006; Castellacci & Zheng, 2010).

Knowledge development through collaborative linkages comes with the exposure to proprietary knowledge and includes uncertainty regarding the control of knowledge assets which, in turn, relates to the risk of unbounded knowledge externalities and partner opportunism. Therefore, the extension of a firm’s network into new business contexts with new partners increases the sensitivity of engagement to appropriability conditions, especially in the absence of mediators such as past collaborative linkages, the diversity of social capital and interpersonal networks (Herstad et al., 2014). Thus, availability and the use of IPR encourage firms to extend their business networks and to involve in global innovation linkages by mitigating the risk in unknown business contexts.

2.3.4 Technological opportunities

Opportunity conditions refer to the possibility of a firm to innovate depending on the amount of the resources invested in search (Breschi et al., 2000; Malerba & Orsenigo, 1997). Here, technological opportunities describe the availability of a rich variety of technologically feasible solutions, approaches, and activities. The sources of opportunities vary among technologies and industries where for some industries, major scientific breakthroughs in universities may be a source of technological opportunity while for others opportunities are related to advancements in R&D and endogenous learning or external sources of knowledge such as suppliers, users, etc. (Breschi et al., 2000)

Geographical fragmentation and territorial specialization of industrial activities which have been resulted from globalization increased the number of localized markets and knowledge pools to be utilized in innovation processes. Therefore, the rate of return of innovation which is translated into sales is tangled with the use of localized assets. Hence, opportunity conditions are very likely to influence the degree of international involvement (Herstad et al., 2014).

To say the final remarks on technological regimes, it is important to highlight some issues regarding the role of institutions. Despite the fact that the properties of technological regimes influence the structure of innovation processes across different sectors, the role of institutions or non-firm organizations is far from neglecting in the evolution of sectoral innovation systems. Here, several factors such as institutions rooted in a country or region, the working style of organizations, policies adopted by the governments and the accumulated competences of firms contribute to the development of a historical and path-dependent process (Nelson, 1993). Moreover, the role of organizations seems to be at the center of the notion of technological regimes in which the level of technological opportunities is highly dependent on the basic research conducted by universities and research organizations as the major sources of knowledge. Accordingly, the level of appropriability conditions is likely to alter in different organizational contexts. Furthermore, both appropriability and cumulativeness are contingent on the policies and the competences of firms due to having strategic and organizational dimensions (Breschi & Malerba, 1997). Therefore, the relationship between the dimensions of technological regimes and the degree of international involvement is in the need of further examination to be verified under diversifying national frameworks of countries. Here, we lead our final hypothesis which refers to the firm-level diversification given the impacts of the properties of technological regimes under the distinct nature of national contexts:

Hypothesis 7. The effects of the properties of technological regimes on firms' behavior to engage in international collaboration vary under different national contexts.

3 Data

This chapter provides insight into the dataset used in the empirical analysis. Several aspects of the data such as validity and reliability, and the procedure to create variables have been critically investigated and presented in detail.

3.1 Micro Data

The analysis is conducted on micro-level data from the Community Innovation Survey (CIS), covering a large sample of 14 European countries to be representative beyond the national level. CIS data is a tool for generating official statistics at the European scale and has been widely used for researches in economics, management studies and economic geography (Herstad et al., 2014; Ebersberger & Herstad, 2011). The participating countries implement CIS methodology which has been developed by Eurostat by means of their national statistical offices. Surveys are conducted within two year-intervals and collecting CIS data is compulsory for most of the member states (Eurostat). This study has relied on the 2012 round of innovation survey which compiles information for innovation and innovation activities across three years between 2010 and 2012 (Eurostat, 2012).

Firm-level datasets of Community Innovation Survey (CIS) in Europe comprise a substantial amount of information regarding innovation activities and the strategies of thousands of enterprises. Therefore, it is possible to improve the measurement of inputs and outputs of the innovation processes and to combine them with other related factors by using CIS data (Castellacci & Zheng, 2010). The CIS also offers information related to the spatial configuration of innovation networks at firm-level with other relevant control variables (Grillitsch & Chaminade, 2018). CIS data in Europe has enabled to focus on a variety of different aspects, such as “the distinction between product and process innovation, the relevance of organizational innovation, the type and the composition of innovation expenditures (R&D, acquisition of machineries, training activities, etc.), and the patterns of cooperation and interactions of innovative firms with other actors in the sectoral system of innovation” to make empirical analysis across several countries (Castellacci, 2007). However, despite we can distinguish whether or not the focal firm cooperates with external partners in different geographical areas, the CIS survey does not provide information regarding the intensity of these linkages (Srholec, 2015). This issue should be noted as the limitation of this study.

The dataset used in the analysis covers 9 countries including Bulgaria, Germany, Hungary, Norway, Portugal, Romania, Slovakia, Croatia, and Lithuania. Countries are selected from a larger dataset of 14 countries based on the data available to define core independent variables of the analysis. Here, excluded countries had no answers for some of the questions that we have relied on for our analysis, such as the knowledge sources and the means of appropriability. Furthermore, general questions such as the number of employees, group membership or distance to major markets have been provided by all firms, however, only firms with innovation activities have answered further questions regarding their innovation activities. Thus, before starting the analysis, the survey data has been updated in line with the CIS 2012 questionnaire filters to fix the missing values. The dataset contains 45.859 observations in total. Nevertheless, innovation collaboration can only be observed for firms that attempt to innovate. Hence, for our analysis we are only interested in firms with innovation activities which are detected based on whether they introduced a new product or service, implemented a new process or reported not yet completed or abandoned innovation activities or positive innovation expenditure (Srholec, 2015; Ebersberger & Herstad, 2011; Herstad et al., 2014). Due to the fact that the analysis is confined to innovation active firms, it is likely to introduce a sample selection bias that needs to be considered in the interpretation of econometric analysis (Srholec, 2009; Srholec, 2015). As a result, our analysis is conducted with a sub-sample of 11.252 firms with innovation activities. The distribution of observations by country is shown in Table 1.

Table 1 The number of observations by country

Country	Number of observations	Percent
Bulgaria	2 225	19,77
Germany	2 303	20,47
Hungary	406	3,61
Norway	1 121	9,96
Portugal	3 241	28,8
Romania	190	1,69
Slovakia	447	3,97
Croatia	711	6,32
Lithuania	608	5,4
Total	11 252	100

As regards international cooperation, the data offers four main geographical distinctions (other Europe, United States, China or India, all other countries) with collaboration ties to suppliers, customers, competitors, consultants and commercial labs, universities and higher education institutions and, public and private research institutes. First, firms are asked to answer whether they have collaboration ties in any of their innovation activities with other enterprises or institutions. Further, it is questioned if they have a partner in their home country or in other geographical locations mentioned above. Based on this information, we define our dependent variable -international involvement- if the focal firm cooperated in its innovation activities only with foreign partners.

The nature of internal knowledge base enables us to capture different dimensions of knowledge. Breschi et al. (2000) developed an indicator for relevant knowledge base relying on a measure of total scores given by respondents to value the importance of ten fields of basic and applied science. However, Herstad et al. (2014) offered a more applicable measure reflecting the relative importance of knowledge sources which we have used in this study. In this respect, any importance that is ascribed to particular knowledge sources is assumed to indicate the internal knowledge base of the focal firm that is likely to represent its geography of innovation activities. In the CIS survey, information sources are graded based on a four-level scale (3=high importance, 2=medium importance, 1=low importance, 0=not used). Here, the valuation of importance has been done for two distinct groups of knowledge sources - scientific and industrial sources- where relatively higher valuation of industrial sources (suppliers, customers, competitors, etc.) is categorized as having a synthetic knowledge base (synthetic knowledge base =1, otherwise =0) and vice versa (analytic knowledge base =1, otherwise =0).

To Breschi et al. (2000), cumulativeness is equal to the importance of frequent technological improvements while Castellacci and Zheng (2010) measure cumulativeness relying on whether the focal firm is involved in continuous R&D. However, for this variable, we adopt the measurement of Herstad et al. (2014) where they assume cumulativeness (=1) for the knowledge development if internal sources of knowledge are regarded as having higher importance compared to the external sources (otherwise =0). The higher relative importance of internal sources refers to the dependence on previous rounds of innovations.

The CIS survey measures the degree of effectiveness of appropriability conditions on a four-level scale (3=high importance, 2=medium importance, 1=low importance, 0=not used). We reflect the degree of appropriability conditions of the focal firm by summing the scores for both formal and informal appropriability means (patents, design registration, copyright, trademarks, lead time advantages, complexity of goods and services, secrecy) and then, dividing it by 7 which is the total number of the methods offered in the survey to find the mean.

Technological opportunities are captured by measuring the importance of technical knowledge derived from external sources such as suppliers, customers, competitors, consultants and commercial labs, universities and higher education institutions, and public and private research institutes. For each observation, the technological opportunity is the sum of the valuation for each external knowledge source (Breschi et al., 2000) where a higher score represents the existence of a variety of technological opportunities to be exploited.

Additionally, several other controls have been included in regression models to capture the firm-specific characteristics that are known to be influential on the firms' engagement in external knowledge networks. The size of a firm and export orientation are known to determine the collaboration tendency of firms (Dachs et al., 2008). Moreover, size advantages are important to control where bigger size is seen highly related to stronger management capabilities and more enriched internal competences (Herstad et al., 2014; Srholec, 2015; Nooteboom et al., 2007), thus, larger firms are presumed to be able to allocate the necessary resources for partner search (Dachs et al., 2008). Due to being regarded as confidential information, the size of firms is presented as the classification of firms in three broad categories rather than the number of employees. Here, a categorical variable is created for the size of the company covering the groups of small (under 50 employees), medium (50-259 employees) and large (250 and more employees). Small is taken as the base category.

As regards the export orientation, firms that hold abroad sales experience a higher propensity to engage in R&D collaborations (Dachs et al., 2008). In the CIS survey, firms are asked to indicate their largest market in terms of turnover. Relying on that information, a dummy variable is generated for foreign markets in the case of that the largest market is other than the country in which firm is located, to represent the market proximity to foreign locations and to indicate that the focal firm has exports. Affiliation with a corporate group may trigger the knowledge flows. Moreover, financial and administrative resources may act as a facilitator for innovation collaboration (Ebersberger & Herstad, 2011; Herstad et al., 2014). Therefore, a dummy is defined to refer if the focal firm is a part of an enterprise group, to consider the potential sources of the extension both organizationally and geographically (Srholec, 2015).

The emphasis on innovation which notion is directly under the control of management may also drive differentiation at micro-level. In this respect, R&D intensity is captured by the expenditure in intramural R&D as the share of total turnover. Strong R&D performance may dampen international collaborative involvement where both of them are organizationally demanding and dependent on management capabilities, therefore, firms struggle to combine them successfully (Ebersberger & Herstad, 2013). Moreover, involvement in global international networks generally aims to access additional capabilities that are somewhere else rather than the exploitation of additional capabilities already present in the firm (Barnard & Chaminade, 2017).

Accordingly, the absorptive capacity of firms which embodies the cognitive resources and organizational routines is suggested being crucial to assimilate and to transfer knowledge (Nooteboom et al., 2007). R&D activities may contribute to the development of the absorptive capacity which is conducive to extend the space of collaborative networks (Herstad et al., 2014). Moreover, engagement in external R&D may also indicate the capabilities of firms to interact with external partners and be representative for the absorptive capacity. Nevertheless, contractual R&D sourcing may substitute collaboration activities or contrary may underpin the establishment of collaborative linkages (Herstad et al., 2014). Hence, a dummy is included to indicate if the firm is engaged in extramural R&D.

Finally, given that the properties of technological regimes are operative "on average" at the industry level, sector dummies are included to all specifications with 18 categories in industry and services at a two-digit level (NACE Rev. 2). The number of observations by industry which indicates a relatively coherent representation of all entities is given in Table 2.

Table 2 The number of observations by industry

NACE	Industry	Number of observations	Percent
10-12	Food products, beverages and tobacco	812	7,22
13-15	Textiles, wearing apparel, leather and related products	624	5,55
16-18	Wood, paper, printing and reproduction	577	5,13

19-21	Petroleum, chemical, pharmaceutical	510	4,53
22-23	Rubber and plastic products and other non-metallic mineral products	855	7,60
24-25	Basic metals and fabricated metal products	934	8,30
26-28	Computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c	1 373	12,20
29-30	Motor vehicles and other transport equipment	357	3,17
31-32	Other manufacturing	454	4,03
33	Repair and installation of machinery and equipment	205	1,82
35	Electricity, gas, steam and air conditioning supply	148	1,32
36-39	Water collection, sewerage, waste management, remediation activities	326	2,90
45-47	Wholesale and retail trade and repair of motor vehicles and motorcycles	1 031	9,16
49-51	Land transport and transport via pipelines, water transport and air transport	341	3,03
52-53	Warehousing and support activities for transportation and postal and courier activities	227	2,02
58-63	Information and communication	1 207	10,73
64-66	Financial and insurance activities	421	3,74
69-75	Legal and accounting activities, activities of head offices, architectural and engineering activities, technical testing and analysis, scientific research and development, advertising and market research	850	7,55
	Total	11 252	100,00

3.2 Macro Data

Several studies in the literature pointed out that the exploitation of external knowledge is substantially determined by the development of “national technological capabilities” or in other words “absorptive capacity” within the context of “national innovation systems” (Fagerberg et al., 2018). Edquist (2010) (cited in Fagerberg and Srholec, 2008) put forward a broad definition of national innovation systems covering “all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations”.

In this paper, we are interested in multilevel interactions where firms are nested in countries to investigate the influence of country-level and industry-level variables on international collaboration patterns of firms. Therefore, in addition to the components of technological regimes and other several variables which capture the firm-level characteristics, we also need country-level indicators. For that purpose, first, we rely on national differences in technology and innovation to refer to the quality of national research infrastructure. Being located in the same environment with universities, R&D labs and research institutes may postulate positive externalities in the national economy and is prone to decrease the cost and uncertainties related to the innovation activities of firms (Goedhuys & Srholec, 2015; Fagerberg & Srholec, 2008). Yet, it is not an easy task to capture the differences in innovation and technology, therefore, we rely on three different indicators; (1) research and development expenditure (% of GDP), (2) the number of patent applications for residents, and (3) the number of scientific and technical journal articles (per 1000 people).

Educational infrastructure stands for another salient framework condition that is capable to impact the technological advancements through the supply of qualified workforce as stated by Nelson (1993). Moreover, education is located at the center of social capabilities where it is regarded as being the key factor of technological catching up (Abramovitz, 1986 (cited in Fagerberg and Srholec, 2008)). Three crude measures of the national educational system are considered in the analysis; (1) school enrollment, secondary (% gross), (2) school enrollment, tertiary (% gross), and (3) government expenditure on education, total (% of GDP).

It is also important to control the institutions that regulate how business is conducted under a certain set of rules. Therefore, we include some indicators from "Governance Matters" project by Kaufmann et al. (2009) which is highly cited in the literature (Goedhuys & Srholec, 2015). Here, based on the scoring scheme, higher points refer to better governance. Additionally, to assess the general "rules of the game" (Goedhuys & Srholec, 2015), we add political constraint (POLCON3) index where a broader consensus to take government decisions may decrease the threat of arbitrary changes, thus, is likely to foster a favorable environment for investments in R&D. Moreover, well-structured governance can facilitate interactions with foreign business environments in line with the regulation system. Both public research infrastructure and the educational system of the country are under the influence of governance institutions. In this respect, a set of indicators is preferred to denote the governance dimension; (1) political stability and absence of violence/terrorism, (2) government effectiveness, (3) regulatory quality, (4) rule of law (Kaufmann et al., 2009), and the political constraint index.

The openness of the country is evaluated to affect the productivity of firms in the literature (Goedhuys & Srholec, 2015) but also can be a source of dense interactions where foreign companies will be more willing to make cooperative arrangements with firms located in a country that is highly involved in international trade. In this respect, past trade ties can strengthen collaborative linkages. Indicators of (1) foreign direct investment, net inflows (% of GDP) and (2) imports of goods and services (% of GDP) are included to capture the openness dimension. Finally, ease of doing business may underpin domestic knowledge flows in an environment with a high variety of relevant partners like foreign companies. Therefore, both measures may draw contradicting effects on the firm's involvement in international innovation collaborations. We have relied on measures of (1) time required to start a business (days) and (2) start-up procedures to register a business (number) to be representative for ease of doing business. Given the notion of that, the impacts of institutional changes take time to disseminate, country-level indicators have been chosen from an earlier reference year based on their availability. Here, for Germany, tertiary school enrollment was generated taking the average of the values that come before and after the reference year. Data sources and the reference years for each country-level variable are offered in Appendix A.

All these aspects of national framework conditions may reveal a multicollinearity problem due to being correlated with each other. Hence, in line with Fagerberg and Srholec (2008); Goedhuys and Srholec (2015), we adopt the factor analysis to define the joint effect of the indicators mentioned above. For that reason, we have applied principal component analysis and the orthogonal varimax rotation procedure where the analysis distinguished four different components with eigenvalues higher than 1 that explains 85 percent of the variance. However, we have included the fifth component with an eigenvalue very close to 1 to be able to capture 92 percent of the variance. The factor loadings for each component are shown in Table 3.

The factor loadings are the correlation coefficients which indicate the relationship between the country-level indicators and the components, thus, represent the relevance of the indicators. A factor loading in bold indicates the state of belonging to a particular group. Based on the factor loadings, the components have been interpreted to show the adherence to the following dimensions of national framework conditions, respectively, the quality of research infrastructure, education, the quality of governance, ease of doing business and openness. With the creation of five components that carry the joint effect of country-level variables, our regression model does not suffer from multicollinearity.

Descriptive statistics for micro and macro-level variables are presented in Appendix B.

Table 3 Results of the principal component analysis

	Research infrastructure	Education	Governance	Ease of doing business	Openness	Unexplained
Research and development expenditure (% of GDP)	**0.4378**	0.0565	0.0324	0.1194	0.0423	.03966
Patent applications, residents	**0.5285**	0.1578	0.0483	0.0393	0.0721	.1106
Scientific and technical journal articles (per 1000 people)	**0.5266**	0.0036	0.1153	0.1359	0.0970	.02304
School enrollment, secondary (% gross)	0.0434	**0.5266**	0.0594	0.1611	0.0939	.03162
School enrollment, tertiary (% gross)	0.2082	**0.5105**	0.0573	0.0768	0.1012	.2884
Government expenditure on education, total (% of GDP)	0.0500	**0.4317**	0.0021	0.2132	0.1238	.1412
Political stability and absence of violence/terrorism	0.0258	0.0113	**0.4585**	0.3716	0.0247	.03025
Government effectiveness	0.1654	0.2625	**0.3082**	0.0561	0.0269	.04611
Regulatory quality	0.2046	0.1790	**0.3666**	0.0362	0.0745	.06073
Rule of law	0.2253	0.2342	**0.2264**	0.1253	0.0131	.02296
The political constraint index	0.1329	0.0928	**0.6063**	0.1524	0.1180	.1378
Time required to start a business (days)	0.0498	0.0871	0.0605	**0.6773**	0.0925	.05772
Start-up procedures to register a business (number)	0.1894	0.0898	0.0620	**0.4859**	0.1823	.07001
Foreign direct investment, net inflows (% of GDP)	0.0511	0.0333	0.0580	0.0046	**0.8421**	.04531
Imports of goods and services (% of GDP)	0.1571	0.2575	0.3273	0.1102	**0.4211**	.07342
Minimum value of the component score	-1.7973	-2.2261	-3.9240	-2.3178	-0.8386	
Maximum value of the component score	5.2430	3.5693	1.7677	1.6689	3.2644	
Total explained variance (cumulative)	0.3982	0.6077	0.7439	0.8595	0.9214	

4 Methods

This chapter delineates the methodology that has been relied on for the analysis as well as the underlying reasons for the model selection.

4.1 The Multilevel Model

The macro-level analysis does not always find its repercussion on the micro-level. It is a matter of fact that the variance at the firm-level becomes blurry with the adoption of macro-level data. Therefore, if some country-level characteristics are more likely to foster cooperation on innovation activities, this does not necessarily mean that firms behave in the same way (Srholec, 2015). The risk that macro analysis carries can be explained with the so-called “ecological fallacy” which occurs when the inferences about the nature of individuals are understood based on the inferences derived from the aggregate-level relationships such as inferences for the group of these individuals attached. In this respect, both firm-level and industry-level may be the sources of differentiation between countries to drive the tendency to cooperate at macro-level rather than the observed country-level pattern. Therefore, it is not an easy task to solve the controversy regarding the appropriate unit of the analysis (Goldstein, 2011).

On the other hand, a firm’s decision to engage in collaboration can be fully understood by considering firm-level and higher-level factors that are likely to affect collaboration behavior (Srholec, 2015). However, despite the patterns of collaboration on innovation are shaped under different levels, the studies on innovation mainly use a methodology that solely relies on one single level. The major drawback of single-level analysis is that it acts on the assumption that observations are independent of each other. Nevertheless, a nested structure violates that assumption and enables us to analyze the firm behavior by nesting it in higher levels such as industry, region or country. Thus, multi-level modeling provides a tool to model the country-level effects on firms.

In this paper, we are interested in the variance in international collaboration engagement of firms that is explained by a set of variables both from the firm and country levels. We also include the properties of technological regimes according to which firms in the same industry are seen to behave in a correlated manner. Therefore, our analysis requires a multilevel modeling technique to be elaborated by which the variance is divided between country-level and firm-level variables.

A multilevel model which is also called as “hierarchical”, “random coefficient” or “mixed-effects” model, analyzes the interactions between the dependent variable and explanatory variables that are defined at different levels (Goedhuys & Srholec, 2015). In this respect, in a hierarchical structure, we can estimate to which extent the higher-level units, namely countries, are accountable for collaboration pattern at the micro-level.

A conventional random intercept model in the multilevel terminology is defined as below;

(1) $Y_{ij} = \beta_{00} + \beta_{10}X_{ij} + \beta_{01}Z_j + u_j + e_{ij}$

where i denotes a firm and j is a country. Y_{ij} is the outcome derived from the equation, β_{00} is the standard intercept and, β_{10} and β_{01} are the coefficients related to X_{ij} that is a vector of firm-level (level-1) predictors and country-level Z_j which denotes to a vector of country-level (level-2) explanatory variables, respectively (Goedhuys & Srholec, 2015; Goldstein, 2011; Srholec, 2015). The firm-level error term (e_{ij}) is accepted to be distributed independently across countries and firms with zero mean and constant variance σ_e^2. u_j is the latent country effect which is accepted to be a country-level random variable independent across countries with zero mean and constant variance σ_u^2. It is assumed that u_j and e_{ij} are uncorrelated with each other and with X_{ij} and Z_j (Goedhuys & Srholec, 2015). A multilevel model is a subject under discussion when we let the intercept (β_{00}) or the slopes to be random (Srholec, 2011). This first model is utilized to test the hypothesis from 1 to 6.

Then, additional to intercepts if we let the slopes to vary given the interdependencies between the firm-level predictors and the country-level effects, the model becomes more complicated where the intercept and the slopes should be regarded as random coefficients with a certain mean value, variance, and distribution (Goedhuys & Srholec, 2015). The structure of this so-called "slope as outcomes" model is shown below;

(2) Firm-level model:

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + e_{ij}$$

Country-level model:

$$\beta_{0j} = y_{00} + y_{01}Z_j + u_{0j}$$
$$\beta_{1j} = y_{10} + y_{11}Z_j + u_{1j}$$

where β_{0j} denotes to the firm-level intercept in country j and β_{1j} is the slope coefficient linked to the firm-level variable Xij in country j. In this respect, the country-level equations formulate that the relationships -explained by these coefficients in the firm-level equation- are contingent on the characteristics of the country. Here, X_{ij} is no longer regarded as having a common effect across all countries. Hypothesis 7 is tested using this second model.

With the inclusion of β_{0j} and β_{1j} into the firm-level model and after the arrangement, the entire model can be presented in a single equation:

(3) $Y_{ij} = y_{00} + y_{01}Z_j + y_{10}X_{ij} + y_{11}Z_jX_{ij} + (u_{0j} + u_{1j}X_{ij} + e_{ij})$

Due to having a binary dependent variable, we need to use a non-linear multilevel model, thus, we rely on multilevel mixed-effects logistic regression for the analysis in this paper. The conditional distribution of the response given the random effects is assumed to be Bernoulli. Binary dependent variable models generate a set of coefficients which "parametrizes the impact of exogenous variables on the endogenous one", thus, gives information regarding the sign and the significance of the relationship. The regression coefficients generated by mixed-effects logistic regression are unstandardized and on the logit scale.

(4) Firm-level logit model:

$$E\,(Y_{ij} = 1 \mid \beta_j) = \varphi_{ij}$$
$$\text{Log}\,[\varphi_{ij} / (1 - \varphi_{ij})] = \eta_{ij}$$
$$\eta_{ij} = \beta_{0j} + \beta_{1j}X_{ij}$$

Country-level model:

$$\beta_{0j} = y_{00} + y_{01}Z_j + u_{0j}$$
$$\beta_{1j} = y_{10} + y_{11}Z_j + u_{1j}$$

As mostly preferred in the literature, the model can be estimated separately for different countries in which case we can determine if country-level predictors account for some of the variations at the firm-level. Nevertheless, in that case, we are not able to derive any inference regarding what really matters among the higher-level factors. Therefore, by solely relying on micro-level, we cannot go beyond speculating the underlying reasons for the observed differences in the estimates. In other words, these kinds of studies lack the ability to detect mechanisms through which the micro and macro-level effects interact with each other (Srholec, 2015).

Besides, one can simply prefer to include dummies for sectors, regions or countries by ignoring the random variability associated with the higher-level indicators to structure the data hierarchically. However, these efforts just lead to a quick-hand solution to control for the compositional effects of country-level given the nature of country dummies as being "catch-all" variables. Therefore, they are not consistent to detect what really matters for the engagement of firms in global collaboration networks or to gauge how cross-level interactions are shaped. Instead, we can use dummies to check for the improvement in the predictive power of the model in order to decide whether or not a multilevel analysis is reliable (Srholec, 2011).

Finally, Srholec (2015, p.26) mentions an important caveat of the model with his words "it should be noted that an important caveat of the multilevel model is the assumed orthogonality of the estimated random effects, particularly vis-a-vis the country-level predictors. Unfortunately, not much could have been done about this potential source of endogeneity, because valid instruments are extremely hard to find, which is admittedly a chronic problem for empirical research on innovation".

The analysis has been performed by means of STATA 13.0.

5 Empirical Analysis

In this chapter, the results of the empirical analysis and the further discussion of the inferences are presented considering the existing major findings of the literature.

5.1 Results

5.1.1 Baseline regression results: the two-level random-intercept model

For our analysis, we rely on the multilevel mixed-effects logistics regression which is established on a dummy dependent variable that takes the value of 1 if a firm has foreign cooperation on its innovation activities and vice versa. We have a set of firm-level and country-level variables as well as the properties of technological regimes. Given the structure of multi-level models, the cross-level elements are numerous where the variation can be established in the intercept and the firm-level slope coefficients. However, each variation applied in the model increases the complexity of the interactions where interpretation should be directed in a cautious manner. In this respect, for the simplicity of the interpretation, we follow the trails of Srholec (2015) to build a model in line with a bottom-up approach where we add new variables in several steps to elaborate the effects of multiple levels on collaboration behavior of firms across countries.

First of all, to capture the main variation driven by the unobserved heterogeneity at country-level, we are interested in u_j which is the intercept variance explained by the higher level. For that purpose, we test a null specification in which all predictors are excluded. In that way, by calculating the intraclass correlation coefficient (ICC), it is possible to infer to which extent countries account for the variation in cooperation patterns at firm-level. ICC is useful to decide on whether or not we can pool the data or continue with a more complex hierarchical structure. The low scores for intraclass correlation represent low higher-level variability whilst high scores support the establishment of multi-level specifications.

In a linear model, the formulation is ICC = $\sigma^2_{uo}/(\sigma^2_{uo}+\sigma^2_e)$ in which σ_e is the variance for firm-level residuals (e_{ij}). Since σ_e is not calculated for logit multilevel model, it is assumed that e_{ij} follows a standard logistic distribution with variance $\pi^2/3$, thus, σ^2_e is roughly 3.29 and ICC = $\sigma^2_u/(\sigma^2_u+ \pi^2/3)$ (Rodriguez & Elo, 2003; Srholec, 2015). Table 4 shows the results for the ICC calculations. The results of the null model indicate that countries are accountable for 10% of the variance regarding the micro-level diversification in international innovation collaboration. However, Srholec (2015) states that most studies in the field of the multilevel analysis found out a variability lower than 5% regarding the firm-level behavior that is driven by various aggregation levels. Therefore, a 10% percent variation to be accounted for country-level delineates the hierarchical structure of the data where the multilevel model should be preferred to get consistent inferences. Moreover, our findings confirm Hypothesis 1.

Table 4 Results for the intraclass correlation coefficient (ICC) for intercept

	Dependent variable: International involvement
Multilevel logit null model	0.102
Multilevel logit base model	0.114
Number of firms	11.252
Number of countries	9

Based on the findings derived from the “null” model, now we test the “base” model which is established with only firm-level indicators including industry dummies. Here, the country-level predictors are excluded from the specification to understand to which extent our selected firm-level indicators absorb the differences among countries. Nevertheless, the calculations show no difference, even a little bit increase in the correlation coefficient. Given the unaccounted country-level variability, one can state that our firm-level indicators do not differ substantially within and between countries, thus, are not capable to explain some portion of the cross-country heterogeneity. In this respect, the results support the influence of national framework conditions on the firm-level variables to shape the cooperation behavior of firms abroad. To get more insight into this inference, a more detailed analysis including the country-level variables is needed.

Hitherto, our calculations indicated a diversity across countries, but we have not been able to understand the conditions that drive these differences between countries. For that reason, as being the next step of our analysis, we use the so-called “intercept-as-outcome” multilevel model where country-level variables are included in the specification additional to the firm-level variables as the predictors of the intercept. In that way, we aim to understand whether there is a direct impact of national framework conditions on the tendency of firms to engage in international innovation collaboration. Here, we include all five dimensions of framework conditions which we have generated through principal component analysis by using various country-level indicators. These dimensions are the quality of research infrastructure, education, governance, ease of doing business and openness that are considered to be influential to shape the foreign cooperation behavior of firms.

Here, we build a specification in which firms are nested in countries. However, regarding “intercept-as-outcome” multilevel model, all firm-level variables are constant across countries, thus, our fixed effects are the coefficients of firm-level predictors. Random effects are specified at the level of group variable which is country-level in our case (level-two) to define a random intercept. Table 5 shows the results for “base” and the so-called “intercept-as-outcome” multilevel model.

Table 5 Results of "base" and "intercept-as-outcome" multilevel models

Dependent variable: International involvement				
	Base model		Intercept-as-outcome model	
Firm-level				
Synthetic knowledge base	-0.410***	(0.106)	-0.410***	(0.106)
Cumulativeness	-0.878***	(0.208)	-0.879***	(0.208)
Appropriability	0.137***	(0.041)	0.140***	(0.041)
Technological opportunities	0.148***	(0.009)	0.148***	(0.009)
R&D intensity	-0.00440	(0.005)	-0.00434	(0.005)
Engagement in extramural R&D	1.151***	(0.063)	1.157***	(0.061)
Exports	0.513***	(0.064)	0.512***	(0.064)
Corporate group affiliation	0.504***	(0.067)	0.506***	(0.066)
Size - medium	0.205***	(0.070)	0.207***	(0.070)
Size - large	0.870***	(0.086)	0.872***	(0.086)
Country-level				
Research infrastructure	-		-0.215***	(0.076)
Education	-		-0.0576	(0.153)
Governance	-		-0.0281	(0.115)
Ease of doing business	-		-0.00393	(0.191)
Openness	-		0.0523	(0.131)
Constant	-3.646***	(0.278)	-3.703***	(0.229)
Industry dummies	Yes		Yes	
σ_u	0.651***	(0.157)	0.381***	(0.095)
ICC	0.1139		0.0423	
Number of firms	11,252		11,252	
Number of countries	9		9	
Log-likelihood	-4053.1059		-4048.4208	
AIC	8164.212		8164.842	
BIC	8376.732		8414.004	

Note: Presented are the coefficients and standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10% level.

Country dummies are not included in the specifications due to being subject to multicollinearity. In "intercept-as-outcome" model, as indicated in Table 5, with the inclusion of country-level variables, the correlation coefficient decreased substantially from 11% to 4% where relatively a little is left unexplained. Nevertheless, despite this reduction, only the dimension for research infrastructure has a statistically significant and robust correlation with the dependent variable while all other indicators are not even close to being significant. On the other hand, the quality of research infrastructure is strong enough to absorb the biggest part of the cross-country heterogeneity, which is around 8 percent, by its own. If we consider the impact, research infrastructure came out with a negative sign which is interpreted like that firms in an environment with underdeveloped research infrastructure tend to collaborate more with foreign partners. This is consistent with Hypothesis 2. This inference confirms the findings of Srholec (2015) and major conclusions of the literature on regional innovation systems regarding the outward tendency of firms located in regions with less developed RISs. These firms establish external collaborative ties to compensate for the lack of local knowledge spillovers (Grillitsch & Nilsson, 2015).

Furthermore, despite having their expected signs, education, ease of doing business and openness dimensions of national framework conditions are statistically insignificant and hence, do not provide any explanation regarding the behavior of firms to engage in international collaboration. Moreover, the governance dimension is also statistically insignificant as well as wrong in its sign. However, Goedhuys and Srholec (2015) throw a hint on that the predictors for governance, which are used in this study and prepared by Kaufmann et al. (2009), may be improperly calculated, thus, fall short to explain what they are supposed to, given their findings on negative correlation between the governance dimension and firm-level productivity. Referring to our hypothesis, the general tendency of firms to engage in foreign collaborative linkages varies across countries and we observe that the quality of research infrastructure presents the only statistically significant correlation where it carries most of the country-level differences.

As regards the properties of technological regimes, contrary to country-level variables, all of them resulted to have statistically significant and robust relationships with firms' engagement in international collaboration networks in line with the findings of Herstad et al. (2014). Synthetic knowledge base is detected to have a negative and diminishing impact on firms' tendency to establish foreign collaborative ties. Firms that rely on synthetic knowledge base, which is characterized by context-specific knowledge generated through an inductive process of learning by doing, using and interacting, indicate lower degrees of involvement in international collaboration compared to firms that have an analytical knowledge base. Similarly, firms that act on synthetic knowledge base conduct their innovation activities based on the application or novel combinations of existing knowledge, thus, substantially depend on the previous rounds of innovation processes and accumulated knowledge. Hence, these firms are likely to experience higher degrees of cumulativeness which lead them to be more selective to interact with partners in broader geographical scales. This notion is proved by the significant and negative relationship between cumulativeness and international collaboration involvement.

Furthermore, in line with the expectations, appropriability conditions indicate a robust positive correlation with the dependent variable, thus, serve to foster the tendency of firms to engage in collaboration with partners at distance, similar to the findings in the literature (Herstad et al., 2014). Additionally, as it is shown, the importance of technical knowledge derived from external sources, which is captured by technological opportunities, is confirmed to be conducive to increase the willingness of firms to source knowledge externally. In short, the properties of technological regimes are estimated to be robustly influential on the micro-level differentiation regarding the degree of international involvement.

The firm-level control variables mainly throw highly significant effects on international involvement behavior of firms. Here, R&D intensity is the only statistically insignificant firm-level variable. Furthermore, beyond being significant, the firm-level indicators also appear with expected signs. The coefficients for the engagement in extramural R&D and the firm size especially are higher in the magnitude. Foreign cooperation ties are highly associated with the firm size which is regarded as a close proxy for the absorptive capacity of firms. Accordingly, this positive and robust relationship is well expected given the increased complexity coming with international engagement to manage a large number of units distributed across different institutional settings (Grillitsch & Chaminade, 2018). The engagement in extramural R&D and corporate group affiliation also refer to management capabilities, absorptive capacity and the availability of organizational support where both of them positively and significantly affect the degree of international collaboration (Herstad et al., 2014).

Another proxy for international engagement is the export variable that is captured by the biggest market in terms of its share in total turnover. Foreign sales can act as a facilitating mechanism to broaden the international ties by enlarging the search space for relevant partners and fortifying the internal capability of firms to overcome hindrances driven by institutional differences (Grillitsch & Chaminade, 2018). In line with that notion, a positive and significant impact of exports on international collaboration pattern is detected in the way of corroborating the major findings (Herstad et al., 2014; Srholec, 2015). R&D intensity has a negative sign which is in line with the recent findings in the literature regarding the trade-off between innovation performance and international collaborative involvement (Ebersberger & Herstad, 2013; Barnard & Chaminade, 2017). However, it is surprisingly statistically insignificant which notion contradicts with the main conclusion in the literature (Herstad et al., 2014).

Since we have applied principal component analysis to derive five dimensions of national framework conditions, our model has not yielded a multicollinearity problem. However, in reality, we cannot neglect the interactions taking place between our components such as the high interdependencies between education and the research infrastructure as well as the strong relationship between governance and other national framework conditions. Hence, for the sake of the reliability and the robustness of our findings, it would be beneficial to measure the independent effects of country-level variables. For that purpose, we add the respective country-level predictor one at a time, thus, estimate five regressions separately for each of them.

The results are shown in Table 6. Here, only the inclusion of the predictor for the quality of research infrastructure triggered a decrease in the intraclass correlation coefficient below 5% which means that it accounts for more than the half of the cross-country heterogeneity that is estimated by the null model. However, the other four dimensions of national framework conditions showed no explanation capacity and did not alter the ICC calculations. Therefore, the country-level differences remained unexplained by the selected variables. Overall, these estimates put forward the key role played by the research infrastructure to shape the micro-level differentiation as a crucial determinant of the international collaboration behavior of firms. Firms are under the direct influence of the institutional setting in terms of research facilities and the relevant research partners such as universities, public and private research institutes and R&D labs where foreign collaboration ties are contingent on the local knowledge spillovers between the partners of the innovation system.

5.1.2 Baseline regression results: the two-level random-intercept and random-slope model

In this step of the analysis, we let the impact of the firm-level variables to vary across countries to investigate the differences in micro-level relationships. The main notion here is that the country-level differences, including unobserved heterogeneity, affect not only the estimated intercept but also the slope coefficients (Srholec, 2015). Initially, we define a model in which slope random effects are included to calculate the intraclass correlation coefficient in the same way for the intercept. ICC results inform us to which extent the firm-level predictors differ across countries or, in other words, to which extent the country effects are perceived by firms in different ways due to the variation of firm-level variables.

For that purpose, we run nine separate specifications for each of which only one firm-level variable is allowed to have slope random effects. Here, only the specification for R&D intensity cannot be calculated due to failure to converge. The regression results are presented in Table 7.

The general conclusion derived from the ICC results is that the random variance of the slopes does not differ from the variance of intercept which is estimated based on the "intercept-as-outcome" multilevel model and suggested a 4% unexplained heterogeneity for country-level differences. In this respect, the correlation coefficients for slopes range between 1% and 5% where synthetic knowledge base with the lowest, and the cooperate group affiliation and the engagement in extramural R&D with the highest ICC values. Therefore, we can fairly state that the effects of firm-level variables do not largely vary across countries and firms are likely to experience, to some extent, similar country effects. The only exception to that notion is the model with slope random effects of synthetic knowledge base where the correlation coefficient dropped below 1% level and the cross-country differences are explained substantially. In this respect, knowledge dynamics can be defined as a crucial factor to describe the firm-level differentiation to participate in foreign collaborative linkages additional to the quality of research infrastructure. Referring to Hypothesis 7, we can say that only the effects of knowledge bases on firms' behavior concerning international innovation collaborations vary under different national contexts.

Furthermore, another inference that can be drawn from the results is that the firm-level predictors are similar to the ones generated through the "intercept-as-outcome" model and the inclusion of the slope random effects did not change the results. Hence, the results are robust. Accordingly, in regard to country-level variables, only the dimension of research infrastructure came out as being significant and with an expected sign except for one specification in which opportunity is allowed to have slope random effects. Nevertheless, p-value of research infrastructure was 0.101, thus, very close to being significant. In this respect, the robustness of the results for research infrastructure is confirmed. Similarly, openness did not alter in sign but stayed statistically insignificant across all specifications.

Yet, education, governance and the ease of doing business responded to the addition of different slope random effects and experienced changes in their signs. However, they kept continuing to be insignificant for all equations tested. Here, it is beneficial to remind two caveats highlighted in the literature. First, Goedhuys and Srholec (2015) question the possible incapability of the governance predictors to measure what they are supposed to given the contradictory results in respect to macro findings. Similarly, given the changes in the dimensions of education and ease of doing business, one can also raise concerns regarding the relevance of the indicators included in the components to reflect what has been aimed to measure. Second, Srholec (2015) reports that, in respect to his analysis on innovation cooperation, the country-level variables are sensitive to the inclusion of slope random effects and most of them including openness turns out to be insignificant. As the underlying reason, he points out the orthogonality of the estimated random effects especially vis-a-vis the country-level indicators which stands for a potential source of endogeneity. However, due to being hard to find valid instruments, this issue stays as a chronic problem in front of the empirical research on innovation (Srholec, 2015).

Table 6 Results of "intercept-as-outcome" multilevel models for each country-level variable

Dependent variable: International involvement					
Country-level indicator:	Research Infrastructure	Education	Governance	Ease of doing business	Openness
Firm-level					
Synthetic knowledge base	-0.410***	-0.411***	-0.409***	-0.410***	-0.409***
	(0.106)	(0.106)	(0.106)	(0.106)	(0.106)
Cumulativeness	-0.880***	-0.878***	-0.877***	-0.878***	-0.878***
	(0.208)	(0.208)	(0.208)	(0.208)	(0.208)
Appropriability	0.140***	0.137***	0.137***	0.137***	0.137***
	(0.0409)	(0.0409)	(0.0409)	(0.0409)	(0.0409)
Technological opportunities	0.147***	0.149***	0.148***	0.148***	0.148***
	(0.00980)	(0.00981)	(0.00980)	(0.00981)	(0.00980)
R&D intensity	-0.00411	-0.00429	-0.00430	-0.00422	-0.00495
	(0.00503)	(0.00506)	(0.00506)	(0.00506)	(0.00508)
Engagement in extramural R&D	1.155***	1.153***	1.153***	1.152***	1.153***
	(0.0626)	(0.0626)	(0.0626)	(0.0626)	(0.0626)
Exports	0.511***	0.513***	0.514***	0.513***	0.512***
	(0.0639)	(0.0639)	(0.0639)	(0.0639)	(0.0639)
Corporate group affiliation	0.503***	0.506***	0.506***	0.505***	0.504***
	(0.0656)	(0.0656)	(0.0656)	(0.0656)	(0.0656)
Size - medium	0.208***	0.205***	0.205***	0.205***	0.205***
	(0.0695)	(0.0695)	(0.0695)	(0.0695)	(0.0695)
Size - large	0.876***	0.868***	0.867***	0.869***	0.870***
	(0.0862)	(0.0861)	(0.0861)	(0.0861)	(0.0861)
Country-level					
Research infrastructure	-0.249***	-	-	-	-
	(0.0672)				
Education	-	-0.153	-	-	-
		(0.115)			
Governance	-	-	-0.161	-	-
			(0.127)		

Ease of doing business	-	-	-	0.130	-
				(0.173)	
Openness	-	-	-	-	0.206
					(0.168)
Constant	-3.687***	-3.667***	-3.657***	-3.596***	-3.680***
	(0.219)	(0.263)	(0.264)	(0.280)	(0.266)
Industry Dummies	Yes	Yes	Yes	Yes	Yes
σ_u (Country)	0.403***	0.594***	0.598***	0.630***	0.601***
	(0.099)	(0.144)	(0.145)	(0.153)	(0.146)
ICC	0.0469	0.0967	0.0981	0.1077	0.0989
Number of firms	11,252	11,252	11,252	11,252	11,252
Number of countries	9	9	9	9	9
Log-likelihood	-4048.9083	-4052.2912	-4052.3638	-4052.8344	-4052.4139
AIC	8157.817	8164.582	8164.728	8165.669	8164.828
BIC	8377.666	8384.431	8384.577	8385.518	8384.677

Note: Presented are the coefficients and standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10% level.

Table 7 Results of "slope random effects" multilevel models

	Dependent variable: International involvement							
Slope random effects:	Synthetic knowledge base	Cumulativeness	Appropriability	Technological opportunities	Engagement in extramural R&D	Exports	Corporate group affiliation.	Size
Firm-level								
Synthetic knowledge base	-0.312*	-0.410***	-0.408***	-0.400***	-0.406***	-0.409***	-0.401***	-0.411***
	(0.167)	(0.106)	(0.106)	(0.106)	(0.106)	(0.106)	(0.106)	(0.106)
Cumulativeness	-0.872***	-0.879***	-0.879***	-0.900***	-0.883***	-0.884***	-0.878***	-0.881***
	(0.209)	(0.208)	(0.208)	(0.210)	(0.208)	(0.208)	(0.208)	(0.208)
Appropriability	0.144***	0.140***	0.141***	0.145***	0.140***	0.139***	0.144***	0.141***
	(0.0410)	(0.0409)	(0.0464)	(0.0411)	(0.0410)	(0.0409)	(0.0411)	(0.0410)
Technological opportunities	0.148***	0.148***	0.148***	0.143***	0.148***	0.148***	0.148***	0.148***
	(0.00982)	(0.00981)	(0.00982)	(0.0221)	(0.00983)	(0.00981)	(0.00986)	(0.00984)
R&D intensity	-0.00449	-0.00434	-0.00432	-0.00464	-0.00455	-0.00427	-0.00496	-0.00431
	(0.00509)	(0.00509)	(0.00508)	(0.00512)	(0.00511)	(0.00513)	(0.00515)	(0.00515)
Engagement in extramural R&D	1.153***	1.157***	1.156***	1.149***	1.130***	1.156***	1.167***	1.159***
	(0.0627)	(0.0626)	(0.0628)	(0.0630)	(0.129)	(0.0627)	(0.0629)	(0.0628)
Exports	0.516***	0.512***	0.511***	0.514***	0.513***	0.541***	0.504***	0.508***
	(0.0640)	(0.0639)	(0.0639)	(0.0641)	(0.0640)	(0.0924)	(0.0642)	(0.0640)
Corporate group affiliation	0.501***	0.506***	0.506***	0.506***	0.502***	0.502***	0.472***	0.509***
	(0.0657)	(0.0656)	(0.0657)	(0.0658)	(0.0657)	(0.0658)	(0.147)	(0.0658)
Size - medium	0.208***	0.207***	0.208***	0.209***	0.200***	0.212***	0.196***	0.197**
	(0.0696)	(0.0695)	(0.0696)	(0.0698)	(0.0697)	(0.0697)	(0.0698)	(0.0821)
Size - large	0.876***	0.872***	0.873***	0.875***	0.868***	0.880***	0.872***	0.863***
	(0.0864)	(0.0862)	(0.0863)	(0.0866)	(0.0863)	(0.0865)	(0.0868)	(0.119)
Country-level								
Research infrastructure	-0.218***	-0.215***	-0.212***	-0.148	-0.231***	-0.221***	-0.206**	-0.190**
	(0.0554)	(0.0759)	(0.0767)	(0.0899)	(0.0866)	(0.0722)	(0.0874)	(0.0866)
Education	-0.0925	-0.0576	-0.0539	0.123	-0.0445	-0.0872	-0.112	-0.171
	(0.119)	(0.153)	(0.153)	(0.185)	(0.173)	(0.147)	(0.178)	(0.193)
Governance	0.0278	-0.0281	-0.0353	-0.364**	-0.0118	-0.0119	0.0623	-7.42e-05
	(0.0967)	(0.115)	(0.116)	(0.163)	(0.129)	(0.111)	(0.134)	(0.136)
Ease of doing business	-0.0854	-0.00392	0.00398	0.160	0.0432	-0.0183	-0.122	-0.0927
	(0.138)	(0.191)	(0.190)	(0.220)	(0.215)	(0.182)	(0.221)	(0.228)
Openness	0.0418	0.0523	0.0634	0.155	0.0590	0.0273	0.00620	0.0101

	(0.0996)	(0.131)	(0.133)	(0.156)	(0.148)	(0.127)	(0.153)	(0.156)
Constant	-3.832***	-3.703***	-3.703***	-3.631***	-3.675***	-3.728***	-3.695***	-3.749***
	(0.199)	(0.229)	(0.228)	(0.239)	(0.243)	(0.225)	(0.245)	(0.246)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
σ_u (Slope)	0.34304***	0.00000092	0.05571	0.05658***	0.31269**	0.17726**	0.38139***	0.11309**
	(0.13326)	(0.22030)	(0.08139)	(0.02044)	(0.13413)	(0.09833)	(0.11384)	(0.06061)
σ_u (Country)	0.18013*	0.38137***	0.37563***	0.38385***	0.42943***	0.35836***	0.43362***	0.40814***
	(0.13326)	(0.09456)	(0.09554)	(0.12663)	(0.10737)	(0.09157)	(0.10952)	(0.11443)
ICC	0.0097	0.0423	0.0411	0.0428	0.0531	0.0375	0.0541	0.0482
Number of firms	11,252	11,252	11,252	11,252	11,252	11,252	11,252	11,252
Number of countries	9	9	9	9	9	9	9	9
Log-likelihood	-4046.0294	-4048.6052	-4048.5178	-4043.6648	-4045.4326	-4047.6492	-4036.7647	-4047.4392
AIC	8162.059	8167.21	8167.036	8157.33	8160.865	8165.298	8143.529	8164.878
BIC	8418.549	8423.701	8423.526	8157.33	8417.356	8421.789	8400.02	8421.369

Note: Presented are the coefficients and standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10% level.

5.1.3 Robustness checks: The three-level model

According to the notion of technological regimes, firms that belong to the same industry are exposed to the same technological and knowledge conditions. In that line, they are likely to perform a correlated behavior (Nelson & Winter, 1982; Winter, 1984). Furthermore, empirical findings indicate that innovation collaborations do not follow a prevalent distribution pattern among firms with respect to different industries instead tend to perform specific patterns (Dachs et al., 2008). There are crucial interindustry differences in respect to the sources, technical change and how actors of a particular industry interact with each other. Accordingly, the mix of industries varies across countries where, in turn, these differences define the way of how national innovation systems evolve and operate (Nelson, 1993).

Departing from that point, we test a three-level model in which firms (level-1) are nested in industries (level-2) and industries are nested in countries (level-3). In this respect, our model now entails two random-effect equations and therefore, two random intercepts, one at the country level and the other at the industry level. The most important differentiation of this model is that it is fitted to account for both country and industry level effects that are likely to influence the tendency of a firm to engage in international collaborations. The ICC calculations for the three-level null model in which no predictors are included indicate as much as 16% variation for the industry-within-country level which refers to the differences jointly driven by industries and countries. Moreover, the country-level variation is calculated as 10.7%. The correlation coefficient for the industry-within-country level signifies a much higher variation attributed to unexplained heterogeneity than the one found in the earlier steps of the analysis for the two-level null model. Therefore, these results encourage further examination and lay the ground to test the robustness of the estimators.

The results of the three-level model are given in Table 8. The calculations are presented for base and intercept-as-outcome models separately. The order in which we have specified that firms are nested in industries and industries are nested in countries is significant. After the adjustment according to the three-level nested structure, the estimated coefficients did not alter so much. The firm-level variables excluding R&D intensity, and the properties of technological regimes are statistically significant at 1% level. Moreover, the quality of research infrastructure keeps its significance at the same level. Accordingly, the main results of the analysis are confirmed to be robust.

Table 8 The three-level model

Dependent variable: International involvement				
	Base model		Intercept-as-outcome model	
Firm-level				
Synthetic knowledge base	-0.418***	(0.106)	-0.418***	(0.106)
Cumulativeness	-0.889***	(0.209)	-0.889***	(0.209)
Appropriability	0.137***	(0.041)	0.140***	(0.041)
Technological opportunities	0.148***	(0.010)	0.148 ***	(0.010)
R&D intensity	-0.00419	(0.005)	-0.00413	(0.005)
Engagement in extramural R&D	1.157***	(0.063)	1.162***	(0.063)

Exports	0.510***	(0.064)	0.509***	(0.065)
Corporate group affiliation	0.496***	(0.066)	0.498***	(0.066)
Size - medium	0.209***	(0.070)	0.211***	(0.070)
Size - large	0.877***	(0.087)	0.880 ***	(0.087)
Country-level				
Research infrastructure	-		-0.221***	(0.078)
Education	-		-0.0483	(0.156)
Governance	-		-0.0314	(0.118)
Ease of doing business	-		-0.0029	(0.195)
Openness	-		0.0501	(0.134)
Constant	-3.645***	(0.287)	-3.700***	(0.241)
Industry dummies	Yes		Yes	
σ_u (Country)	0.657***	(0.159)	0.387***	(0.097)
σ_u (Industry)	0.176***	(0.049)	0.176***	(0.050)
ICC (Country)	0.1148		0.0431	
ICC (Industry|Country)	0.1232		0.0519	
Number of firms	11,252		11,252	
Number of countries	9		9	
Log-likelihood	-4050.4143		-4045.8075	
AIC	8160.829		8161.615	
BIC	8380.678		8418.105	

Note: Presented are the coefficients and standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10% level.

By adding the firm-level variables, the explanatory capability of the model has increased where now we have a correlation coefficient equal to 12% at the industry-within-country level. Despite the fact that these results are in line with the two-level model, ICC calculations of null three-level model delineate that if we nest industries within countries, the variation between different contexts increases substantially where firms are under the influence of the joint effect created by industries and countries. Furthermore, another insightful result within the context of three-level modeling is the decrease in the random industry-within-country effects for intercept following the inclusion of country-level predictors. Here, one can fairly state that a major part of the heterogeneity is explained by the model and the remaining part is relatively small.

As regards the three-level nested model, the unexplained heterogeneity across countries has resulted in 4% where it is 5% for the industry-within-country level. Here, despite our model has a high explanatory power regarding the cross-country heterogeneity, for the unexplained rest, it is important to point out several other factors. In that sense, some differences are beyond the scope of the quantitative analysis and hard to measure in a proper way. For instance, cultural background, social capital and the extent of trust can be counted in the list of unmeasurable factors (Srholec, 2015). Similarly, the selection of external partners and the intensity of knowledge flows are also conditioned by the degree of trust that is present between firms (Maskell & Malmberg, 1999a). Different from being engaged in local relations with existing proximate actors, trust needs to be developed in a conscious and systematic way with external partners throughout the way of establishing global pipelines wherein it requires time and dealing with the costs of involvement (Bathelt et al., 2004). Additionally, the cognitive differences of survey respondents which affect their perception differently by each country to interpret what is “novel”, “major” and “highly important” may generate measurement errors for micro variables. Therefore, beyond the certain limitations of the quantitative methods, the unexplained rest requires further qualitative research (Srholec, 2015).

5.2 Discussion

In the literature, the key characteristics of firms and the sources of differentiation have been extensively debated within different respects. The trajectories that firms follow lead them to develop and adopt distinct organizational routines which, in turn, define the guidelines of how to explore, accumulate and exploit different knowledge sources. Furthermore, this differentiation has been regarded to drive the commercial viability, thus, the outcome of the competition inevitably has been the micro-level heterogeneity that is veiled in the nature of organizationally embedded knowledge (Herstad et al., 2014). In this respect, the cumulativeness and knowledge base dimensions of technological regimes refer to the nature of knowledge and its development process to reflect the behavioral differentiation at micro-level (Breschi et al., 2000). Additionally, technological regimes also capture appropriability conditions that firms individually face, and the technological opportunities to generate economic value as the crucial determinants of behavior. These four dimensions identify the way through which firms source relevant knowledge (Malerba & Orsenigo, 1997). However, according to Breschi and Malerba (1997) both the level of appropriability, cumulativeness and technological opportunities are conditioned under different contexts that are characterized by organizations, institutions, policies and the capabilities of specific firms.

Accordingly, firms in isolation lack the opportunities to undertake the competitive advantage instead, it can be generated by means of collaborative relationships with other actors including other firms and rivals as well as institutions that carry the aim of knowledge generation, and the actors of vertical linkages such as suppliers and customers (Dachs et al., 2008). Here, by creating collaborative linkages in the space, firms transfer and make a synthesis of several inputs derived from external knowledge sources to translate them into new ideas in a process which is determined by the technological opportunities (Ebersberger et al., 2012).

Furthermore, the approach of innovation systems defines geographical boundaries in which firms act in interaction with firms, universities, public research institutes and the government (Breschi & Malerba, 1997). In this respect, all these actors and institutions refer to the characteristics of specific areas shaped by shared features, thus, create a context-specific environment to impact the behavior of firms to innovate and collaborate. Therefore, as well as firm-specific characteristics, also country-level differences are needed to account for more robust results towards enriching our understanding of the diversification at firm-level. Here, the research methodology adopted in this paper enables us to delineate the circumstances under which collaborative behavior of firms are created in a broader perspective by attributing it to the notion of technological regimes and national framework conditions as well as to a set of other firm-level predictors. The analysis not just detects whether the country-level differences pose challenges or favorable conditions for firms, or in other words whether they matter, but instead evaluates the impact of a broad range of national framework conditions. We relax the emphasis on firm-specific capabilities but still refer to the dynamism at firm-level, which is required to sustain the competitive advantage, and lay the ground for country-level effects to appear within the context of multilevel modeling.

To the best of the author's knowledge, Srholec (2015) has been the one to study the collaboration patterns of firms in innovation activities by adopting a multi-level model in which research infrastructure, openness and the size of the economy are included as the components of national framework conditions. Yet, in this study, we have adopted a broader measure of country-level differences which is reflected by the dimensions of the quality of research infrastructure, education, governance, ease of doing business and openness. Furthermore, the properties of technological regimes, namely the internal knowledge base, cumulativeness of knowledge development, appropriability conditions and technological opportunities, which are indicated to be influential on the international involvement patterns of firms by Herstad et al. (2014) are also taken into consideration to enhance the robustness of the results.

Empirical analysis unveiled that out of a broad set of aforementioned country-level variables only the quality of research infrastructure has a significant correlation with cooperation behavior of firms which was negative in the sign while others were far away to be significant. Accordingly, firms acting in less developed research environment tend to collaborate extensively with foreign partners abroad and vice versa. This notion has also been tested by Srholec (2015) and resulted in a way to support the diaspora thesis which links the external collaborative linkages to the absence of relevant partners at home. Furthermore, the literature on regional innovation systems puts forward corresponding evidence on that global innovation networks are indeed “lifelines” of the peripheral regions (Trippl et al., 2017; Grillitsch & Nilsson, 2015) and of crucial importance for firms operating in institutionally and organizationally thin regional innovation systems (Chaminade & Plechero, 2015) due to being exposed to limited local knowledge resources. Also, recent studies shed light on the compensatory role of global innovation networks to substitute local or regional knowledge linkages in the case of their absence rather than being complementary (Grillitsch & Nilsson, 2015; Fitjar & Rodríguez-Pose, 2013). Hence, our findings support the results of the existing research in the literature given the diminishing effects of well-developed research infrastructure on the tendency of firms to collaborate internationally in innovation activities.

Furthermore, according to the results yielded in this paper, despite having a positive sign, the dimension for openness holds its insignificancy across all specifications. It only reacts when we include the slope random effects by experiencing changes in the sign, however, stays insignificant. Contrary, based on the results of Srholec (2015), openness draws a positive and significant relationship to encourage the establishment of international collaborative linkages. However, it is sensitive to the addition of random slope coefficients separately for each firm-level variable and turns into being insignificant. For that reason, our inference seems to be more consistent in the respect of the outcomes derived from the regression analysis.

We first tested a two-level model and then, establish a three-level hierarchical model given the effects of technological regimes which converge the behavior of firms by exposing the same technological and knowledge conditions. In that line, the main findings of the two-level model also hold to be robust and significant for the specifications of the three-level model. Herstad et al. (2014) paved the way for empirical analysis to enhance our understanding on the role of the dimensions of technological regimes to influence firms' engagement in collaborative networks, however, their arguments lacked the appreciation of the diversifying nature of national contexts and stuck within the borders of one single small economy. Yet, the results drawn in this study confirmed the properties of technological regimes as being a general phenomenon under the diverse characteristics of various national contexts rather than being specific to one country. All these dimensions established statistically significant and robust relationships with the degree of international involvement across all specifications while having expected signs.

Martin et al. (2018) put forward that not just firms which dominantly rely on analytical knowledge base but also firms with synthetic knowledge base and even firms that act in symbolic industries can take part in global innovation networks to source knowledge. However, the degree of involvement is strongly conditioned by the internal knowledge base where firms with synthetic knowledge base are less likely to establish international collaborative linkages compared to firms operating on analytical knowledge base (Herstad et al., 2014). Furthermore, after letting synthetic knowledge base to have slope random effects, the unexplained heterogeneity across countries dropped under 1% where our model best fitted to explain which factors are capable to shape firms' behavior to engage in international innovation collaboration. Within this respect, one of the most important contributions of this study has been the indication of the crucial role played by knowledge dynamics to influence the micro-level differentiation.

Here, one possible explanation regarding the diversifying effects of knowledge bases in different national framework conditions can be given relying on the notion of combinatorial knowledge bases. In reality, most activities rely on more than one knowledge base, and the degree of dominance of knowledge base may differ substantially across different industries, firms and even different type of activities and occupations (Asheim & Hansen, 2009). Moreover, the same industries can reveal distinct knowledge base combinations in different countries. For instance, the inclusion of analytical knowledge to synthetic knowledge base may affect the geography of the search for collaboration partners in innovation activities. The difference between the traditional textile and smart textile can exemplify in that line where the latter shows a higher tendency to collaborate with distant actors (Grillitsch et al., 2019). Hence, further studies can appreciate the combinatorial nature of knowledge bases.

The ability of a firm to source new knowledge is dependent on the accumulated knowledge and, thus, what has been learned before, which notion comes into being as cumulativeness (Grillitsch et al., 2015). Cumulativeness requires past knowledge development to be built upon for new knowledge generation. Hence, the establishment of R&D facilities provides a stable flow of innovations where the improvement of technological and organizational capabilities of firms can lead to cumulativeness in a gradual learning process. Moreover, innovative success can be translated into profits which notion is likely to stimulate more R&D investment and, in turn, to increase the likelihood to innovate (Malerba & Orsenigo, 1997). Based on that reasoning, one can expect a highly correlated impact of cumulativeness and R&D intensity where firms broadly rely on their internal capabilities to create knowledge.

However, with respect to our findings, only the degree of cumulativeness matters and draws hindering effects to engage in international collaborative linkages. This negative relationship has been corroborated through all models in line with the conclusion of Herstad et al. (2014).

Furthermore, both appropriability and opportunity conditions increase the likelihood of a firm to involve in international collaboration in a way of confirming the main findings in the literature (Herstad et al., 2014) and hold under the direct impact of national framework conditions. Despite the fact that one can expect the variation of these conditions under distinct national contexts, results revealed a little variation of all significant firm-level characteristics. It can be interpreted like that the cooperation behavior of firms is more likely to differ by country and industry-within-country levels. Therefore, the properties of technological regimes transcend the specificities of national framework conditions and are capable to explain a substantial part of the firm-level heterogeneity.

Finally, it is of crucial importance to state that the structure of innovation policies can be throwing effects on the results which notion is hard to evaluate quantitatively. For instance, as stated by Herstad et al. (2010) and Ebersberger and Herstad (2011), Norwegian innovation policy targets to establish domestic collaborative linkages rather than external ones.

6 Conclusion

Collaboration over long distances is the key mechanism for companies to directly interact with globally distributed knowledge sources (Ebersberger & Herstad, 2013). Within this respect, studies on international innovation collaboration shed light on the organization of innovation activities at the global scale, its key actors and drivers as well as its impacts on companies and regions by bringing insights from economic geography, international business and innovation studies (Grillitsch & Chaminade, 2018). However, most studies in this field evaluate cooperation on innovation by treating all factors that impact a firm's behavior as acting at one single level. Nevertheless, firms' decision to collaborate cannot be successfully analyzed at any single level, instead, it can be understood by factors that are assigned to relevant hierarchical levels such as firm, industry and country levels (Srholec, 2015; Goedhuys & Srholec, 2015). Therefore, this paper aimed to help in filling the gap with respect to multilevel interactions in a more comprehensive way compared to the limited number of existing studies in the literature. While nesting companies in national contexts that they belong to, it has been appreciated that national framework conditions matter. The reasoning was drawn upon the approach of innovation systems which underlies the interdependencies of actors in a particular country and the effects of varying institutional setting on firms' behavior.

Within the respect of this study, it is attempted to pin down what drives the propensity of firms to engage in international cooperation for innovation activities in terms of cross-country differences. For that purpose, the analysis is conducted based on the data derived from Community Innovation Survey (CIS) that has been collected in 2012 using a large micro dataset of 11,252 innovating firms and macro data from 9 countries. A broad set of national framework conditions, including the quality of research infrastructure, education, governance, ease of doing business and openness, and the features of technological regimes are extensively debated and econometrically tested to understand their impacts on micro-level diversification to shape firms' behavior in international innovation collaboration. Accordingly, to our knowledge, this study is the first attemp to examine a broad set of country-level and firm-level predictors including the properties of technological regimes within the framework of multilevel thinking.

The main contributions of this paper lie in three areas. First, innovation systems can be described on their capabilities to create new knowledge as well as their endowments to facilitate and improve the distribution and utilization of knowledge for the partners involved (Foray, 1997). Notwithstanding, the results indicate that the intensity of interactions in line with the effectiveness of an innovation system negatively affects the tendency of firms to collaborate internationally. Here, firms embedded in an environment with well-developed research infrastructure benefit from local opportunities and a dense network of supportive institutions to cooperate and source knowledge. Given the relatively low-cost of interaction and highly endowed local conditions, firms tend to cooperate exclusively with domestic partners in innovation activities where these local knowledge spillovers act to the disadvantage of international collaborative linkages. On the other hand, firms operating in low-quality research infrastructure are not supported by local resources in terms of knowledge flows, thus, search for compensatory international collaborative linkages.

Second, Herstad et al. (2014) enhanced our understanding of the properties of technological regimes as being key factors to drive the firm behavior in international collaboration on innovation activities. This study extends their inference and puts forward evidence for that the conditions of technological regimes even hold under the influence of distinct national contexts to be significant, thus, describe a general phenomenon beyond national borders. Furthermore, most importantly, knowledge bases throw diversifying effects on micro-level given national framework conditions and account for a noteworthy part of country-level differences while the unexplained rest is very little. In this respect, knowledge dynamics are highly influential to define the international collaboration patterns of firms or in other words, they matter.

Third, the analysis reveals that the establishment of the model structure in which we assign each variable to the relevant hierarchical level is also crucial to measure the real impacts of the selected variables in a proper way. In this respect, the capability of firm-level variables to explain the country-level differences has increased substantially with the adoption of the three-level base model where firms are nested in industries and the industries are nested in countries. Here, in comparison to the null model, firm-level variables including the properties of technological regimes are accounted for 4% of cross-country heterogeneity despite having no explanatory power in the two-level base model. Moreover, the contribution of country-level variables increased in relatively conservative amounts. Therefore, this study puts forward evidence for the importance of different levels in innovation studies by defining the three-level hierarchical model as a novelty for the analysis of cooperation on innovation. The findings suggest that this approach would be also beneficial for other studies in the field of innovation.

Taken together, the results confirm a considerable heterogeneity across countries where the higher levels of analysis such as industry and country condition the diversification at the micro-level. Furthermore, they are robust to the level of analysis as well as to the specification of the model. A substantial part of country-level diversity can be explained by the quality of research infrastructure by its own as the crucial determinant of international involvement. Moreover, knowledge dynamics are shown to be important in the form of knowledge bases where their effects on micro-level differ given the cross-country differences. In conclusion, our study in terms of its conceptual framework and methodological approach offers novel inputs to our understanding of international innovation collaboration by providing insights into the drivers of cross-country heterogeneity, and thus, micro-level diversification in collaboration patterns.

6.1 Future Research

Grillitsch et al. (2015) throw a hint on the potential differentiation of innovative and networking behaviors of companies across sectors and regions given the context surrounding them. Within the framework of this study, the importance of different levels to enhance our understanding of international innovation collaboration has been indicated. In this respect, the findings suggest that future studies which appreciate the regional level would be of interest. Moreover, as a limitation of this study, we were not able to distinguish the intensity of collaborative linkages. Therefore, more detailed studies are required to get more insight into the motives of firms to establish linkages of different strength.

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Appendix A

Definitions and sources of country-level variables

Explanation	Year	Source
Research and development expenditure (% of GDP)	2008	World Bank (World Development Indicators)
Patent applications, residents	2008	World Bank (World Development Indicators)
Scientific and technical journal articles (per 1000 people)	2008	World Bank (World Development Indicators)
School enrollment, secondary (% gross)	2008	World Bank (World Development Indicators)
School enrollment, tertiary (% gross)	2008	World Bank (World Development Indicators)
Government expenditure on education, total (% of GDP)	2008	World Bank (World Development Indicators)
Political Stability and Absence of Violence/Terrorism	2005	Governance Matters' project by Kaufmann et al (2009)
Government Effectiveness	2005	Governance Matters' project by Kaufmann et al (2009)
Regulatory Quality	2005	Governance Matters' project by Kaufmann et al (2009)
Rule of Law	2005	Governance Matters' project by Kaufmann et al (2009)
The Political Constraint Index	2008	The Political Constraint (POLCON3 index) Dataset
Time required to start a business (days)	2008	World Bank (World Development Indicators)
Start-up procedures to register a business (number)	2008	World Bank (World Development Indicators)
Foreign direct investment, net inflows (% of GDP)	2008	World Bank (World Development Indicators)
Imports of goods and services (% of GDP)	2008	World Bank (World Development Indicators)

Appendix B

Descriptive Statistics

VARIABLES	N (1)	Mean (2)	Std. Dev. (3)	Min (4)	Max (5)
Firm-level variables					
International involvement	11,252	0.178	0.383	0	1
Synthetic knowledge base	11,252	0.895	0.306	0	1
Cumulativeness	11,252	0.0665	0.249	0	1
Appropriability	11,252	0.970	0.807	0	3
Technological opportunities	11,252	8.064	3.740	0	18
R&D intensity	11,252	0.623	5.491	0	97.44
Engagement in extramural R&D	11,252	0.264	0.441	0	1
Exports	11,252	0.273	0.446	0	1
Corporate group affiliation	11,252	0.400	0.490	0	1
Size	11,252	1.645	0.728	1	3
Country-level variables					
Research infrastructure	11,252	0.633	2.487	-1.797	5.243
Education	11,252	0.0538	1.685	-2.226	3.569
Governance	11,252	0.254	0.966	-3.924	1.768
Ease of doing business	11,252	-0.392	1.346	-2.318	1.669
Openness	11,252	-0.136	0.946	-0.839	3.264