UNIVERSITY-FIRM COLLABORATION FOR INNOVATION IN CHILE

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by

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Abstract

University-firm collaboration has been regarded as central to the innovation performance of firms and, at aggregate level, of countries. These linkages have been widely promoted as part of innovation policy in many countries. However, there are no conclusive studies of the dynamics of these interactions in developing countries and most of the research on the topic has focused on one side of a two-sided interaction. This gap in our understanding is particularly relevant in the case of developing countries since their innovation systems are 'immature.'

This thesis attempts to explain how multi-level factors shape the incentives for agents to engage in collaboration. The analysis reveals conflicting incentives on both sides of university-firm interactions. The productive and institutional environment, as well as the public policy under which academics, universities, and firms operate, create, often unintended, incentives both for and against collaboration. Increasing understanding of these interactions helps to align policy design.

By studying university-firm collaboration in Chile, this thesis aims at advancing scholarship in four key ways: (i) by studying university-firm linkages in a developing country that possesses comparative advantages in natural resources; (ii) by incorporating management and innovation theories in the study of innovation incentives, which, until recently, have only been studied using market failure analysis in developing country settings; (iii) by using a novel analytical approach that combines the analysis of the supply and demand sides of these linkages, while also incorporating the multi-level factors influencing them; and (iv) by assessing the impact of university-firm collaboration on the innovation performance of a sample of Chilean firms using a novel dataset specially prepared for this thesis. This quantitative analysis provides valuable insight about the type of firms that benefit from collaboration with universities and about the type of innovations activities that produce these benefits.

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Acronyms and abbreviations

AUTM	Association of University Technology Management
CIS	Community Innovation Survey
CMEs	Coordinated market economies
CMI	Committee of Ministers for Innovation (*Comité de Ministros para la Innovación*)
CNIC	National Council of Innovation for Competitiveness (*Consejo Nacional de Innovación para la Competitividad*)
CONICYT	National Commission on Science and Technology (*Comisión Nacional de Investigación Científica y Tecnológica*)
CORFO	National Development Agency (*Corporación Nacional de Fomento*)
CRUCH	Council of Presidents of Chilean Universities (*Consejo de Rectores de Universidades Chilenas*)
EIT	Survey of Technological Innovation (*Encuesta de Innovación Tecnológica*)
FDI	Foreign Direct Investment
FDI-CORFO	Development and Innovation Fund (*Fondo de Desarrollo e Innovación*)
FIC	Innovation Fund for Competitiveness (*Fondo de Innovación para la Competitividad*)
FOB	Free on board
FONDECYT	National Fund for Scientific and Technological Development (*Fondo Nacional de Desarrollo Científico y Tecnológico*)
FONDEF	Scientific and Technological Development Support Fund (*Fondo de Fomento al Desarrollo Científico y Tecnológico*)
FONTEC	National Productivity and Technological Development Fund (*Fondo National de Desarrollo Tecnológico y Productivo*)
FTE	Full-time equivalent
GDP	Gross domestic product

GERD	Gross domestic expenditure on R&D
HES	Higher education system
HMEs	Hierarchical markets economies
IADB	American Development Bank
INE	National Institute of Statistics
IP	Intellectual property
LMEs	Liberal market economies
MINECON	Ministry of Economy
MNCs	Multinational corporations
NIS	National innovation system
OECD	Organisation for Economic Co-operation and Development
PBCT	Bicentennial Programme of Science and Technology (*Programa Bicentenario de Ciencia y Tecnología*)
PCT	Science and Technology Programme (*Programa de Ciencia y Tecnología*)
PDIT	Programme of Technological and Innovation Development (*Programa de Desarrollo e Innovación Tecnológica*)
PISA	Programme for International Student Assessment
PUC	Catholic University of Chile (*Pontificia Universidad Católica de Chile*)
R&D	Research and development
RE	Random effects
SMEs	Small and medium enterprises
TTOs	Technology transfer offices
UCHILE	University of Chile (*Universidad de Chile*)
UDEC	University of Concepción (*Universidad de Concepción*)
UTM	Unidad Tributarias Mensuales

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Chapter 1: Introduction

1.1 Introduction

The concept of technology transfer has been used in development studies to refer to the movement of commercial technologies across countries and to a lesser degree within them (Lall, 2001). Foreign sources of technology are very important for most countries and represent almost 90% or more of their domestic productivity growth (Keller, 2004: 752).

The focus of the literature on international technology transfer would assume that the absorption by new recipients (firms in less advanced countries) of new information was easy, costless and rapid once created—at least by firms in more advanced countries. This view has been replaced by the recognition that the transfer of technologies is not free and that there is investment in adapting available knowledge to local productive setting. According to Kruss et al. (2015b), the term ‘technology transfer’ has generally played down the difficult learning processes involved. Since the tactic elements of knowledge that cannot be fully embodied in equipment, blueprint and instructions (Nelson and Winter, 2009), firms in developing countries have to invest to absorb and adapt technological knowledge to local needs.

In the context of technology transfer within countries, there has also been often suggested that the transfer of technologies from universities to firms is crucial for knowledge-based economies.[1] For this reason university-firm relationships have recently received considerable attention from different disciplines, most notably economics, management, and innovation studies. The literature agrees that universities are expected to transfer their inventions to firms so that new products and new processes can help increase a country's competitiveness and contribute to its economic development (Griffith et al., 2004; Keller, 2004; Lall, 1992). Cooperation between these institutions is thus important in promoting economic growth.

Studies of university-firm linkages have understood technology transfer activities as the movement of technological knowledge between these organizations. Most empirical studies of university-firm collaboration have been based on cases from developed countries. This empirical research has led to the belief that universities *should* contribute to innovation and technological development (Argote and Ingram, 2000; Etzkowitz and Leydesdorff, 2000; Kaufmann and Todtling, 2001). Consequently, governments, including those in developing countries, have created policies aimed at increasing the links between universities and firms. However, there is still no agreement on the part played by universities in the innovation of firms. In addition, policy initiatives fostering greater university-firm linkages have been criticized for being largely based on anecdotal evidence from successful licensing and spin-off activities from private American universities such as Stanford, MIT, and Columbia University (Larsen, 2011:7). It is only recently, however, that research has begun to focus on university-firm linkages in developing countries

[1] This expression was coined to describe trends in advanced economies towards greater dependence on knowledge, information and high skill levels, and the increasing need for ready access to all of these by the business and public sectors (OECD, 2005a).

Aside from this bias towards evidence from the developed world, methodological gaps also persist in the empirical research on university-firm linkages. Firstly, most of the empirical studies have focused on a *one-sided* analysis of a *two-sided* interaction. This has deepened our knowledge of the supply and demand of innovation but, at the same time, it has limited our understanding of how university-firm linkages work under 'real' conditions. Secondly, there has been little research that considers the multi-level factors that influence these innovation linkages. While focusing on a one-sided analysis has helped focus the scope of research, it has undoubtedly meant that the combined forces influencing agents' incentives have been overlooked. These micro, meso and macro influences, in addition to the relationships between the agents within the innovation system, shape the innovation incentives and the innovation strategies of both sides of the university-firm relationship.

In response to these gaps in the literature, this thesis seeks to advance understanding of university-firm linkages in developing countries by examining the drivers that shape the incentives for firms and universities to collaborate on innovation and the impact of these incentives on the performance of firms. Focussing on university-firm linkages in Chile, this thesis addresses the following questions:

- What factors influence innovation linkages between academics, universities, and firms?
- What factors explain the incentives for firms to engage in linkages with universities?
- Is university-firm collaboration beneficial for the innovation performance of firms?

The research was carried out by analysing both the demand and supply sides of university-firm innovation interactions through a combination of case studies and econometric work. The findings reveal inconsistent incentives for collaboration on both sides of university-firm interactions. These incentives are created by the productive and institutional environments, and by the public policies under which academics, universities and firms co-exist. The findings highlight the importance of taking the dynamics of these interactions into account in policy design. Policy makers not only need to *identify* but also *assess* the direction and magnitude of incentives so that they are aligned to the innovation policy objectives.[2]

1.2 Research rationale

University-firm innovation collaboration has increasingly been regarded as relevant to the creation of new businesses, the growth of existing firms, job creation (Harmon et al., 1997), and the promotion of technological change in many industries (Mansfield and Lee, 1996). This has led to a growing number of governments in both developed and developing economies seeking to use universities as contributors to knowledge-based economic development and change rather than perceiving them only as institutions devoted to the pursuit of knowledge for its own sake (Mowery and Sampat, 2005). Moreover, as innovation is recognised as an important driver of growth in developing economies, it has become a primary objective for firms and governments in most countries (Chen and Puttitanun, 2005; Chuang and Lin, 1999; Wu, 2007).

[2] Edquist (2014) defines innovation policy as all intended and unintended actions by public organizations that influence innovation processes.

According to Zanello et al. (2015) innovation in countries is about the creation or adoption of new ideas and technologies. However the capacity for innovation is embedded in, and formed from, dynamics between geographical, socio-economic, political and legal subsystems (Zanello et al., 2015: 1). In developing countries, the innovation environment is characterized by a weak business environment, a lack of human capital, and poor information infrastructures (Aubert, 2005). All three of these factors influence the capacity for innovation in these economies (Aubert, 2005). In particular, universities have limited capacity to create and transfer technology, while firms lack the absorptive capabilities necessary to recognise and extract value from local knowledge.[3] Meanwhile, dynamic inconsistency in policy design requires the agents in the innovations system to adapt on a regular and consistent basis.[4] All this underscores the importance of assessing the impact of university-firm collaboration in developing countries.

It is in this context that this thesis contributes to the current debate about the role of universities in developing countries. Universities perform a central role in societies by training people and carrying out research (Perkmann et al., 2013). In recent decades, however, universities have also started to conduct what has been called a 'third mission' by promoting links with knowledge users and by facilitating technology transfer. These organisations are increasingly expected to make a direct contribution to economic development and to the well-being of society as well as to teaching and research (Carvalho de Mello and Etzkowitz, 2008). However,

[3] In this thesis I use Roessner's (2000) definition of technology transfer. This author describes the concept as 'the movement of know-how technical knowledge, or technology from one organizational setting to another' (as cited in Bozeman, 2000: 629).

[4] According to the OECD (2009: 31) dynamic inconsistency of innovation refers to the 'inconsistency between the time scales and incentive structures under which political decision-makers live and the governance needs of the innovation system, which tend to involve much longer time horizons.'

according to Brundenius et al. (2011: 314), policies have exaggerated expectations regarding how university research can contribute directly to innovation through university-industry links. Any discussion of the potential of university-firm linkages in the promotion of economic growth therefore demands a healthy share of cautious scepticism.

There has been a long-standing debate about whether the major function of universities is to promote higher education in order to serve all sectors of the society or to engage in research and about the nature of the relationship between these two activities (Brundenius et al., 2011: 311). This debate is even stronger in developing countries, partly due to a strong presence of international advice alongside the commanding positions held by local actors and partly due to the level of the challenges faced by these countries and their universities (Brundenius et al., 2011: 311). In addition, it is important to recognize that most developing countries are not in a transition towards a knowledge-based and innovation-driven economy, as in certain other countries (Arocena et al., 2015). In developing countries the capacities to produce and to use knowledge, particularly advanced knowledge, is structurally weak (Arocena et al., 2015). At the same time, there is an important heterogeneity in terms of capacities, in both universities and firms. In particular, in the case of Latin America, Carvalho de Mello and Etzkowitz (2008) claim that there is a paradox regarding the role of universities in knowledge and technology transfer. The paradox is that in these developing countries the economic need for a university role in economic development is greater than in developed countries but the ideological and research base to support such an intervention is much narrower (Carvalho de Mello and Etzkowitz, 2008: 193).

Furthermore, it is important to keep in mind that most of the innovations introduced in developing countries are developed abroad. Therefore most of the firms' efforts to innovate are concentrated in absorbing and adapting technologies already available in markets rather in incorporating technologies developed in local universities. However, universities enjoy an exclusive concentration of highly-skilled personnel while other potential partners such as suppliers may not have the skills to collaborate with firms that introduce new innovations. This creates two direct effects. It means, firstly, that universities collaborate with firms to adapt available technologies to local production processes since the required skills to conduct these activities may not be available in other firms, such as suppliers. Second, most firms would not benefit from collaborating with universities since technological innovation is limited among firms and even fewer introduce innovations to the local market.

In this context, Chile presents itself as a particularly interesting case for studying the experience of university-firm collaboration on innovation in a developing country. Three reasons may be advanced for why this should be so. Firstly, the productive structure of this country, including the fact it has experienced significant economic growth in the last two decades, make a particularly relevant case study. Chile has an open economy with comparative advantages in natural resources. Its growth has been based on the export of commodities and primary-based manufacturing. The productive structure, cultural closeness, and even some institutional features found in Chile are shared by other Latin American countries. This productive structure is in fact a characteristic feature of the type of capitalism generally observed in this region (as developed by the work by Hall and Soskice (2001) and Schneider (2009; 2013a) and which marks it out as different from the types of capitalism observed in other economies. Consequently, studying university-firm collaboration in a developing country with comparative advantages in natural resources also contributes to the study of these dynamics in a specific but not exclusive type of economy.

Secondly, as with other developing countries, Chile is a net importer of technology (OECD, 2007). In general, universities in these countries are the main performers of R&D (OECD, 2007; UNESCO, 2016) and firms are more focused on acquiring and adopting imported technologies and know-how rather on introducing new products and process as part of their competitiveness strategies (OECD, 2007: 123). This may influence the scope for universities to act as collaboration partners for firms. Some consideration of the importance of universities for the production of knowledge in developing countries, together with an informed understanding of the factors influencing how these institutions and academics decide to collaborate with firms, would help create a more complete survey and analysis of the innovation process.

Additionally, the impressive growth of Chile between the 1990s and the early 2000s has been followed by slowing growth rates in the last few years, mostly caused by stagnant productivity (OECD, 2007; 2010). In the policies implemented to return the country to high productivity growth rates, policy makers have put significant effort into increasing the low levels of innovation in the country. This brings us to the third reason for Chile’s particular interest as a research context: the country has placed particular emphasis on the promotion of innovation and on fostering university-firm collaboration. Since the 1990s Chile has been building a more comprehensive innovation system, which has explicitly promoted innovation in general and university-firm collaboration in particular as the mechanism for supporting competitiveness in firms. Moreover, since the mid-2000s national innovation policy has specifically promoted R&D and technology transfer between universities and firms.

From its initial beginnings in providing scattered funds mainly aimed at basic research, Chile's innovation policy has evolved to support university-firm R&D collaborative projects and the strengthening of technology transfer capacity in universities. Despite these efforts, however, the country has not experienced improvement in its innovation levels; it ranks lowest among the Organisation for Economic Co-operation and Development (OECD) countries in terms of research and development (R&D) as a percentage of its gross domestic product (GDP) (OECD, 2015c), which in 2010 was at around one third of the level of the mean of other OECD countries (OECD, 2010). Taken together, these complementary features make Chile a particularly interesting developing country in which to study university-firm linkages.

1.3 Main findings and contribution to the literature

By considering both sides of university-firm linkages while also considering the multi-level incentives that influence these linkages I was able to elaborate a rich analysis that captures the complex dynamics of university-firm collaboration in a developing country. From the supply side, the research shows that public policy creates inconsistent collaboration and technology transfer incentives in academics and universities. The findings signal that these incentives have led academics to participate in university-firm collaboration programmes to engage in technology transfer activities, firstly and most importantly to secure research funding, and only secondly to facilitate technology transfer. What is more, public policy allocating R&D grants at both the organisational (university) and individual (academics) level produces conflicting incentives towards conducting basic versus more applied research.[5] This in turn further influences how universities develop their technology transfer organisational capacity and how academics decide on their research and collaboration strategies.

On the other side, Chile's productive structure at the macro level in combination with the other features of hierarchical market economies (HMEs)[6] have produced a business environment in which R&D is not seen as imperative to a firm's survival and which have influenced the approach of firms to innovation and technical upgrading, This environment has reduced the importance of R&D and universities in the innovation strategies of firms, which then narrows their focus on the acquisition of technologies already available. This trend, combined with a lack of absorptive capability and capacity to manage the coordination and information costs associated with collaboration with universities, has made university-firm linkages the preserve of a select group of firms. Among those firms with the resources and capabilities to introduce innovations, the quantitative analysis shows that collaboration with universities has a positive and significant effect on the

[5] Basic research considers experimental or theoretical work undertaken mainly to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is original investigation undertaken in order to acquire new knowledge buts primarily directed towards a specific practical aim or objective (OECD, 2002: 30).

[6] Schneider (2009) developed the concept of hierarchical capitalism as an institutional variation from the varieties of capitalism approach developed by Hall and Soskice (2001) that responded to the institutional features of Latin American countries (including Chile). This author claims that the four core empirical features HMEs in Latin America are: diversified business groups, multinational corporations (MNCs), atomistic labour relations, and low skills (Schneider, 2009: 555).

innovation performance of firms by increasing their sales of innovative products. The results also suggest, however, that collaboration with universities is not useful per se but that is only relevant for the introduction of new-to-the-market innovations while it appears not to influence the introduction of new-to-the-firm innovations.[7]

These results provide both theoretical and policy insights. They support the argument that the capacities and resources of firms are essential if firms are to take advantage of collaboration with universities. They also show that, in the case of Chile, where innovation is confined to a small group of large firms, promoting university-firm collaboration may have limited scope as a tool for development. Unless policy makers consider the incentives directly and indirectly influencing the decisions of the agents in the innovation system, and unless innovation policy influences the behaviour of *both* sides of university-firm interactions *simultaneously*, the incentives to collaborate will remain scant and it is unlikely these policies will have a significant impact.

This dissertation contributes to the literature on innovation and development in four significant ways. Firstly, as we have seen, it advances the understanding of university-firm collaboration for innovation in a developing country that has comparative advantages in natural resources. By examining Chile, the investigation of university-firm innovation linkages and technology transfer offered in this thesis aligns itself with recent efforts to understand these interactions in the context of developing countries (e. g. De Fuentes and Dutrénit, 2012; Dutrenit and Arza, 2010;

[7] The Oslo Manual (OECD, 2005b), which is the OECD publication that provides guidelines to collect data about innovation in firms, defines three types of innovation according to their degree of novelty: new-to-the-firm, new-to-the-market and new to the world. New-to-the-firm innovations consider the diffusion of an existing innovation to a firm (an existing innovation). New-to-the-market innovations are those innovations that are introduced by a firm but are new to the market in which the firm operates. An innovation is new to the world when the firm is the first to introduce the innovation for all markets and industries.

Dutrenit et al., 2010; Fu and Li, 2016; Goedhuys and Veugelers, 2012; Kafouros et al., 2015; Povoa and Rapini, 2010).

Secondly, using a supply-demand analytical lens and examining the multi-level factors influencing university-firm linkages, from the macroeconomic to the firm level, I develop a novel approach that allows for a rich analysis of the dynamics at work in a developing country's innovation system. This attempt is timely and relevant given the growing importance of fostering innovation as part of the development strategy of many developing countries.

Thirdly, by incorporating management and innovation theories in the analysis, and particularly by focusing on the incentives influencing the decisions of agents in the innovation system, this thesis contributes to the literature on these streams in a developing country context. This provides a different perspective from neoclassical theory, which has been used extensively in the elaboration of public policies, but which according to Nelson (2008) cannot adequately deal with an economic context in which innovation is important. Chile has extensively based its design of innovation policy on the analysis of market failures (OECD, 2007)—a framework that has allowed policy makers to argue for public intervention and allowed them to identify *where* innovation policy is needed to correct market failures, yet has failed to provide guidance on *how* and *why* these policy interventions and the environment shape the incentives of agents. Moreover, according to the World Bank (2008: 22), market failure arguments offer relatively little guidance on the magnitude of the corrections required or on the nature of the interventions. In the words of Charminade (2011: 363), the concept of market failure 'fails to deliver practical recommendations for policy makers when it comes to delimiting scale, scope and timing of interventions’. In addition, the recognition of the growing role of innovation in developing countries has opened a new subfield of research at the intersection of innovation, management studies, and development studies (Zanello et al., 2015: 4).

My fourth contribution is empirical. I assess the impact of university-firm collaboration on the innovation performance of a sample of Chilean firms using a novel dataset specially prepared for this thesis. This evaluation provides valuable insight into the type of firms that benefit from collaboration with universities and the type of innovation activities that produce these benefits.

1.4 Methodological approach

In terms of research methods I used a combination of quantitative and qualitative data collection methods. The qualitative component of the thesis considered carrying out a case study of university-firm collaboration in Chile. The quantitative part of thesis consisted of estimating the impact of university-firm collaboration in a sample of Chilean firms using Tobit, probit, and random effects methods.

In practice, in order to answer the first research question of this thesis—what factors influence innovation linkages between academics, universities, and firms?—I carried out semi-structured interviews with academics and technology transfer managers from the three most important Chilean universities in terms of knowledge production, as well as with civil servants working on innovation policy making. I combined the information from the interviews with qualitative and quantitative secondary data to understand the incentives that academics and universities have to engage in to build collaborative linkages with firms for innovation.

To explore the factors influencing the incentives of innovation and collaboration in firms I conducted semi-structured interviews with industry representatives, key informants from firms, and senior civil service engaged in the design and implementation of public programmes aimed at increasing innovation in firms and promoting university-firm collaboration. I complemented this data with descriptive analysis of quantitative data from the innovation of firms in Chile, official reports, and other secondary sources.

By combining research methods I was able to capture not only the incentives directly but also indirectly influencing firms and universities, which allow me to observe distinct forces framing university-firm linkages in Chile. I believe this strategy has provided me with an overall picture of how university-firm linkages work in practice.

As mentioned earlier in this section, the quantitative component of the thesis was aimed at assessing the effects of collaboration with universities in the innovation performance of firms. By applying quantitative methods in a purpose-made panel database I was able to explore whether university-firm collaboration is beneficial for the innovation performance of Chilean firms.

In summary, in this thesis I seek to offer a comprehensive understanding of university-firm linkages in Chile by analysing the demand and supply sides of these interactions for innovation. This *two-sided* approach provides a more ‘realistic’ understanding of these interactions than one which focuses the study on only one side of the linkages. Such an approach allows this thesis to capture the particular features of developing countries, a significant necessity since their innovations systems differ from those of developed countries (Lundvall et al., 2011). The qualitative analysis focuses on the supply side of technology transfer and complements the quantitative analysis by studying firms and their inter-organisational linkages.

1.5 Dissertation Outline

This dissertation is divided into three parts. The first part (Chapter 1: Introduction, Chapters 2 to 4) presents the motivation behind the dissertation, explores the research questions which it seeks to address, reviews the literature, and discusses the methods used to answer the research questions. The second part (Chapters 5 to 7) presents the empirical findings of the research, while the third part (Chapter 8) discusses the findings of the analysis and presents the main conclusions of this research.

In **Chapter 2**, I review the literature on the topic of university-firm R&D linkages, with a focus on evidence from developing countries, and summarize the stock of knowledge and the gaps in the literature that my research aims to overcome. In this chapter I argue: that empirical gaps have led to the broad belief that university-firm collaboration is key to the technological development of countries; that there is limited research on the role of universities as collaboration partners for firms in developing countries; that research has largely focused on one side of a two-sided interaction; and that there is limited research considering the multi-level effects of factors influencing these linkages. By examining these issues I hope to contribute to filling these gaps.

In **Chapter 3** I present the methodology used to carry out this research. First, I discuss the rationale and benefits of using mixed methods to answer the research questions. Then I explain the qualitative and quantitative components of this research and discuss why I chose to use a case study as my main research method. This section also presents the criteria used for the recruitment of participants for the interviews and the data analysis strategy. I also describe the quantitative components of the research methods, describing the main source of quantitative information—the Survey of Technological Innovation (EIT) (*Encuesta de Innovación Tecnológica*)—and the construction of a purposely built panel database using three waves of this survey. The panel is used to estimate the impact of university-firm collaboration on the innovation performance of firms in a sample of Chilean companies. I conclude the chapter by describing the methodological challenges faced during the design of this research.

In **Chapter 4** I analyse the main features of the Chilean system of innovation in order to describe the research settings of this dissertation. To do this I focus the narrative on the productive structure of the country, the development of the innovation system, and its main characteristics and innovation constraints. I show that Chile's innovation system is embedded in the productive structure of an open-oriented small economy based on the exploitation of natural resources. The innovation performance of the country is low in terms of input and outputs and the R&D efforts of firms are limited.

Throughout this chapter, I show how the development of the innovation system, which has been driven by the evolution of Chile's innovation policy, has moved from scattered and uncoordinated public policy programmes mainly oriented to the promotion of R&D in the 1980s and early 1990s towards a system that provides support to its actors throughout the innovation process. I then proceed to contend that, in spite of significant development, the Chilean innovation system still has several challenges to overcome, for example, a lack of coordination and linkages among its actors and a lack of efficiency.

In **Chapter 5** I study the engineering schools of the three most important universities in terms of knowledge production. Based on this, I seek to understand the dynamics of university-firm innovation linkages from the supply side of this interaction. In this chapter I also analyse the effects of public funding on the development of technology transfer organisational capacities in the universities and on the motivations of these organisations and academics to engage in collaborative innovation activities with firms.

In the first part of the chapter I discuss the influence of the innovation processes of public grants on the motivations of both researchers and universities in relation to technology transfer strategies. I then analyse how the establishment of matching grants has framed the creation of technology transfer capabilities in universities and study the effects of this public funding on the motivations of academics towards R&D collaboration with firms and the problems it generates. Throughout this chapter, I argue that the allocation of research funding to universities has produced inconsistent incentives in universities and academics regarding the nature of research, the collaboration with firms, and the organisational technology transfer capacity. Further, the analysis shows that an important motivation for universities to establish organisational technology transfer capacities has been the desire to secure shares of the newly available public funding. Against this background, the next empirical chapter (Chapter 6) analyses the other side of university-firm innovation linkages, i.e. the demand side of knowledge production.

In **Chapter 6** I explore the innovation activities of Chilean firms and the role of universities as innovation partners. I devote special attention to the R&D activities of firms and their innovation strategies. I carry out the analysis through a detailed study of three main issues: the incentives created by the effect of the macro-environment on Chilean firms; the behaviour of firms regarding innovation, which concentrates on process innovation through the acquisition of machinery; and the factors hindering the capacity of firms to engage in collaborative R&D activities with universities.

In this chapter I argue that the existence of negative incentives produced by the type of capitalism found in this country and the lack of capabilities in firms have created an environment in which R&D as a type of innovation activity is not critical to the growth and survival of firms, even though the country presents innovation rates similar to developed countries. Furthermore, I claim that the capabilities of firms in the presence of coordination and information costs have made universities a potential R&D partner for only some firms.

In the third empirical chapter of this dissertation **(Chapter 7)** I assess the impact of collaboration with universities, on the innovation performance of a sample of Chilean firms. In the first part of this chapter, I review the literature of university-firm linkages. This specific literature review is focused on assessing the empirical quantitative evidence of the impact of university-firm linkages with a focus on developing countries. Based on the review I develop the following hypotheses in this chapter: firms collaborating with universities are more likely to introduce novel innovation rather than innovations already available in the country, and show a better innovation performance, as measured by their share of innovative sales. I then proceed to present the econometric model and then discuss the rationale for using Tobit, probit, and random effects methods. After describing the data, the chapter then presents the results of the estimations. The analysis shows that collaboration with universities has a positive impact on the likelihood of introducing new-to-the-market innovations and that it also has a significant positive effect on a firm’s share of innovative sales. Collaboration with universities, however, appears not to influence the likelihood of firms introducing new-to-the-firm innovations. Other types of collaboration partners appear to have a positive effect on the likelihood of introducing this type of innovation.

The findings from this chapter signal the relevance of adapting the innovation strategies of firms regarding collaboration and the selection of potential innovation partners with due consideration of the type of innovations conducted by firms. This means collaboration *per se* may not have positive effects in firms but depends on the type of innovations firms would like to introduce.

An overall discussion of the findings of this dissertation is presented in the third part of this thesis, **Chapter 8**. I begin by summarising the main findings of the dissertation and examining them within the context of the technical literature. The findings from this thesis suggest that low innovation collaboration and technology transfer can be partly explained by two main separated but interconnected factors:

(i) the incentives structure of public policy, which is dominated by the desire to obtain resources rather than to increase technology transfer; (ii) the productive structure of the country, which creates limited incentives for firms to innovate. In contrast, open innovation strategies[8] appear to have a positive impact on innovation in firms while collaboration with universities is only beneficial for already innovative firms. I argue that these positive effects may have limited effects on helping to create sustainable growth because of the low numbers of firms collaborating with universities. The summary of findings is followed by a discussion of the main theoretical and policy implications of the findings. I close both the chapter and the dissertation with a discussion of future areas for research.

[8] Open innovation has been defined by Chesbrough et al. (2006) as ‘a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model’ (Chesbrough and Bogers, 2014: 1).

Chapter 2: Literature Review

2.1 Introduction

Innovation[9] plays an important role in the economic growth of countries (Jones, 1995; Lall, 1992; Romer, 1990) and technology plays a significant role in explaining the productivity changes (Keller, 2004) that account for much of the variation in income across countries. Research has found a strong positive relationship between the level of innovation (measured as the number of patents), labour productivity, and GDP per capita across OECD countries (Someshwar et al., 2001). Consequently innovation has become a primary objective for firms and governments in most countries around the world (Chen and Puttitanun, 2005; Chuang and Lin, 1999; Wu, 2007). In this context, innovation is increasingly inter-organisational and collaboration with other organisations is becoming a requirement, rather than an option, for many firms (Lichtenthaler, 2011: 89). Many of the empirical studies about collaboration between universities and firms have been based in developed countries and have examined only one side of this two-sided interaction. This chapter focuses on these gaps and proposes an analytical framework under which university-firm collaboration is influenced by the innovation system in which these actors participate. From this viewpoint, factors at micro, meso and macro level can be seen to affect *both sides* of the interaction and shape whether, how, and what type of university-firm linkages and technology

[9] As a working definition, innovation is understood as the first attempt to put an idea for a new product or process into practice (Fagerberg, 2005:4).

transfer activities between these organisations occur in a developing country such as Chile. Table 1 presents a non-exhaustive list of the factors influencing university-firms linkages identified in this review. These are categorized by whether they influence firms, academics, or are environmental/institutional.

Table 1: Factors influencing university-firm linkages

Firms	Academics	Environmental/Institutional
Access to and share of knowledge Sector Size Strengthening absorptive capacities Benefit from complementarities Reducing risk Reducing costs Enhancing capabilities Competence creation Network building Compensating for missing capabilities Expanding their competencies Short term problem-solving	Access to funds Field Academic quality (frontier research) Intellectual interest Research interest Reputation Career progress	Cultural differences Characteristics of the innovation system (education, intellectual property rights) Institutional settings

Source: Own elaboration based on the articles examined for this review.

The topics studied in the literature on university-firm collaboration fall into a broad number of categories ranging from the study of the determinants for collaboration, to the impact of this type of linkage and its effects on technology transfer. However, three main strands within the literature are relevant for this dissertation: (i) studies that focus on the motives for firms to collaborate with universities; (ii) studies that deal with the rationale for and reasons why academics and universities collaborate with firms; (iii) studies dealing with innovation, university-firm linkages and technology transfer between these organisations in the context of developing countries. In the following sections, I consider each of these categories in turn before summarising the current state of research, identifying the gaps in the literature addressed by this dissertation, and introducing the analytical approach to my research.

However, before exploring the literature on collaboration, it is worth briefly exploring what collaboration means. In general, cooperation and collaboration are used interchangeably and loosely in the literature, which may have helped researchers to capture the heterogeneity of types of inter-organisational arrangements. In this research I also use these terms interchangeably. Yet there are subtleties in what cooperation means here, that need to be acknowledged. Bozeman et al. (2013:3), for example, define collaboration as 'social processes whereby human beings pool their human capital for the objective of producing knowledge.' However, in the literature the definition of collaboration can change according to the type of data available and the research question. For instance, literature using patents and publications data usually defines cooperation as co-authorship or citations of patents and publications (e.g. Dornbusch and Neuhäusler, 2015; Katz and Martin, 1997; Mowery and Ziedonis, 2015). On the other hand, literature using the Community Innovation Survey (CIS) or similar datasets (Ballot et al., 2015; Mairesse and Mohnen, 2010; Segarra-Blasco and Arauzo-Carod, 2008), such as the EIT dataset used in this thesis, generally define cooperation as formal cooperation agreements. It is necessary to acknowledge that cooperation is, in this sense, not limited to R&D projects but is defined as the broader concept of cooperation for innovation. In order to maintain consistency between the quantitative and qualitative components of this dissertation, I follow the definition provided in the

EIT, in which cooperation on innovation activities is defined as ‘active participation in innovation projects with other institutions’ (INE, 2009b).

2.2 On why firms collaborate on innovation

Companies are increasingly willing to collaborate as a way of uncovering new ideas, converting inventions into products faster, fending off competition, compensating for technology lock outs, and adapting to swift market changes (Markman et al., 2009: 644). Underpinning this is the understanding that innovation originates not only within firms, but also arises from the local environment of competitors, suppliers, customers, universities and research laboratories (Powell and Grodal, 2005). This approach to—designated as ‘open innovation’ by Henry Chesbrough (Chesbrough, 2003)—argues that ideas can come from inside or outside a firm and assigns the same importance to internal and external ideas paths to markets (Chesbrough et al., 2006: 2). The open innovation paradigm (Chesbrough et al., 2006: 2) views research and development as an open system, assumes that useful knowledge is widely distributed, and that even the most capable R&D organisations must identify, connect to, and leverage external knowledge sources as a core process in innovation (Chesbrough et al., 2006: 3).

The reason for collaboration is simply that firms cannot carry out all their innovation activities in-house (Lichtenthaler, 2011). Indeed, organisations have neither the human capacity nor the capability to cover all the scientific disciplines that can contribute to their product development and innovation (Markman et al., 2008). There are several potential benefits for firms from engaging in collaboration.

According to Mairesse and Mohnen (2010: 17) cooperation in R&D, or more generally in innovation activities, is often pursued by enterprises in order to share knowledge, to benefit from complementarities, to reduce risk, or to save on costs. Collaboration also facilitates the transfer of certain types of knowledge and enhances firms' learning capabilities (Hagedoorn et al., 2000: 572), while enabling them to attain complementary assets related to innovative labour (Mowery et al., 1996).

Firms use external relations not as a temporary mechanism to compensate for missing capabilities, but as a means to expand their competencies (Powell et al., 1996). Combining external search with internal R&D capabilities provides firms with a larger spectrum of technological options and allows them to dedicate relatively more resources to R&D areas that they consider as being to their core advantage (Perkmann and West, 2014: 41). According to the work of Powell et al. (1996), external linkages are necessary for knowledge creation and can take several forms varying from informal personal relationships to formal alliances. Formal collaboration may allow a division of innovative labour that makes it possible for firms to accomplish goals they could not pursue alone (Powell and Grodal, 2005). Collaboration among organisations is vitally important for knowledge-based economies (Inzelt, 2004).

2.3 On why firms collaborate with universities

Collaboration with universities is one specific mode of open innovation strategy (Perkmann and West, 2014). In this regard, a common assumption of management studies is that the creation and transfer of knowledge is the basis for competitive advantage in firms, is central to the innovation process, and that interaction with science stimulates firms' innovativeness (Argote and Ingram, 2000; Kaufmann and Todtling, 2001; Powell and Grodal, 2005). Indeed, through interaction with science, a far more diversified range of knowledge sources become accessible to firms than is available through intra-business interaction (Kaufmann and Todtling, 2001). Moreover, according to Etzkowitz et al. (2000), universities play an enhanced role in technological change because of the changing nature of both knowledge production and economic production.

Previous studies have analysed the influence of 'public' research[10] (e.g. Cohen et al., 2002; Eom and Lee, 2010; Faems et al., 2005; Mazzoleni and Nelson, 2010; Mazzoleni and Nelson, 2007; Robin and Schubert, 2013). Research has found that benefits from interactions with universities are multifaceted and include enhancement of the firm's explorative and exploitative capabilities (Bishop et al., 2011).[11] Research partnerships also allow firms to participate in the generation of new knowledge, since they can use the capacities and resources available at institutions conducting public research (Perkmann and West, 2014: 54). Using data from Belgian manufacturing firms, the work of Cassiman and Veugelers (2006) uncovered complementarities between internal and external innovation activities. In particular, they found that the extent to which internal innovation processes rely on universities and research centres as sources of information increases the complementarities between internal R&D and external knowledge acquisition in

[10] Defined as the knowledge produced by universities and research and development laboratories (Cohen et al., 2002).
[11] Bishop et al. (2011: 30) argue that the benefits firms get from collaborating with universities can range from explorative returns (such as those related to access to information) to exploitative benefits (such as those related to commercial exploitation).

firms. These findings underscore the importance of universities and research centres as sources of information for the innovation process.

However, collaboration with universities is not limited to R&D projects. It can also reflect a firm's desire to access universities' problem-solving capabilities for its ongoing R&D programmes (Perkmann, 2015: 3) or to source other support services, such as consulting (Mansfield, 1995). Furthermore, it has been suggested that university research not only contributes to new R&D projects but also to the completion of existing projects (Cohen et al., 2002). This could be interpreted as showing that the role of universities is not limited to providing firms with access to frontier science (Perkmann, 2015: 3). In this regard, empirical research on the rationale for firms to interact with universities has found that indirect mechanisms such as learning, competence creation and network building are at least as important as the direct results of collaborative R&D efforts with universities (problem-solving, commercialization) (Broström, 2012: 323). Further, empirical research has found that firms working with universities appear to introduce more radical innovations than non-collaborating firms (Belderbos et al., 2004).

In broad terms, it is possible to differentiate between the commercialization of intellectual property rights—which can occur by intellectual property creation and academic entrepreneurship—and other mechanisms in the transfer of technologies between universities and firms. Those other mechanisms include what the work of Perkmann et al. (2013) have identified as *academic engagement*, which includes collaborative research, contract research, consulting and informal relationships. The authors further underscore the differences between academic engagement and commercialization (intellectual property creation and academic entrepreneurship).

They find that academic engagement is different from commercialization in being more widely practised, closely aligned with research activities and academic career, and pursued by academics to foster their research agenda through access to funding. It is important to note, however, that the distinction between different types of transfer mechanisms may be blurred. For instance, the work of Wright et al. (2008: 1221) has found that for small and medium enterprises (SME) small-scale collaborative projects may be viewed more as consultancy than contract research. It is important, however, to keep in mind that only a minority of firms work with universities. For instance, the results from the 2013 CIS conducted in the United Kingdom show that suppliers, customers and even rivals are generally much more likely to be sources of supply-side input for innovation than universities (Coad et al., 2014).

Research on the determinants of university-firm linkages has found that engagement in open innovation increases with firm size and R&D expenditure, at least in the case of UK firms (Mina et al., 2014: 853). These authors found that, compared to manufacturers, business services are more active open innovators, are more engaged in informal relative to formal open innovation practices, and attach more importance to scientific and technical knowledge than to market knowledge (Mina et al., 2014: 853).

Impact on firms

A significant amount of studies have focused on identifying and assessing the impact of university-firm linkages on firms.[12] In general, economic studies analyse

[12] The literature about this topic is reviewed in Chapter 7, which assesses the impact of university-firm collaboration for innovation in a sample of Chilean firms.

the effect of collaboration on innovation in terms of innovative output and efficiency (e. g. Acs et al., 1994; Greenhalgh et al., 2004; Jaffe, 1989), while organisation theory has focused on the strategic and organisational characteristics of the interaction between firms universities and academics. These scholarly efforts have furthered our understanding of the factors influencing university-firm linkages, including revealing how research field, productive sector, research interests, reputation, framework conditions (including regulation and legislation), promotion programmes, and institutional settings appear to affect university-firm collaboration.

Many of the empirical studies about the effects of university-firm collaboration have largely been conducted within the context of developed countries (Cassiman et al., 2008; Kodama, 2008; Mowery, 2011). In general, research focused on these countries has found that firms with science linkages seem to enjoy at least some superior innovation performance (Cassiman et al., 2010: 21), in particular with respect to innovations that are new-to-the-market (Belderbos et al., 2004b). At the same time, research has also found an important heterogeneity in the use of different forms of university-firm linkages and that furthermore different types of linkages are not necessarily complementary (Cassiman et al., 2010: 21). Research has also shown that there is no straightforward positive association between these links and innovation performance and that other factors, such as the type of innovation and the sector, come into play in determining success (Cassiman et al., 2010). For instance, the work of van Beers and Zand (2014) claims that external collaboration is more effective for radical innovations in high-tech sectors than for incremental innovations in low-tech sectors.

Empirical research also has found that firms who adopt 'open' search strategies and invest in R&D are more likely than other firms to draw knowledge from universities (Laursen and Salter, 2004: 1201). This is because openness to external sources allows firms to draw on ideas from outsiders in order to deepen the pool of technological opportunities available to them (Laursen and Salter, 2006: 146). Their results strongly suggest that searching widely and deeply across a variety of channels can provide ideas and resources that help firms gain and exploit innovative opportunities (Laursen and Salter, 2006: 146).

In terms of research methods, an important portion of the literature has used quantitative methods based on surveys such as the CIS and similar surveys (for instance, Belderbos et al., 2015; Faems et al., 2005; Lokshin et al., 2008). To my knowledge, there is only one study in a developed country context that has considered *both* universities and firms simultaneously (see Hughes, 2011). By using survey methods to collect data on individual academics and firms from the UK, Hughes analysed the data from a *Mode 2* perspective[13] and revealed an extensive range of linkages between academics and industry, many personal rather than institutional.

So far the analysis of the literature, which is mainly based on developed countries cases, has shown that firms collaborate with universities for several reasons including to gain access to knowledge and to increase their competitiveness. Technology transfer between universities and firms can occur through various mechanisms from patent licenses to research agreements and personal interaction.

[13] The *Mode 2* perspective of knowledge creation stresses that knowledge is generated in the context of specific applications. It argues that the process of knowledge production is seen as embodied in the capabilities and expertise of research teams; and that knowledge is produced in a much wider range of locations than in the conventional university sector. (Hughes, 2011: 414).

Whether firms choose to employ open innovation strategies and their choice of partner depends on factors such as their capabilities, the type of innovation they want to carry out and the sector in which they operate.

2.4 On why universities and academics work with firms

Academics—the other side of the university-firm interaction—display different reasons for their engagement with firms, which include, expanding their research (D'Este and Perkmann, 2011; Geuna and Muscio, 2009), increasing their tacit knowledge (Ramos-Vielba and Fernandez-Esquinas, 2012), providing improved understanding of research applications in industry (Geuna and Muscio, 2009: 109), and commercializing their inventions (D'Este and Perkmann, 2011). Research has also found that the decision of academics to engage in collaborative activities with industrial partners is influenced by factors such as access to resources (Bozeman and Gaughan, 2007; Tartari and Breschi, 2012), academic freedom (Tartari and Breschi, 2012), and social capital (Geuna and Muscio, 2009; Tartari et al., 2014).

Universities' interest in obtaining research funds is not a new finding in the literature. According to Yusuf (2008: 1169), universities may seek research and linkages with firms in order to grow, to keep their academic standing and to diversify their source of funding. Indeed, potential access to research funds has also been identified as a motivation for participating in technology commercialization activities, such as licensing. For instance, Thursby and Thursby (2007) studied the university licensing goals in the United States using secondary data from the Association of University Technology Management (AUTM) licensing survey, documents from the universities, and primary data collected by interviews with academics and personnel of the technology transfer offices (TTO). They found that, although income is the most important objective for the central administration and the TTOs, the most important objective for faculty, as identified by the TTO managers, was access to the sponsored research funds associated with licensing activities (Thursby and Thursby, 2007).

Additionally, research on the determinants of academics' collaboration with firms has found that scientists perceive the value of patenting differently depending, among other factors, on their scientific careers, and that their commercial involvement is shaped by the level of reputational importance placed on scientific compared to commercial achievements (Haeussler and Colyvas, 2011: 41). For instance, the work of Haeussler and Colyvas (2011) examined engagement in consulting, patenting and funding of new companies among academics in Germany and the UK. These authors found that characteristics reflecting professional security, advantage, and productivity are strong predictors of academic entrepreneurship but not of the other forms of technology transfer (Haeussler and Colyvas, 2011: 41). Further, using data from the United Kingdom, D'Este and Perkmann (2011) found that most academics engage with industry to further their research rather than to commercialise their knowledge. Professional and environmental factors also come into play. For instance, Bozeman and Gaughan (2007) found that most academics engaged with industry were tenured or senior researchers, which indicates the existence of career stage effects in those actively engaged with industry. In addition,Bercovitz and Feldman (2008) found that when the head of the department participated in technology transfer activities other members of the department also were more likely to participate, even if only for symbolic reasons.

Several factors related to the field of the inventions and the quality of researchers may also influence the relative importance and performance of different technology transfer mechanisms. For example, some disciplines, e.g. biological sciences and engineering, are quite likely to work with industry, while others have almost no involvement, e.g. physical sciences (Bozeman and Gaughan, 2007; Thursby and Kemp, 2002). The more applied nature of engineering and the better market opportunities of biological sciences could partly explain these differences (Thursby and Kemp, 2002). In terms of the quality of researchers, a highly cited literature review conducted by Perkmann et al. (2013) underscores the importance of differentiating 'frontier researchers' and their external academic engagement from those who do not participate in external engagement or do not conduct frontier research (Perkmann et al., 2013). In addition, these authors claim that differences in the governance of universities across countries can also be important in determining academics' engagement with non-academic organisations.

The broad range of factors that the literature has found to influence university-firm linkages underscores the complexity of these interactions. University-firm interactions appear to be influenced not only by a range of direct and indirect benefits and motivations but also by the way in which the accepted range of norms and culture of the universities influence how academics perceive working with firms.

In terms of methods, in general studies analysing the factors influencing universities collaboration with firms have employed surveys (Bekkers and Freitas, 2008;

Boardman, 2009; D’Este and Patel, 2007; Giuliani et al., 2010) and interviews (Barbolla and Corredera, 2009), or a combination of these two methods (Lam, 2011).

Barriers to collaboration

Research has also examined the factors hindering university-firm collaboration (e. g. Baldini, 2009; Bruneel et al., 2010; West and Bogers, 2011) and discovered that cultural differences between universities and firms form a significant barrier (West and Bogers, 2011). However, other research has found that cultural differences may only be a barrier for large firms (Hughes, 2011). The work of Bruneel et al. (2010) has found that firms’ prior experience of collaborative research with universities appears to lower the barriers related to the orientation of universities’ research while greater levels of trust appear to reduce not only this type of barriers but also those related to the management of the projects’ transactions associated with working with university partners. These authors argue that breadth of interaction has also been shown to diminish orientation-related, but increase transaction-related barriers (Bruneel et al., 2010: 858)

Lack of support from the university administration has been found among the obstacles to patenting activity (Baldini, 2009), while factors that hinder knowledge exchange include lack of time, insufficient internal capability to manage relationships, and insufficient information to identify partners (Hughes and Kitson, 2012). However, intellectual property rights disputes appear not be prominent reasons for lack of knowledge exchange between universities and firms (Hughes and Kitson, 2012).

Other factors influence technology transfer in universities, and the work of Mowery and Sampat (2005) has shown that there are several points of tension regarding the role of universities within knowledge-based economies. These authors claim that universities struggle to juggle their role as creators of new knowledge regardless of its commercial or innovative value with their role as promoters of technological development. This may suggest the relevance of 'political' issues inside the universities that may affect technology transfer depending on the level institutional support given to the activity. It is also relevant to know more about the ways in which universities interact with industry in different settings and to understand how communication, understanding, trust, and people drive university-firm linkages and their success (Plewa et al., 2013).

Research has underscored the importance of contrasting the practices, values, and norms of researchers on the one hand and university managers on the other, rather than studying the university as a single unit. This is because focusing on the organisation as a cultural unit tends to over-determine the contribution of often quite distant structures to groups of people with quite distinct practices (Brown and Duguid, 2001:201). At the same time, the incentive structures in universities are affected by the external environment and by the internal resource allocation mechanisms (Geuna, 1999: 18). Additionally, there is evidence that patenting, licensing, and spin-out require different types of management when they are being developed into profitable academic research projects (Ambos et al., 2008).

Technology Transfer Offices and commercialization of innovations

TTOs are a ‘new’ type of organisation that flourished rapidly in the United States after the Bayh-Dole Act in 1980.[14] This act effectively transferred ownership of intellectual property arising from federal research grants from the sponsoring agencies to universities (Siegel et al., 2007b: 439). In the specific case of technology transfer from universities, it is important to note that intellectual property rights are generally managed by TTOs (Geuna and Muscio, 2009). According to Siegel et al (2007a), the role of TTOs is to act as an intermediary between universities (suppliers of innovations) and those that can potentially commercialise the inventions. TTOs tend to specialise in the patent application process as well as in licensing contract negotiation (Wright et al., 2008). The establishment of TTOs can also be seen as providing both a strategic and structural response to strengthening industry–science links with academic institutions (Debackere and Veugelers, 2005).

Although they are often expected to generate steady revenue streams, royalties in reality are often only a minor part of a university budget (Wright et al., 2008: 1215) and evidence shows that intellectual property (IP) plays only a small role in comparison with other mechanisms of knowledge transfer (Agrawal and Henderson, 2009). So although licensing and patenting, along with contract research and spin-off companies, are typically cited as a high priority in terms of university-firm links, in practice the royalties that can be derived from these patents are very small. This means that universities either lose money on their patents or they make money with one patent to pay off the deficits on the other ones (Geuna and Muscio, 2009; Wright et al., 2008:1220). Research has also found that the vast majority of

[14] This Act allowed universities from the United States to claim the intellectual property of the knowledge created using public funds (Siegel et al., 2004).

inventions licensed are so embryonic that technology managers consider the co-operation of the inventor in further development as crucial for commercial success (Jensen and Thursby, 2001)

Even though TTOs are fairly new organisations, there is an increasing amount of literature focused on explaining the factors influencing their performance. Research on this topic has found that the organisational form (Bercovitz et al., 2001), culture, and incentives schemes for both academics and TTO faculty (Belenzon and Schankerman, 2007), appear to influence TTOs' performance. Furthermore, their experience (Clarysse et al., 2011), licensing strategies, autonomy, and incentives also appear to explain the outcomes of the commercialization of technologies (Markman et al., 2009). In particular, research from these authors has shown that the commercialization outcomes, which they consider revenue and start-up creation, are enhanced when TTOs use diverse licensing strategies, enjoy greater autonomy, share revenues with scientists' departments, and compensate licensing officers well (Markman et al., 2009:640). Conversely, the authors found that sponsored research agreements are negatively related to commercialization.

In sum, the literature on university-firm collaboration and technology transfer from the academics' and universities' perspectives reveals a broad range of factors influencing why academics engage in collaboration and technology transfer. These range from increasing knowledge to accessing resources. Factors related to the institutions and the support from the TTOs, and to the environment and cultural norms, influence whether academics are interested in engaging with firms. However, these findings are mainly based on cases from developed countries and in the next section is a review of the literature about innovation in developing countries.

2.5 Innovation in developing countries

Firms' interactions with their national innovation systems tend to be weaker in developing than in developed countries. In particular, the lack of R&D networking—and especially interactions with academics—may constitute an obstacle to innovation in developing countries (Raffo et al., 2008). In some developing countries, research capacity is also rather limited (Eun et al., 2006) and the innovation climate is characterised by weaknesses in the business environment, a lack of human capital, and poor information infrastructures (Aubert, 2005). All these influence the capacity for innovation in these economies (Aubert, 2005) and suggest that the findings identified in developed contexts may not hold true in developing countries.

According to Chaminade et al. (2011: 362) most innovation in developing countries is related to the absorption of technology and competence building rather than the introduction of new to the world innovations. For instance, in the case of Latin America, technological innovation is highly concentrated in adaptive and incremental innovations, which are not aimed at reaching international markets. This explains the reported dominance of innovations 'new to the domestic market' or 'new-to-the-firm.' (Navarro et al., 2010: 15).

Firms from Latin America are heavily involved in innovation, yet not necessarily in R&D. Instead they are motivated short-term concerns when making investing decisions and invest in innovation mostly in the form of technology and know-how embedded in capital goods (Arocena and Sutz, 2010; Navarro et al., 2010: 19). In the words of Arocena and Sutz (2010: 578), ‘innovation policies have not achieved great success’ in the region, and the capacities built from the implementation of science and technology policies remain under-utilized by firms and represent a marginal labour market for researchers (Arocena and Sutz, 2010: 578).

Level of novelty and types of innovations

Innovation as a concept may slightly differ according to the environment and beliefs on which it is framed. For example, Nelson and Rosenberg (1993: 4) follow the Oslo Manual[15], in claiming that innovations may be new to the world, new-to-the-country or new-to-the-firm, and suggest that innovation considers the processes by which firms master product designs and manufacturing processes that are new to them. Consequently, firms can innovate at different ‘levels’ and it is possible to argue that specific resources are needed according to the level of innovation that firms produce. Yet most of the world’s creation of new technology is produced in a few rich countries (Keller, 2004: 752) while in most countries foreign sources of technology are very important, representing almost 90 percent or more of their domestic productivity growth (Keller, 2004: 752). This phenomenon particularly affects developing countries, which usually adapt internationally produced innovation to the local context, meaning that indigenous firms learn processes and technologies already available in developed economies (Nelson and Rosenberg, 1993). This has two main consequences: (i) it makes international technology

[15] The *Oslo Manual* is the foremost international source of guidelines for the collection and use of data on innovation activities in industry (OECD, 2005b).

transfer crucial to technological upgrading in developing countries; (ii) it influences the type of innovation these countries introduce. For instance, in the case of Chile, technology and innovation are often seen primarily as readily imported tools. Innovation and knowledge are yet to be considered as the main source of sustainable wealth creation (OECD, 2007: 122).

2.6 University-firm collaboration in developing countries

It is only recently that the literature on university-firm linkages has begun including evidence from developing countries (e. g. Arza and López, 2011; Bodas Freitas et al., 2013; Dutrenit and Arza, 2010; Dutrenit et al., 2010; Fernandes et al., 2010; Fu and Li, 2016; Kafouros et al., 2015). Several reasons explain this growing interest: the importance of developing countries in international markets; the importance of university-firm linkages for the technological development of countries; the gap in the development of innovation systems in developing countries in comparison with developed countries; and the simple fact that the development of the innovation systems in these economies has increased the availability of data for measuring these interactions.

However, in spite of this increased interest in university-firm linkages in developing contexts, there remains a paucity of research on the subject. Out of the 36 articles focused on academic engagement with firms (not including commercialization of technologies) from three of the most important journals in the field analysed by Perkmann et al. (2013),[16] only one included data from a developing country (Chile),

[16] *Research Policy, Journal of Technology Transfer, and Technovation*.

and even that was as part of a sectoral cross-country analysis not as a focused case study. The other 35 articles focused on empirical analysis from developed countries.

Nonetheless, empirical studies have shown some of the features of university-firm linkages in developing countries. For instance, using a database of Taiwanese firms, Tsai (2009) examined how absorptive capacity affects the relationships between different types of partners and product innovation performance. Although this study is not particularly focused on collaborative partnerships with universities, its findings claim that firms with a high level of absorptive capacity are better able to incorporate new knowledge from research organisations into their existing products, which results in new products with marginal innovations but not in the introduction of radically new products, at least in the short term. They argue that this is because firms require a long time to develop the absorptive capacity to introduce radical new products based on collaboration with universities. Empirical evidence using quantitative data from innovation in Chinese firms has shown that collaboration with domestic universities has played a significant role in the diffusion of advanced technology (Fu and Li, 2016). Meanwhile, Eom and Lee (2010) study of data from Korea's emerging economy, has revealed the potential importance of public policies when examining the determinants of university-firm collaboration. These authors found that participation in national R&D projects was a significant determinant of collaboration for firms. In contrast to evidence from developed countries, these authors did not find that the firms' size and own R&D efforts were significant. These results underscore the importance of public policies in emerging economies. In terms of the impact of the collaboration, their findings suggest that collaboration with universities may be beneficial only for innovative firms and the authors argue that these findings may reflect the transitional nature of the national innovation system in Korea (Eom and Lee, 2010).

When examining university-firm linkages in the context of developing countries it is important to note the importance of universities as knowledge creators. For instance, universities are the most important source of knowledge creation in Latin America (Arocena and Sutz, 2001) but this is not necessarily the case, in developed countries; in the UK, for example, the biggest share of R&D is carried in the private sector (Hughes, 2011).

A relatively significant strand of the literature focused on developing countries has been based on historical and case study analysis (see for instance, Bodas Freitas et al., 2013; Brundenius et al., 2011; Sutz, 2000). This has been joined by an increasing amount of quantitative research based on national innovation surveys. However, the research has largely touched on university-firm collaboration as part of an assessment of the determinants of innovation and the effects of R&D on productivity (Benavente, 2006; Bravo-Ortega et al., 2012; Crespi and Zuniga, 2012; Lauterbach, 2012) or an examination of the factors influencing open innovation strategies in general (Benavente and Contreras, 2011; Bianchi et al., 2011). Among their findings these studies have revealed the importance of public funds as a determinant of collaboration with universities (Benavente and Contreras, 2011; Bianchi et al., 2011). A common characteristic of all these studies is that they only look at one side of the university-firm collaboration.

Few articles have considered the view from both universities and firms when studying collaboration for innovation between these organisations. However, in a series of articles (Arza and Vazquez, 2010; Dutrenit et al., 2010; Fernandes et al., 2010; Orozco and Ruiz, 2010) published by the journal *Science and Public Policy* studying the benefits and assessing the importance of different collaboration channels between firms and public research organisations in four Latin American countries (Argentina, Brazil, Costa Rica, and Mexico)[17], all of the studies were prepared using data collected from questionnaires sent to both academics and firms (Dutrenit, 2010). Overall these articles identified similar patterns of interaction between these organisations. In particular, the findings show that researchers give more importance to intellectual rather than economic benefits when collaborating with firms (Dutrenit and Arza, 2010), while firms tend to connect to public and research organisations for short-term problem solving rather than to gain insights for their long-term innovative strategies (Dutrenit and Arza, 2010).

2.7 Literature gaps and analytical framework

So far the literature review has revealed three important gaps. First, the majority of the literature focuses only on one side of a two-sided interaction. The studies discussed have been focused on analysing either factors influencing the demand or the supply side of university-firm linkages, or the factors influencing firms' association with universities. I contend that this approach cannot provide a comprehensive account of the 'real' dynamics of the linkages. Furthermore, although empirical research on university-firm linkages has been largely theoretically linked to the national innovation system approach, it has failed to integrate into the analysis the interdependence among actors that is a feature of this

[17] The articles are part of the outcomes of a project funded by Canada's International Development Research Centre (IDRC) and other agencies (Dutrenit and Arza, 2010)

approach (Arocena and Sutz, 2000: 57). One possible reason explaining the use of a single approach when studying these linkages could be found in the fact that developed countries have 'more mature' national innovation systems and therefore they have more developed linkages among actors.

Second, the available literature is largely based on cases from developed countries. There is an emerging strand of literature focusing on the study of these interactions in developing countries, but the evidence from these countries, and particularly from the Latin American region, is still limited. I contend that the conclusions and findings obtained from developed countries may not necessary hold true in developing countries. National innovation systems in these countries are not mature; they are, in the words of Chaminade et al. (2011), 'emerging'. In addition to the challenges to innovation produced by its characteristic as public goods, developing countries also need to deal with innovation systems lacking integration between firms in the production system, the financial sector, research and education activities, and the policies of the public sector (Bogliacino et al., 2012).

Third, studies on university-firm linkages and technology transfer fall short in capturing the influence of the multi-level factors—illustrated by the non-exhaustive list in Table 1 presented earlier in this chapter—that may affect them. Since developing countries have emerging innovation systems, these factors, especially the direction and importance of the interaction between both sides, cannot be underestimated. This is especially relevant for the adequate design of innovation policies.

National innovation system (NSI)

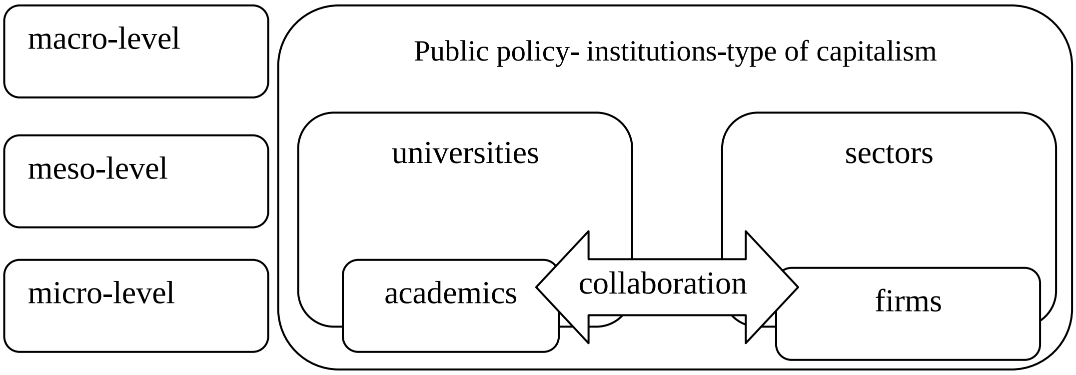
NSI is the set of institutions whose interactions determine the innovation performance of national firms (Nelson and Rosenberg, 1993). This framework was coined by Freeman in 1987 (Arocena and Sutz, 2000) and places innovation at micro, meso and macro levels as the driving force behind growth (Lundvall et al., 2011), and provides a systemic perspective by linking micro behaviour to the system in a two-way direction (Lundvall et al., 2011: 3). According to Lundvall et al. (2011: 3), the changes at the system level are seen as an outcome of the interactions at the micro level, whereas the system shapes the learning, innovation and competence-building at the micro level.

Under the NSI approach, a country's innovation and technology development are the result of the interactions and relationships between the different agents in the system, including enterprises, universities and public institutions related to the promotion of innovation (OECD, 2007). According to Lundvall (2010: 2), the NSI is a social and dynamic system. Social because a central activity in the system is learning and this is a social activity, and dynamic because it is characterised by both positive feedback and reproduction. Other characteristics of NSI are that it employs historical and evolutionary perspectives, which means that the processes of innovation are developed over time and that they evolve according to the influence of many factors and feedback processes (Johnson et al., 2003), and it stresses interdependence and non-linearity based on the understanding that firms normally do not innovate in isolation but interact with other organisations using complex relations that are often characterized by reciprocity and by a feedback mechanism in several loops (Johnson et al., 2003: 6).

Under this approach learning potential depends on the country's 'absorptive capacity' (Lundvall et al., 2011: 17). According to Zahra and George (2002), absorptive capacity is a type of dynamic capability and is defined by Cohen and Levinthal (1990: 128) as the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends. These authors argue absorptive capacity is critical to a firm's innovative capabilities and suggest that it is related to the existing knowledge of the firm. They also suggest that it may be created as a by-product of a firm's R&D investment.

Building on the NSI approach and with the aim of taking into account both sides of the university-firm collaboration linkages, I will use a supply–demand lens as an analytical framework to answer the research questions of this thesis. In practice, this means that I will examine the incentives academics and universities on the supply side of the interaction have to collaborate with firms and examine the factors that shape the incentives of firms on the demand side. Furthermore, in order to take into account the systemic nature of innovation, I aim to identify and explore the multi-level factors shaping both sides of the university-firm interactions. When analysing the supply side I consider academics as the micro-level environment, universities as the meso-level and the innovation policy and the institutional context as the macro-level environment framing the incentives academics have to collaborate with firms. When examining the demand side of the interaction, I consider firms as the micro-level, sectoral differences as the meso-level, and the environment and type of capitalism of Chilean firms as the macro-level influences on firms' incentives to collaborate with universities. Figure 1shows the analytical approach proposed.

Figure 1: Analytical approach



2.8 Conclusion

In this review I have tried to show that despite being a recent area of research, there is a broad coverage of university-firm linkages in the literature. Largely, the literature agrees on the potential benefits of these linkages for both universities and firms. At the same time, through the review I have tried to show the broad variety of factors influencing the determinants of collaboration as well as its impact on firms' performance. This review, however, has identified several gaps in our understanding— the one-sided nature of current research, the bias towards developed countries, and the absence of analysis of the multi-level factors, such as the particular environment and set of institutions present in countries, that may also affect how universities and firms interact with each other for innovation—which this thesis hopes to address by employing a supply–demand analytical framework to explore cases of university-firm collaboration in Chile.

Chapter 3: Methodology

3.1 Introduction

To answer my research questions, I chose to conduct a case study as my research method and used a combination of qualitative and quantitative data collection methods depending on the particular research question under analysis. In particular, I used the data from semi-structured interviews to examine the effects of public policy on the incentives of academics and universities to engage in collaborative innovation projects and technology transfer with firms. I also used semi-structured interviews as the main type of research method when analysing the productive structure in Chile and its potential influence on the innovation strategy of firms, and when examining the role of universities as potential research collaborators. To conduct the third and final part of this study, I drew on quantitative methods to assess the impact of university-firm collaboration for innovation. Throughout the dissertation, I have complemented the primary data from the case study with data collected from secondary sources such as national and international organisations and academic research.

This chapter is structured in five sections. Following this introduction, section 2 presents the rationale for using mixed methods as a research approach. Section 3 describes the qualitative components of the research strategy and the data collection and analysis. Section 4 describes the quantitative component of this research, which is based on the elaboration of a panel dataset using three waves of the Survey of

Technological Innovation (EIT) (*Encuesta de Innovación Tecnológica*). Finally, section 5 discusses the methodological challenges faced during this research. The chapter concludes by summarising the main aspects of the research design.

3.2 Rationale for mixed methods

The empirical analysis for this dissertation is based on mixed methods, drawing on both qualitative and quantitative data. According to Creswell and Plano Clark this methodological approach involves more than simply collecting and analysing both types of data; it also involves the use of both approaches in tandem so that the overall strength of a study is greater than either qualitative or quantitative research alone (Creswell and Plano Clark, 2007).

I chose to use a mixed methods approach to answer the research questions of this dissertation for three main reasons. First, the use of mixed methods extends 'the breath and range of inquiry by using different methods for different inquiry components' (Greene et al., 1989: 259). Second, it has been suggested that using mixed methods helps to offset the weakness of both quantitative and qualitative methods while drawing on the strengths of both (Bryman, 2006: 106). In particular, quantitative methods are at odds with one of the intrinsic characteristic of knowledge, which is that it is either tacit or difficult to codify.[18] Hence, it is difficult to measure transference of knowledge. Limiting the analysis to the more traceable

[18] Codify refers to the ability of the firm to structure knowledge into a set of identifiable rules and relationships that can be easily communicated (Kogut and Zander, 1992: 387).

sources of knowledge flows like patents, licenses and publications may underestimate the relevance of less traceable sources of knowledge transfer such as consultancy and personnel mobility (Schartinger et al., 2002), all of which can influence the type of collaboration between universities and firms. To limit the definition of knowledge transfer to its traceable sources when assessing knowledge transfer effectiveness is a shortcoming of quantitative methods. In contrast, qualitative methods help to identify non-measurable reasons for collaboration between universities and firms. Qualitative studies about university-firm technology transfer are generally focused on case studies that include interviews, surveys, and document analysis as methods of analysis (see for instance, Bercovitz et al., 2001; Debackere and Veugelers, 2005; Kesan, 2009; Owen-Smith and Powell, 2001). Thus, the combination of quantitative and qualitative methods offers a more comprehensive analysis of the dynamics of university-firm linkages technology transfer in general, and between universities and firms in particular.

Third, using mixed methods allows for *completeness*, meaning that 'the researcher can bring together a more comprehensive account of the area of enquiry in which he or she is interested if both quantitative and qualitative research are employed' (Bryman, 2006: 106). Furthermore, the combination of quantitative and qualitative methods makes the study more robust and provides a systemic perspective from which to understand the relevance that different stakeholders of the technology transfer system confer on universities. In the words of Creswell 'there is more insight to be gained from the combination of both qualitative and quantitative research than from either by itself; their combined use provides an expanded understanding of research problems' (2009: 203).

Mixed methods are implemented following a component design, which means that qualitative and quantitative methods are implemented as discrete aspects of the overall inquiry and remain distinct throughout the inquiry (Caracelli and Greene, 1997: 22). Combining the components of the different methods occurs during the interpretation and conclusion stages of research rather than during the data collection or analysis stages (Caracelli and Greene, 1997: 22). In practice, I selected the methods that would best help me answer each of the research questions separately. Thus, I chose to use qualitative methods to answer the first and second of my research questions, which sought to identify the factors influencing university-firm collaboration in Chile and used quantitative methods to answer the third question and assess the impact of these interactions on the innovation performance of firms.

3.3 Qualitative component

The qualitative component of this dissertation examines the factors influencing the dynamics of university-firm collaboration in Chile through case study methods. Following the analytical framework discussed in Chapter 2 (see Literature Review), it examines the dynamics of collaboration and technology transfer between academics and universities and firms by focusing on one side of the interaction at a time.

Three reasons justify the use of a case study rather than other qualitative research methods: (i) the analysis is holistic rather than based on isolated factors (Descombe, 2003:38); (ii) it is a useful design for research on organisations and institutions

(Hakim, 1987:69); and (iii) it allows the combination of more than one method, resulting in more compelling and robust research (Yin, 2003). In comparison, other methods present different characteristics that limit their usefulness in this study. For instance, an experiment deliberately divorces a phenomenon from its context, so that the focus is only on a few variables (Yin, 2009:13), while history deals with the relationship between phenomenon and context, but usually with non-contemporary events (Yin, 2009:13), and surveys try to deal with phenomenon and context, but their ability to analyse the context is very limited.

In the first of two empirical chapters based on the qualitative component of this dissertation, Chapter 5 focuses on the analysis of the supply side of university-firm collaboration and is based on a descriptive and explanatory analysis of the engineering schools of the three most relevant (in terms of knowledge production) universities in Chile. The selection of this purposive sample allowed me to examine the universities that are in the best position to undertake technology transfer and research collaboration activities with firms under the same general context (national innovation system), while considering their organisational and institutional differences. Chapter 6 focuses on the analysis of the demand side of the university-firm collaboration and is based on an exploratory analysis of the factors explaining the reduced interest of Chilean firms in engaging in collaborative innovation activities with universities.

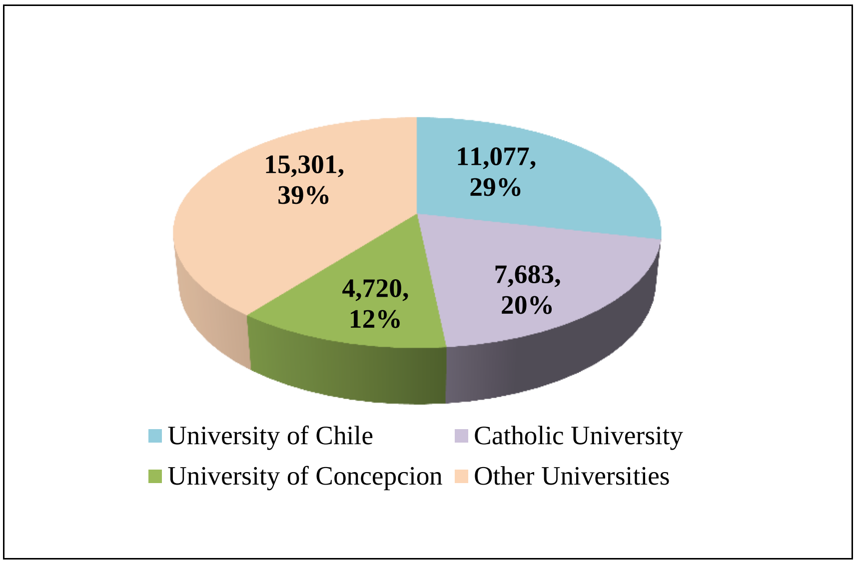
3.3.1 Selection of universities

In selecting the three universities for this study I used a purposive sampling technique to find the largest universities that generate most of the innovations in order to understand the dynamics at work in the few, but potentially most impactful institutions.[19] I chose three similar universities, which shared common particular variables other than the explanatory ones and/or the outcomes (Gerring, 2007: 90), on the basis of three conditions: relevance in terms of knowledge production as measured by publications and patents; comparability among the cases (regarding fields of knowledge production); and comparability regarding institutional development of their technology transfer organisations.

The three universities—University of Chile (*Universidad de Chile*, UCHILE), the Catholic University of Chile (*Pontificia Universidad Católica de Chile*, PUC), and the University of Concepción (*Universidad de Concepción*, UDEC) —were selected on the basis of their academic publications and patents applications. Figure 2 shows the share of the country's total knowledge output enjoyed by the three universities as indicated by the number of academic publications; the figure shows that the selected universities represent around half of the knowledge production of all universities during the period 2000–2010.[20]

[19] Purposive sampling techniques are primarily used in qualitative studies and may be defined as selecting units (e.g., individuals, groups of individuals, institutions) based on specific purposes associated with answering a research study's questions (Teddlie and Yu, 2007: 77).
[20] In 2010 there were 61 universities in Chile (MINEDUC, 2015).

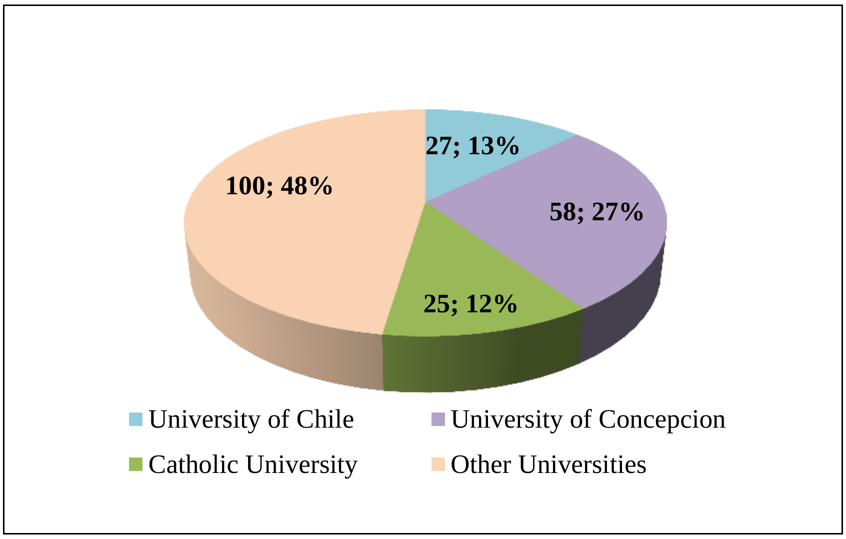
Figure 2: Number of Publications Web of Science (ISI), 2000–2010 selected universities (number, percentage)



Note: Documents considered: articles, letters, editorials, revisions, discussion papers, notes, and proceeding papers.
Source: Own elaboration using data from (CONICYT, 2012a).

Figure 3 shows the number of university patent applications made by universities in Chile between 2000 and 2008; more than half of them came from the three selected universities.

Figure 3: Number of Patents Application in Chile, selected universities, 2000–2008 (number, percentage)



Source: Own elaboration using data from INAPI (2012).

The universities selected differ in two aspects that I believe may be relevant for this research: their geographical location, and their ownership structure. Two of the universities, UCHILE and PUC, are located in the capital of Chile, Santiago de Chile, while UDEC is located in the country's third largest city, Concepción. This city is located 496 km southern Santiago and is the capital of the Bío-Bío region (*región del Bío-Bío*).[21] The region benefits from abundant natural resources and, one of its strengths are the existing and emerging clusters in these sectors, notably forestry and fisheries (OECD and The World Bank, 2010). Furthermore, the Bío-Bío region has been a pioneer in incorporating the concern for innovation capacity and performance into its overall regional economic development efforts (OECD, 2015e: 86; OECD and The World Bank, 2010).

All three universities belong to the group of 25 autonomous universities coordinated by the Council of Chancellors of Chilean Universities (*Consejo de Rectores de Universidades Chilenas*), the so-called group of 'traditional' universities (MINEDUC, 2005) founded before the 1980s. However, UCHILE is a public university created by the State while PUC and UDEC are private universities that receive partial funding from the State (MINEDUC, 2005).

Engineering schools

After choosing the universities to include in the study, I decided to limit my research to the engineering schools of each university in order to facilitate comparability across the different settings. The results of the seventh innovation survey, which measured the innovation efforts of firms during the 2009–2010

[21] Please refer to the Appendices for a map of Chile.

period, showed that the sectors with the highest innovation rates were electricity (40%), mining (35.7%), and manufacturing (30.9%) (MINECON, 2012b). These results suggested that engineering schools would be most likely to collaborate with industry. The reasons are two-fold. First, because the empirical literature has found that technology transfer activities are heavily influenced by the scientific field of knowledge (Bercovitz et al., 2001; Feldman and Desrochers, 2003; Owen-Smith and Powell, 2001; Shane, 2001) and engineering has been found to be quite likely to work with industry (Thursby and Kemp, 2002). Moreover, the engineering schools of these universities have developed specific institutions to support effective interaction with firms and have been able to facilitate the commercialization of services such as consultancy and research contracts. This reflects a higher organisational development in technology transfer activities in these engineering schools than in many other departments. Consequently, by focusing on the engineering departments of these universities, I was well-placed to cover a broad range of technology transfer mechanisms as well as to observe the interactions within universities between those local and central units managing university-firm linkages.

3.3.2 Data collection and analysis

My research was divided into three stages: two periods of fieldwork separated by time spent elaborating the quantitative analysis. I carried out my first fieldwork between November 2010 and February 2011,[22] dividing my time between Santiago de Chile and Concepción. The second period of fieldwork was carried out between

[22] A preliminary set of interviews was carried between December 2009 and January 2010.

January 2013 and June 2014, when I spent six weeks in Santiago collecting qualitative data for the second part of the qualitative analysis presented in Chapter 6. The time between these two visits to the field was devoted to analysing the data and conducting the quantitative part of the dissertation. This iterative strategy for collecting data was employed to complement the strengths and reduce the limitations that qualitative and quantitative methods have in analysing university-firm linkages and technology transfer between universities and firms.

In total, I conducted 51 semi-structured interviews with university and public programme managers involved in technology transfer activities, directors of technology transfer units, researchers, senior civil servants from the government agencies working on innovation policy issues, representatives from different industrial sectors, and senior professionals from firms. All but three of the interviews were conducted in face-to-face meetings. The other three were conducted by telephone. The interviews lasted sixty minutes on average and each was recorded then transcribed into Word documents.

3.3.3 Participants and participant recruitment

To create the list of potential interviewees, I followed three different strategies according to the role of the interviewee in research collaboration and technology transfer related activities. This was done with the aim of obtaining a purposive sample of academics, personnel from university technology transfer offices, senior civil servants working on innovation policy, and industry representatives.

In the case of academics—the main contributors to knowledge creation in universities—I built a dataset of researchers working in the selected universities who had experience in technology transfer and collaborative activities with firms. I defined as academics with 'experience' those who had been granted national patents and those who had worked as directors of co-directors of projects from the National Fund for Scientific and Technological Development (*Fondo Nacional de Desarrollo Científico y Tecnológico*, FONDEF), which at the time of the sampling (year 2010) was the largest fund supporting R&D university-firm collaboration grants.[23] Although this definition did not identify all academics or mechanisms involved in technology transfer and collaboration activities, it allowed me to obtain an initial list of potential sources of information. During the interviews additional researchers with a similar sampling profile were identified following a snowball method. Potential interviewees were invited to participate in the study until saturation was reached.

To identify the personnel of TTOs in the universities, I obtained the name of the directors and main managers of these organisations by visiting the universities' websites. This allowed me to initiate contact with the interviewees and additional potential interviewees were then identified through snowball methods.

To identify senior civil servants working on innovation policy, I used my previous experience of working as a civil servant in this area in Chile. Thus, I already knew some of the key informants to interview and additional interviewees were identified through snowball methods until reaching saturation.

[23] Please refer to Chapter 4 for a description of Chile's NSI.

To identify representatives from industrial sectors, I used the information available on their institutional websites. Other key informants from private research funds and firms were identified through former colleagues working on innovation policy.

3.3.4 Data Analysis

Two main strategies were employed to analyse the data for the case study: *relying on theoretical propositions* and *developing a case description*. The first strategy implies that one must follow the theoretical propositions that led to the case study, while the second aims to identify the causal links of analysis (Yin, 2009). Further, following Yin (2009), I chose two specific analytic techniques: *pattern matching* and *explanation building*. According to Yin (2009) pattern matching is one of the most desirable analysis strategies and consists of comparing an empirically based pattern with a predicted one (propositions from the theory). If the patterns coincide, the internal validity of the case improves.[24] *Explanation building* is a special type of pattern matching strategy relevant to explanatory case studies (Yin, 2009). The aim of this technique is to examine the evidence of the case study, then to evaluate the theoretical propositions following once again with the examination from a different perspective, as an iterative mode (Yin, 2009).

To analyse the data collected from the interviews and the complementary secondary data, I drew on two main analytic techniques: *thematic analysis* and *descriptive statistics*. While descriptive statistics were used to analyse the quantitative data,

[24] In order to identify the patterns of the cases, I used Maylor and Blackmon (2005) two-stage process: first, within case examination, and second, paired-case analysis of the cases. Paired-case analysis is the process of simultaneous analysis of the cases in study. In order to conduct the comparison, several categories are chosen and then the fitness with the cases is evaluated.

thematic analysis was used to analyse the interviews. Thematic analysis is a categorization technique that refers to the process of identifying themes in the data that capture meaning that is relevant to the research question and that, through making links between these themes, may contribute to the identification of patterns in the data (Willig, 2014). These analytical techniques allowed me to explore the factors influencing the dynamics university-firm linkages in a complementary way.

3.3.5 Interviews and their purpose

The qualitative part of this case study draws on semi-structured interviews as the main source of primary data. Interviews are one of the most powerful ways we have of understanding others (Punch, 2005: 168) and provide a highly efficient way to gather rich, empirical data, especially when the phenomenon of interest is highly episodic and infrequent (Eisenhardt and Graebner, 2007: 28). Interviews are also a useful way of accessing people's perceptions, meanings, definitions of situation, and constructions of reality (Punch, 2005: 168).

The interviews aimed to gather information about three main themes: experiences regarding collaboration with firms/universities and technology transfer; the effects of innovation public policy; and the organisational dynamics and capacities related to technology transfer and inter-organisational collaboration. However, the interviews were customised according to the type of respondent and developed in response to the interviewee's answers:

- The interviews with the TTO managers included questions about their experience in the field, their professional background and how they got to manage the offices. After building rapport, I went on to ask them about the historical development of the technology transfer unit and their relationship with both the department and central administration of the university. I also enquired about the daily activities of the TTO and its interactions with other units in the engineering faculty and the university, and about the technology transfer process and its development, organisation, governance, regulations, and structure.

- The interviews with academics asked questions about their personal experiences involving collaboration with firms. I investigated their experience in collaborative projects and their motivation for participating, including how the projects originated and who initiated the relationship. I also asked about the outcomes of the projects and whether technology transfer was achieved or not, and their explanation for the outcomes of the collaboration, among others. I also included questions about the effectiveness of their organisations regarding collaboration, and the struggles and opportunities they believed they faced in their daily activities related to collaboration with firms.

In the interviews I conducted with both academics and university managers, I asked questions about particular projects carried out in collaboration with firms, their outcomes, the management of the projects, and commercialization process and outcomes, and the role of TTOs in this regard.

- The interviews with industry representatives and key informants from firms aimed to investigate both the role that universities perform as research partners in technology transfer of different types and level of innovation, and the type of linkages between universities and firms performing these activities. I asked questions regarding their experiences of working with universities as research collaboration partners, how the linkages originated, the characteristics of the linkages, the people involved, duration, outcomes and sustainability, the type of innovations, and who they collaborated with.

- The interviews with policy managers mainly sought to obtain information about the historical development of the Chilean innovation system. Among other issues, the interviews covered topics such as the reasoning behind the creation of public programmes and perception of the role of universities and firm in the innovation system.

The information gathered from the interviews was complemented with secondary data analysis of documents and statistics from material supplied by local organisations such as the Ministry of Economy and the National Council of Innovation for Competitiveness (*Consejo Nacional de Innovación para la Competitividad*, CNIC), from reports and studies from universities and other non-governmental institutions, and from information collected from international organisations such as the World Bank and the Organisation for Economic Co-operation and Development (OECD).

The challenges of interviews as a source of data

Throughout the different stages of work, I was mindful of the challenges presented by interviews as a research method and careful to take these into consideration. Among those challenges was the issue of data management and reduction driven by the fact that interviews produce a large amount of data (Willig, 2014). There was also the risk of forcing data to fit a preconceived hypothesis, although an awareness of those preconceptions can help the researcher become sensitive to how prior understanding informs analysis (Willig, 2014). Interviewers can also encounter issues with impression management, by which interviewees try to put forward their best self during interviews (Alvesson, 2003). Furthermore, a significant issue in using interview data is that any analysis will be a partial representation of the data set (Willig, 2014) since the data may always be subject to analysis from a different theoretical perspective, or to a focus on different aspects (Willig, 2014: 308). To reduce the potential for bias in the interview data, I used—as recommended by the work of Eisenhardt and Graebner (2007: 28)—a large number of highly knowledgeable informants who could provide different perspectives of the local phenomenon.

Three further challenges also particularly affected my interviews. The first challenge was to gain my interviewees' trust. To do this, I allowed participants, particularly the academics, to interview me before I interviewed them. This usually involved more than the usual rapport building at the beginning of the interview and entailed a detailed description of my professional and academic experience. This method of gaining trust also helped me overcome the second challenge—the balance of power in interviews. In particular, I felt that there was an imbalance of power between myself, as a doctoral student, and the senior academic researchers I was interviewing. Only after these academics had assessed whether I was 'worthy' of an interview, did they allow me to formally begin the interviews. The third challenge that I had to be aware of, during both the collection and analysis of data, was that participants may have been *politically motivated* (Alvesson, 2003) and that they may have wanted to promote their own agendas and messages through the interviews. This was a definite possibility in this particular research because university-firm collaboration is part of public policy in Chile and has received significant attention in recent years.

3.4 Quantitative component

The quantitative component of this dissertation (presented in the third empirical chapter of this dissertation, Chapter 7) carried out analysis using Tobit, probit, and random effects methods based on secondary quantitative data. I conducted the analysis on a purpose-built panel dataset prepared using three waves of the Survey of Technological Innovation (EIT) (*Encuesta de Innovación Tecnológica*) covering the innovation performance of Chilean firms for the period 2005–2010. This section discusses the main considerations when using data from this survey to answer the research questions, and describes the survey and methods I used when elaborating the panel dataset.

3.4.1 Using available survey data

My decision to use quantitative methods to answer the third of my research questions—on the impact of university-firm collaboration on the innovation performance of firms—was made for two reasons. Firstly, the nature of the question, which in this case demands quantifiable answers. Secondly, the ready availability of data, since data about the innovation activities of Chilean firms has been collected since the mid-nineties by mandate of the Ministry of Economy. By using data from an existing survey I was able to access data from a national sample, which I would not have had been able to gather by myself. According to Kiecolt and Nathann (1985), this is one of the benefits—which also include saving resources, in terms of funds, time and auxiliary staff, and circumventing data collection problems—of conducting analysis on existing survey data.

Using an existing dataset, however, has pitfalls that need to be considered when conducting research. For example, it is important not only to gain access to the database but also to all its related documentation in order to understand what the dataset is measuring and how it was compiled (Kiecolt and Nathann, 1985). Researchers also need to assess the quality of the data and to consider potential measurement errors that could invalidate the data, whilst understanding that an already available survey may not include all the information required to answer the research question (Kiecolt and Nathann, 1985). At the design stage of this research, I assessed the benefits and limitations of the EIT as a source of information, considering not only the issues mentioned above but also, what Punch (2005) identifies as issues of reliability (related to the consistency of data) and validity (related to ensuring that the EIT measured what I believed it should measure in order to answer the research question).

Although the EIT was not designed to answer the particular questions of this dissertation, the type of variables measured and the overall design of the survey make it similar to the Community Innovation Survey (CIS) carried out by members of the European Union (EUROSTAT, 2016), which has already been used as a dataset for research into the innovation performance of firms, including issues related to university-firm collaboration and innovation firm performance.[25] The fact

[25] For research using the CIS see, for instance, Belderbos et al. (2015), Bodas Freitas et al. (2013), and Faems et al. (2005)

that a similar survey had been used to answer questions closely related to my own made me choose the EIT as the best source of data for the quantitative component of my research.

3.4.2 Survey of Technological Innovation

The EIT is conducted by the National Institute of Statistics (INE) at the request of the Ministry of Economy and measures the innovation efforts of Chilean firms.[26] Its objective is ‘to collect quantitative and qualitative information about the innovation and research and development efforts of the firms according to the OECD recommendations from the Oslo and Frascati Manual’(Zeller, 2002: 4). The EIT was first conducted in 1995 and is carried out every three years, collecting data from the previous two years.

3.4.3 Sector coverage and population of the survey

The first and second versions of the EIT, which measured the innovation efforts of firms for the periods 1994–1995 and 1997–1998, only considered the manufacturing sector. The inclusion of additional sectors was incremental; the mining sector and the electrical generation and distribution sectors were added in the third version of the survey (2000–2001) and in 2005—in the course of the fourth EIT—more sectors were incorporated in the sample in order to obtain better

[26] Under Chilean law, it is mandatory to respond to the surveys carried out by the National Institute of Statistics (Article 20 Law N° 17.374, 15 October 1970, BCN, 1970)

representative information about most of the sectors of the economy (Varela and Contreras, 2008).

The population of the survey are firms that made a tax declaration in the first year covered by the survey and that account for sales over 2,400 Unidades de Fomento (UF), which was equivalent to around £71,762 according to the exchange rate of December 2012.[27]

Each cross-section sample of the EIT is representative of the population for each wave of the survey (INE, 2009c; 2012; SCL Econometrics, 2008). The sampling design also includes an additional 30% of firms to compensate for units discounted in the survey (in the case of bankruptcy, for example) (INE, 2012). The EIT is a mix of survey and census. This is because the sampling strategy of the survey considers a census of the Mining, Generation and, Distribution of Electric Energy, and Gas and Water sectors; and a representative sampling of the Manufacturing industry and the other sectors.

In the fifth survey (2005–2006) there was mandatory inclusion of firms with high innovative activities (identified by the CNIC's Secretariat) and the sample included information about firms that had declared that they performed R&D activities in the National Survey of Private R&D Expenditure in Chile carried out in the year 2002 (SCL Econometrics, 2008). The mandatory inclusion of this type of firms was not considered in the following versions of the survey (2007–2008 and 2009–2010), but the sample size was increased by including sectors not considered in the fifth version.

[27] The UF is an inflation-indexed accounting unit used in Chile. Values converted using http://coinmill.com/CLF_calculator.html#CLF=2400

3.4.4 Access to the survey and construction of the panel

I decided to request access to cross sections of the survey in order to build a panel dataset that would allow me to examine firms' long-term innovation performance. *Panel* or *longitudinal* data is a type of pooled cross-sectional time-series data that contains measurement on the same individual over several periods (Baum, 2006: 46). In panel data each individual's observations are identified and this allows the generation of micro-level measurements not present in the original data (Baum, 2006). The use of a panel dataset allows, firstly, for a detailed examination of the dynamic effects of collaboration and, secondly, to control for the unobserved heterogeneity of firms.[28]

The cross section versions of the surveys covering the period 2004–2012 are publicly available for download on the website of the Ministry of Economy.[29] The information in each dataset is categorised by firm. The sector to which each firm belongs is identified by division (two-digit) of the *International Standard Industrial* Classification *of All Economic Activities*, Rev.3. to ensure the anonymity of the information (INE, 2010). The dataset that I built to carry out the quantitative analysis is an unbalanced panel based on the fifth, sixth and seventh versions of the survey, covering the innovation efforts of firms during the 2005–2010 period.

In order to build the panel I had to negotiate access to purpose-built versions of cross sections of the survey that would allow me to merge the datasets using a common identification number by firm. I arranged this by emailing the Division of Innovation of the Ministry of Economy before meeting with its Director to discuss

[28] The econometrics issues to be considered when using panel data and Tobit methods are discussed in Chapter 7.
[29] www.minecon.cl

the data requirements, the purpose of the dissertation, and the feasibility of my request. After several follow-up interactions with professionals at the Division of Innovation, in early 2012 I received the datasets of the fifth, sixth, and seventh surveys of the EIT coded for panel data purposes. This allowed me to build a panel based on these three cross sections of the survey. Table 2 presents the sectors covered in the three waves of the survey.

Table 2: Sectors included in the EIT during the periods covered in the panel dataset

Sectors covered/Survey	Fifth	Sixth	Seventh
Years	2005-2006	2007-2008	2009-2010
Sectors covered:			
A: Agriculture, hunting and forestry	✓	✓	✓
B: Fishing	✓	✓	✓
C: Mining and quarrying	✓	✓	✓
D: Manufacturing	✓	✓	✓
E: Electricity, gas and water supply	✓	✓	✓
F: Construction	✓	✓	✓
H: Hotels and restaurants	n.a	✓	✓
G:Wholesale and retail; other	n.a	✓	✓
I: Transport, storage and communications	✓	✓	✓
J: Financial intermediation,	✓	✓	✓
K: Real estate, renting and business activities	n.a	✓	✓
K72: Computer and related activities K73: Research and development	✓	n.a	n.a
N: Health and social work	✓	✓	✓
O: Other community, social and personal service activities	n.a	✓	✓
O90: Sewage and refuse disposal, sanitation and similar activities O92: Recreational, cultural and sporting activities	✓		
Number of observations	3,545*	4,269*	3,653

n.a: sector not available.
*Sampling includes subsidiaries.

3.4.5 Database description

The novel panel dataset of innovative firms in Chile that is used in this thesis is built based on three waves of the EIT covering the innovation efforts of firms during the 2005–2010 period (fifth, sixth, and seventh surveys).

The survey provides information about the innovative activities of the firms only for those firms that declared they introduced innovations (product, process, or managerial innovation). In this dataset, however, I only consider as innovative, those firms carrying out technological innovations. This means firms that have conducted product (including innovation in services) or process innovations according to the definition used by OECD (Table 3).[30]

Table 3: Distribution of firms by type and year

Type of firms	2007	2009	2011	Total
Non-innovative	2,125	3,146	2,594	7,865
% Non-innovative	68%	74%	73%	72%
Innovative	1,002	1,104	960	3,066
% Innovative	32%	26%	27%	28%
Total	**3,127**	**4,250**	**3,554**	**10,931**

After standardising and merging the data across the surveys, the dataset was cleaned of missing observations, extreme outliers, and inconsistencies. The resulting unbalanced panel considers 10,931 observations (see Table 3), of which 3,066 declared to have introduced innovations (28% of the full sample). Table 4 shows the distribution of firms across the panel. From this table it is possible to observe that

[30] *Technological innovations* comprise new products and processes and significant technological changes of products and processes. A *product* innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. A *process* innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software (OECD, 2005a)

the panel considers 2,536 firms, of which only 79 firms are in the three waves of the survey (3.12% of the total of observations). This means the panel is highly unbalanced. A reason explaining this is that the survey is not designed to be a panel and the sampling of the firms to be surveyed is independent in each wave of the survey.

Table 4: Distribution of Innovative Firms in the Panel

Freq.	Percent	Cum.	Pattern
745	29.38	29.38	.1.
734	28.94	58.32	1..
606	23.9	82.22	..1
183	7.22	89.43	.11
97	3.82	93.26	11.
92	3.63	96.88	1.1
79	3.12	100	111
2,536	100	XXX	

Note: *Pattern* presents the period of the panel for which there is information of the firms. For instance, the pattern '111' indicates that 79 firms have observations for the three periods of the panel.

3.4.6 Information used to build the panel

I built the panel using the questions from the survey containing the information related to the innovation activities of the firms, their collaboration activities, and additional variables that were identified after analysing the literature and defining the model of estimation. Table 5 presents the questions I included in the panel as well as the criteria used to merge the data across the different versions of the survey.

Table 5: Information from the surveys used to build the panel

		Questions of the surveys used to build the variables		
Name of variables included in the panel	**Definition**	**5th Survey**	**6th Survey**	**7th Survey**
Innovative sales (input to build the ratio of innovative sales)	Average of annual innovative sales in constant prices of December 2010 using the GDP deflator from the Central Bank of Chile	Question 4.1 Indicate the amount of turnover and exports of innovated products and services by the establishment during 2005 and/or 2006? 4.1.1 Turnover of products and/or innovated services	Section III. Innovation in the firm. Importance of the innovations in product and services (innovations new-to-the-market and innovations new-to-the-firm) (Indicate % of total turnover years 2007 and 2008)	Question 3.4 Indicate the % of total turnover from product and services innovations (new-to-the-market and new-to-the-firm), 2009 and 2010.
Total sales (input to build the ratio of innovative sales)	Average of annual sales in constant prices of December 2010 using the GDP deflator from the Central Bank of Chile	Question 1.1 Turnovers. Indicate the amount of turnover of the establishment in thousand of pesos of each year (2005 and 2006)	Question II.1 Indicate the amount of turnover (net value), in thousand of pesos of each year (2007 and 2008)	Question II Turnover. Indicate the net amount of turnover (national and exports) in thousand of pesos of each year.
Innovative firm	Dummy equal to 1 if firm performed any type of innovation (product, process, organisational, and marketing innovations)	Question II.1 Types of Innovation During the years 2005 and/or 2006, your establishment (Yes/No): 1.1 Innovations of product 1.1.2 Innovations new-to-the-firm but available in the market 1.1.3 Innovations new to the national market 1.2 Innovations of services 1.2.2 Innovations new-to-the-firm but available in the market 1.2.3 Innovations new to the national market 1.3 Innovations of process 1.3.2 Innovations new-to-the-firm but available in the market 1.3.3 Innovations new to the national market 1.4 Innovation of marketing 1.5 Organisational management innovations	Question III.1 Types of innovation. During the years 2007 and 2008 the firms introduced (Yes/No): Product innovation (products and services innovation) (new-to-the-firm and new-to-the-market) Process innovation (new-to-the-firm and new-to-the-market) Organisational and managerial innovation	Question III. Product Innovation (goods and services) (new-to-the-firm and new-to-the-market) (Yes/No) Question IV. Process Innovation (new-to-the-firm and new-to-the-market) (Yes/No) Question VI. Organisational Innovation (Yes/No) Question VII. Marketing Innovation (Yes/No)

Collaboration and the collaboration by type of partner variables.	Dummy equal to 1 if the firm collaborated with any of type of the organisations listed.	Question 3.2 During 2005 and/or 2006 did the subsidiary conduct cooperative actions with other firms or institutions in any of the innovative activities carried out? (Yes/No) Question 3.3 Indicate the type of collaboration and its origin (Yes/No)(Chile/Abroad) 3.3.1. Other firms and/or establishments from your group 3.3.2. Suppliers of equipment, materials, or software. 3.3.3. Clients or customers 3.3.4. Competitors or other firms from the sector 3.3.5. Consultants, laboratories, or private R&D institutes 3.3.6. Universities or other higher education institutions 3.3.7. Public R&D institutes	Same as in the the fifth survey	Question 9.2 During 2009 and/or 2010 did the firm conduct cooperative actions with other firms or institutions in any of the innovative activities carried out? (unique answer) (Yes/No) A cooperative innovation is the active participation with other firms or non for profit institutes (universities, research institutes, others) in innovative activities. There is no need for both partners to obtain monetary benefits. It excludes hiring of work that does not include mutual cooperation. Question 9.3 Same as Question 3.3 5th survey.
R&D expenditures	Average of Total R&D expenditures (internal and external) in constant prices of December 2010 using the GDP deflator from the Central Bank of Chile	Question 10. Expenditure on R&D. The sum of totals from questions: Question 10.1: How much is the total R&D expenditure performed inside the establishment in the years 2005 and/or 2006? Question 10.2 How much is R&D sub-contracted in the 2005 and/or 2006 inside Chile? Question 10.3 How much is the R&D sub-contracted by the establishment to other entities abroad during 2005 and/or 2006?	Sum of: Question IV.1 Total Internal Expenditure in R&D by type of expenditure (current and capital) 2007 and 2008. Question IV.7. Expenditure in R&D sub-contracted in Chile by source of funding and type of institution (2007 and 2008) Question IV.8	Sum of: Question III.1 Internal Expenditure on R&D (current and capital) Question III.7 External Expenditure on R&D (National) Question III.8 External expenditure on R&D (Abroad).

			How much was the expenditure in R&D sub-contracted to other entities abroad by source of funding.	
Number of employees	Average of the two years covered in the surveys	Question 1.3 Direct Employment. Indicate the number of employees directly hired by the establishment (average per year)	The sum of Direct and Indirect Employment. Question II.1 Direct Employment: Indicate the number of employees hired by the firm (annual average) 2007 and 2008 Indirect Employment: Indicate the number of sub-contracted employees by the firm (annual average). 2007 and 2008 (Yes/No)	Question II. Total Employment. Indicate the Number of workers of the firm (average annual). Include dependent and independent workers.
R&D department	Dummy equal to 1 if firm declared it has an R&D unit.	Question 8.1: Your establishment has a unit, department or R&D laboratory? Yes/No	Question III.3 The firm has a formal unit, department, or R&D laboratory? Yes/No	Question 8.1: Your firm has a unit, department or R&D laboratory? Yes/No

Source: (INE, 2007; 2011a).

An important change occurred in the survey design of the seventh EIT, as it did not collect detailed information about the R&D activities of firms. These efforts were captured in a separate survey, the *Survey of Research and Development (R&D) in Firms*. The main consequence of the separation of the collection of data about innovation and R&D is that is that there is data about R&D activities only for the firms that were selected to participate in both surveys (seventh EIT and second Survey of R&D in Firms). Thus data is missing in the questions related to R&D as only 278 firms were surveyed in both surveys (7.6%). However, I was able to use the data from the questions related to R&D that are available in the second Survey of R&D to fill in the information gap about R&D in the EIT. In addition, by assuming that the firms that declared that they did not perform internal or external R&D in the seventh EIT declared zero R&D, I was able to reduce the percentage of missing data from 92.4% to 40% in the variable related to R&D expenditure. The questions related to R&D in the seventh EIT are as follows (see Table 6):

Table 6: Questions about R&D included in the seventh EIT

Question 8.1: The firm has a formal unit, department or R&D laboratory? (Yes/No)
Question 8.2: During the year 2009 and/or 2010 your firm performed any of the following activities? Research and Development inside the firm? (Yes/No) If your answer is yes: During the years 2009 and/or 2010 the R&D activities were performed? Continuously/Sporadically Research and Development outside the firm (Yes/No)

Source: (INE, 2009c).

3.4.7 Criteria used for collapsing data from the fifth and sixth surveys.

Until the fifth version of the survey, the unit of observation was the subsidiary and not the firm (INE, 2009b). In the sixth version of the EIT, the unit of analysis was changed and the information started to be collected at the firm level. However, in this version of the survey, some firms, especially in the manufacturing sector (INE, 2009b), were surveyed at the plant level. Since the seventh version of the EIT (covering the 2009–2010 period), the unit of observation has been the firm for the whole sample. Consequently, in order to build a firm-level panel comparable across the three waves of the EIT, I aggregated the information collected at subsidiary level in the fifth and sixth surveys to collapse the data to firm level.

In order to define the collapsing criteria that would fit the adequate management of the data (sum, average, minimum, maximum, and first non-missing value[31]), the variables were classified into three groups: numerical, discrete, and those that should not change across observations (numerical or discrete). I used the following three criteria to collapse the data from subsidiary to firm level according to the type of variable:

1. In the case of numerical variables (such as total sales and turnover from innovative sales) the values given by the subsidiaries from the same firm were added.
2. In the case of dummy variables (such as collaboration and types of innovation performed) the firm was classified as 1 if at least one subsidiary declared yes to the question.
3. For variables measuring general information about firms, such as sector and type of property, the criterion was to collapse the data keeping the information of the subsidiary with the highest level of sales.

After standardizing the names and units of measurement of the variables, collapsing the observations that were at the subsidiary level in the fifth and sixth EIT surveys, and adding the information about R&D from the second Survey of R&D in Firms to the observations of the seventh EIT, I was able to obtain a panel dataset of 2,536 firms and 10,931 observations for the three waves of the EIT covering the 2005–2010 period.

[31] These are the options of the Stata's collapsing command.

3.5 Methodological challenges

I faced two main methodological challenges in this research: (i) the definition of collaboration and cooperation in both the qualitative and quantitative parts of this research; and (ii) the type of innovations carried out in Chilean firms.

Definition of collaboration and cooperation

As discussed in the literature review, an important part of the literature about collaboration and cooperation for technology transfer in firms uses these terms interchangeably. However, these terms may involve different types of interactions and engagement between the agents, which, for example, may be differentiated by levels of intensity and formality. At the same time, there is an issue around what these concepts mean in the qualitative and the quantitative components of this dissertation, so that there is consistency in the analysis. In this regard, of particular importance is the fact that the EIT, following the guidelines of the Oslo Manual (INE, 2009b), considers that cooperation on innovation activities implies an active participation in innovation projects with other institutions. The Oslo Manual states that active participation exceeds external contracts of activities, access to external informal and/or acquisition of knowledge or technology (OECD, 2005b). This means that cooperation, as defined in the EIT, may not necessarily involve *only* R&D collaborative activities. Hence, the quantitative component of this research may include a significant portion of activities that are not classed as R&D collaboration—which is the type of collaboration that innovation policy has been actively trying to foster since the mid-2000s—and on which the qualitative component of this dissertation is focused.

Also it is relevant to consider that when a new product or service is purchased there is some technology transfer associated with it, but there is not transference of the technology embodied in it (Stewart, 1987). According to Stewart, there is actual technology transfer when there is transference of the technology embodied in the new product or processes, such as the case of the transference of intellectual property rights. In contrast, the purchase of equipment requiring specific training would be considered diffusion of use (Stewart, 1987).

At the same time, there may be university-firm collaboration for innovation activities that do not involve the active participation of firms but that involve knowledge and technology transfer between universities and firms, such as, consultancy services. In this sense, the literature shows that technology transfer may not be limited to projects requiring active participation from firms, as defined by the Oslo Manual. For instance, D'Este and Patel (2007) identify five broad categories of interaction: creation of new physical facilities, consultancy and contract research, joint research, training, and meetings and conferences. The EIT measures the innovative activities of firms. According to this survey, innovative activities include (MINECON, 2012a): internal and external R&D; machinery, equipment, and software acquisition; acquisition of external knowledge (patents, licences, know-how); innovation training; introduction of innovations to markets (including market research and advertisement); design (related to the form and aspect of products); and other activities (installation of new equipment and production).

Additionally, knowledge spillovers can also occur when firms use information in their innovation process which comes from freely available sources and involuntary spillovers from innovators (Veugelers and Cassiman, 1999).

Taken together, the type of activities covered in the survey suggest that cooperation in the survey may, on the one, hand overestimate R&D collaboration since it also measures other innovative activities, and on the other hand, not consider activities that do not require the active participation of firms but that nonetheless contribute to knowledge sharing.

Level of innovation in firms: 'new to the world' versus 'new-to-the-market'

Chile is a developing country and therefore one would expect that the main source of knowledge is the adoption of innovations developed abroad. This means that most of the innovations produced in the country are largely 'new-to-the-market' and not 'new to the world'. But the adoption of already available technologies may require additional investment in innovation in order to customize it to the local needs. Although this type of innovation does not necessarily involve R&D collaboration, universities may still play a role, especially considering the limited skilled human capital in the country. Indeed, R&D collaboration may be a very limited activity and therefore the effects of firms' collaboration with universities on innovation may instead be centred in activities focused on adapting and developing already available knowledge.

To sum up, the intrinsic characteristics of the mixed methods approach allows me to develop a comprehensive account of university-firm collaboration and technology transfer but, at the same time, it may not capture the exact same factors. In practice this has meant that throughout this analysis I have had to consider the limited role that R&D collaboration with universities may play as an innovation strategy for firms and that the university's role may be more oriented to supporting other innovative activities.

3.6 Conclusion

By linking quantitative and qualitative analysis, this dissertation aims to provide a broad and systematic comprehension of the technology transfer system in Chile focused on university-firm collaboration on innovation. In terms of broad analytical strategy, I seek to achieve this by analysing the demand and supply sides of university-firm innovation interactions. In terms of research methods, by combining methods I believe will strengthen the conclusions and also contribute to the triangulation of the results of the analysis. The quantitative analysis provides a demand-side perspective of innovation and cooperation in firms. The qualitative analysis focuses on the supply side of university-firm collaboration and technology transfer, and complements the quantitative analysis by studying firms and their inter-organisational linkages. Further, the qualitative analysis offsets the limitations—produced by both the lack of available data in the innovation surveys and the definition of cooperation used in this type of survey–of the quantitative section of the thesis.

Chapter 4: The background to Chile's NSI

4.1 Introduction

In the previous chapters I have reviewed the literature on university-firm collaboration and technology transfer, and described the analytical framework used in this DPhil thesis. In this chapter, I explore in more depth the features of Chile's economic structure, education system, and innovation policy that make the country an interesting place in which to study university-firm linkages.

Understanding the local settings helps get a better sense of the innovation system (Coriat and Weinstein, 2002). This is based on the belief that innovation capacity of countries and their specific national models of innovation are influenced by the basic components of their economic structure, such as the system of industrial relations and the characteristics of labour markets, the structure of the industrial system and the nature of the relations between industry and finance (Coriat and Weinstein, 2002: 280).

Following this introduction, I discuss Chile's economic structure, focusing on its productive structure from the return to democracy in 1990 to the fourth left-wing government coalition (*Concertación de partidos por la democracia*) in 2010. In section 3, I examine the main characteristics and dynamics of the educational system with particular emphasis on the higher education sector, which is central of central importance to this thesis because of its potential for interaction with firms. In section 4, I examine the development of the national innovation system, its performance, governance structure and the public policies put in place to support innovation. In sections 5 and 6, I examine the trends regarding university-firm collaboration in the country and discuss the limitations and constraints of the Chilean innovation system. I conclude the chapter by summarising the settings in which this DPhil research took place.

4.2 General economic features and institutional development

Chile is a small open economy, which has based its growth on the exploitation of natural resources. The country has a population of 17.8 million people, of which a 40.6% live in its capital, Santiago de Chile. Administratively, the country is divided into 15 regions, subdivided into 54 provinces and 346 councils (INE, 2014).[32]

Chile was ruled by a military regime between 1973 and 1989, but became a democracy in 1990. Between 1990 and 2010, the country was governed by four administrations from the left-wing coalition party. In 2010, President Piñera led the country's first right-wing government since the return to democracy and governed until 2014 when President Michelle Bachelet began a second four-year term.

In January 2010 Chile joined the select group of 'developed countries' in the Organisation for Economic Cooperation and Development (OECD). In the view of the OECD, 'Chile's acceptance for OECD membership marks international recognition of nearly two decades of democratic reform and sound economic

[32] A map of the country is presented in the Appendix of this thesis.

policies.'[33] Further, according to the latest data from the Global Competitiveness Index (GCI) elaborated by the World Economic Forum, Chile ranks 33 out of 144 economies in terms of overall competitiveness performance in the period 2014–2015. This means it is in the first quartile of the highest performing countries[34] and is considered the most competitive country in the Latin American region (WEF, 2014).[35]

4.2.1 Reasons explaining Chile's economic growth between 1990–2010

Since 1990, Chile has reported a significant improvement in terms of economic growth. Table 7 shows the average growth of the GDP divided into three periods of time: 1990–1998, 1999–2008 and 2009–2014. From the data it is possible to observe that there are two significant trends during the period: significant growth of 7.1% between 1990 and 1998 followed by average growth rates no higher than 4% from 1999 to 2014.

Table 7: GDP growth Chile

GDP growth Chile*	%
1990–1998	7.17
1999–2008	3.77
2009–2014	3.69

* Annual percentage growth rate of GDP at market prices based on constant local currency.
Source: Own elaboration based on data from World Development Indicators Database. Data retrieved on 4 August 2015.

[33] From OECD website. Visited on 13 August 2015. (http://www.oecd.org/chile/chilesignsupasfirstoecdmemberinsouthamerica.htm).
[34] The GCI is a framework developed by the World Economic Forum in 1979 to measure competitiveness (WEF, 2014). It defines competitiveness as the set of institutions, policies, and factors that determine the level of productivity of a country (WEF, 2014: 4).
[35] See Annex for a summary of Chile's indicators in the GCI 2014.

Chile's current performance is mainly explained by its strong institutional setup, which includes low levels of corruption, an efficient government, macroeconomic stability, low levels of both public deficit and public debt, and sound macroeconomic management (WEF, 2014). Also, according to the OECD, Chile's strong economic performance in 1987–2007 was made possible by its efforts at economic reform and institution building (OECD, 2007). In this sub-section I focus on three factors that have contributed to the current level of economic development and that are directly pertinent to this thesis: the reallocation of resources to natural-based sectors, economic reforms and institutional development, and the influx of foreign direct investment. I argue that these factors have contributed to create the conditions that today influence university-firm collaboration in Chile and which are analysed in the second part of this thesis.

Reallocation of resources and price of commodities

Despite the reduced growth experienced by the country since 1998, Chile was able to most than double its per capita income between 1990 and 2014 (see Table 8). Part of this growth can be explained by the significant increase in the price of copper (the main export of the country), which rose in price by 83% between 2005 and 2006, and by 46% between 2009 and 2010 (DIRECON, 2015).

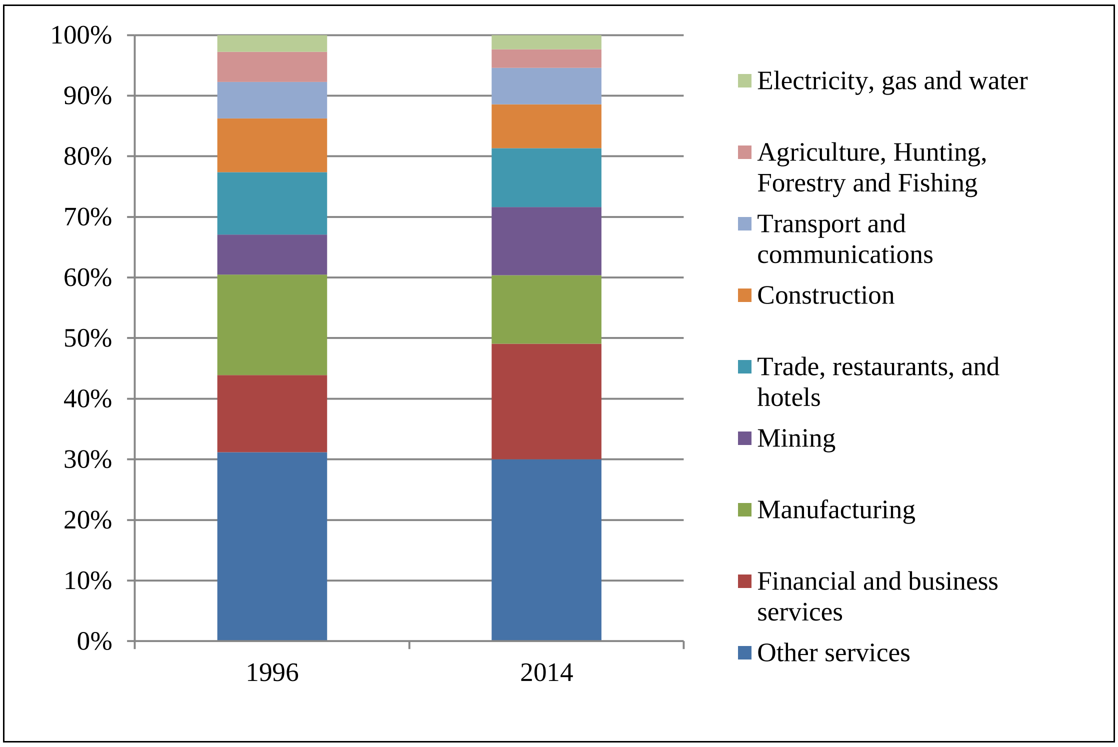
However, Chile's productive structure has also undergone significant changes in its composition since the 1990s. Figure 4 shows the distribution of the GDP by sector in 1996 and in 2014 and shows the relative importance that sectors such as financial and business services, as well as mining and other services, have gained during the period, while manufacturing and construction have reduced their importance in relative terms.

Table 8: GDP per capita Chile and selected countries, PPP (constant 2011 dollars)

Country\Year	1990	1995	2000	2005	2010	2014
Australia	28,604	30,359	35,253	38,840	41,330	43,219
Chile	9,193	12,759	14,614	16,985	19,204	21,967
Brazil	10,331	11,108	11,461	12,373	14,660	15,412
Peru	5,280	6,198	6,485	7,499	9,915	11,514
Turkey	10,670	11,530	13,025	15,176	16,674	18,884
Mexico	12,479	12,491	14,704	14,961	15,460	16,496
New Zealand	24,021	25,476	27,963	31,798	31,824	33,360

PPP: Purchasing power parity.
Source: Own elaboration based on data from World Development Indicators Database. Data retrieved on 4 August 2015.

Figure 4: GDP by productive sector 1996–2014



Source: Own elaboration based on data from Banco Central de Chile. Data retrieved on 3 June 2015.

Because Chile is a small economy, trade and exports are central to its economic development. The exports of this country are based on its comparative advantages in natural resources. Chile is the largest producer of copper in the world (OECD, 2012a) and in 2014, copper represented 50% of the country's exports (DIRECON, 2015). This strong dependency on one commodity has underscored the importance of productive diversification in order to ensure sustainable growth. Chile is also the second largest exporter of salmon in the world (OECD, 2015d). According to the CNIC, the significant growth in natural-resource-based sectors such as copper, fishing, aquaculture, wine, and other foods during 1985–1997 is partly explained by the export-led growth established in the country since the rise to power of the military regime (CNIC, 2010: 109).

Economic reforms and institutional development

The economics of the military regime were characterized by the implementation of 'neutral' policies (Ffrench-Davis, 2014: 193), implemented in the belief that markets such as the long-term capital, technological innovation, labour training, and entrepreneurial markets would automatically complete themselves upon liberalization (Ffrench-Davis, 2014: 146). Furthermore, the approach implemented during that period assumed that, in a privatized economy with inflation under control, the market efficiently controls factors such as employment, internal demand, and stability of the exchange rate (Ffrench-Davis, 2014: 462). The economic growth during the military government was on average 2.9% per year, and produced a significant increase in inequality in the country (Ffrench-Davis, 2014: 462).

Through the 1970s Chile's exports were largely centred on copper, which in 1970 accounted for 76% of total exports (see Table 9), the rest being primarily made up of raw materials and natural-based manufactures. However, the economic reforms implemented by the military regime during the 1970s and 1980s allowed the economy to diversify. By 1996 copper had reduced its share of total exports to 36%. This drop is considered to be an indicator of the success of the diversification of the economy (Meller and Simpasa, 2011: 17) as is the fact by 1970 Chile was exporting 200 different types of product, by 1990 this number had increased to 2,800 and over the last decade it has further increased by 5,000 (Ramos, 2008).

Table 9: Percentage of total exports by type of product (in current million dollars FOB)

Type of product/year	1970	1974	1986	1996	2006	2012	2014
1. Copper	76%	74%	42%	36%	56%	53%	50%
2. Non copper	24%	26%	58%	64%	44%	47%	51%

Source: Ramos (2008) and data from Comisión Chilena del Cobre (www.cochilco.cl. Website visited on 16 February 2016).
FOB: Free on board.

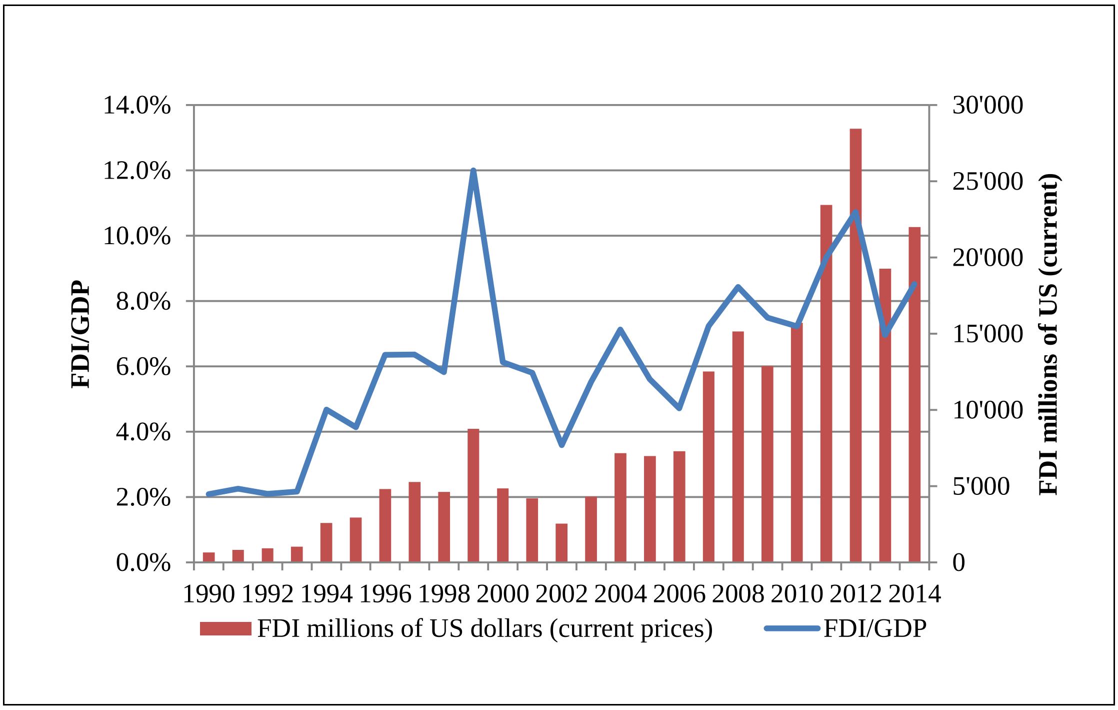
Some of the factors that have contributed to this diversification included: trade liberalization; strong exchange rate depreciation following the military coup of 1974; subsidies to specific sectors (especially forestry); the entrepreneurial activity of the state (through organisations such as *Fundación Chile*); state-sponsored accumulation of factors of production indispensable to the development of specific sectors (agricultural and forestry sciences); and the encouragement of foreign direct investment (FDI) in specific sectors where the country had undeveloped potential comparative advantage, for example, through the debt-equity swaps of the mid- to late-1980s that favoured investment in pulp and paper (Agosin and Bravo-Ortega, 2009: 4). The market reforms carried out by the military government induced the reconfiguration of Chile’s productive structure towards the comparative advantages in natural resources (Katz, 2008: 91).

With the return to democracy in 1990, the *Concertación* implemented several policy measures designed to improve/correct the model inherited from the military regime. These included policies aimed at increasing sustainable development and reducing inequality (Ffrench-Davis, 2014). The reforms continued in the 2000s and included private-sector involvement in infrastructure development, the introduction of competition in telecommunications, further trade reform through unilateral tariff reductions and a series of foreign trade agreements, anti-trust rules, monetary policy, abolition of the exchange rate band, adoption of a structural fiscal surplus of 1% of GDP, lifting of all capital controls, capital market reform, and the creation of competition tribunals (Ffrench-Davis, 2014). According to the OECD (2007), macroeconomic and structural reform and a prudent and predictable monetary and fiscal policy stance have contributed to Chile’s success in achieving sound macroeconomic fundamentals. Pertinent to this thesis is, however, the fact that after the return to democracy the market-oriented model has not only been maintained but also strengthened (OECD, 2007: 51).

Foreign Direct Investment

The third important driver of Chile’s economic growth has been the influx of FDI that followed the process of market liberalization and strengthening of institutions in the 1990s. In the view of Gallego and Loayza (2002), this influx, which has moved from 2% of GDP in 1990 to 8.5% in 2014 (Figure 5), partly explains the significant growth seen in 1990–98.

Figure 5: FDI influx Chile in millions of dollars (current) and as a percentage of the GDP

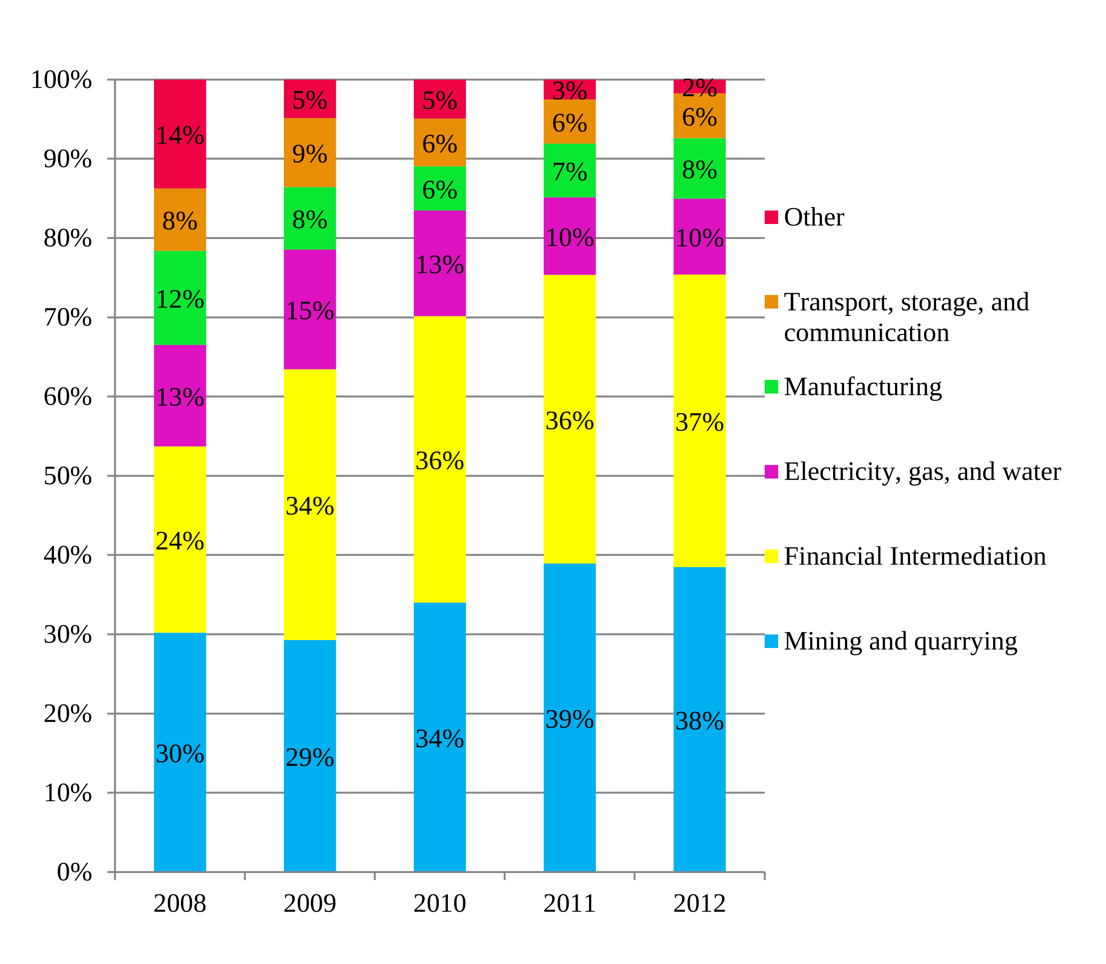


Source: Own elaboration based on World Development Indicators (World Bank), visited on 23 August 2015 and OECD.stat, visited on 20 August 2015.

Chile has one of the highest rates of FDI of all the Latin American countries. Figure 6 shows the distribution of FDI stock in Chile for 2008-2012 by economic sector. From the figures it is possible to observe that FDI is highly concentrated in two sectors: mining and quarrying, and financial intermediation. Together these sectors share 75% of the total of FDI as of 2012.

The influx of FDI in the country has helped increase the importance of multinational corporations (MNCs) and, as we will see in Chapter 6, the importance of MNCs has influenced innovation in Chilean firms and their collaboration and technology transfer strategies.

Figure 6: FDI position by industrial sector (at year end) 2008–2012



Source: Own elaboration based on (OECD, 2014b).

4.3 Education and national capacities for STI

Investment in social and human capital is one of the essential factors of the NSI approach. According to Soete et al. (2010: 1172), it would be possible to argue that social and human capital is 'the cement that holds the knowledge innovation system together'. Further, human capital is basically formed by education and training and renders its productive activities mainly through the labour market (Psacharopoulos, 2014: xv). This underlines the importance of providing background information on Chile's education system in general, in order to understand the education levels of the Chilean labour force, and on the tertiary education system and the universities' research capacity in particular, since this is central to this thesis.

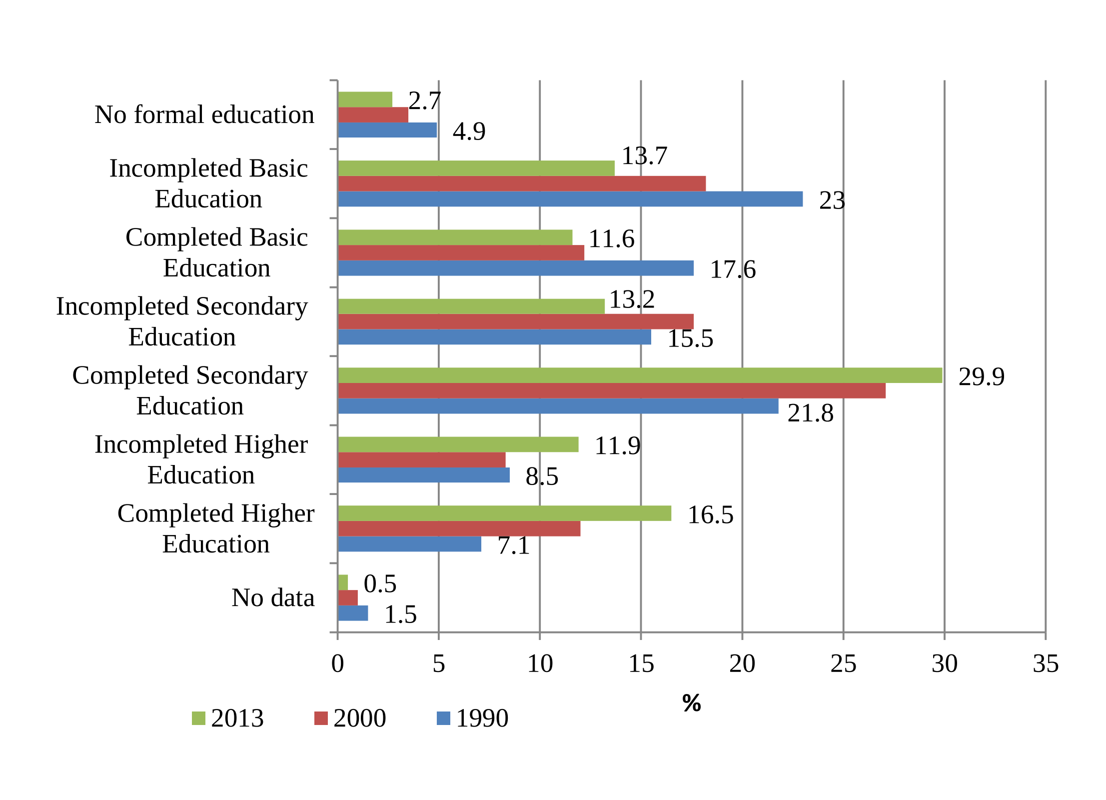
In the view of the OCED, education policy and human capital formation constitute major bottlenecks for productivity growth in Chile (OECD, 2011: 59). Although Chile country has made impressive progress in educational coverage and attainment, the quality of primary and secondary education still lags behind most other OECD countries (OECD, 2013). Also, attainment in upper secondary and tertiary, as well as enrolments in upper secondary vocational education and training (VET) are below the OECD average (OECD, 2015a).[36]

Coverage and attainment

The latest data from the National Socio-economic Survey (*Encuesta de Caracterización Socioeconómica Nacional-CASEN*) conducted by the Ministry of Social Development (*Ministerio de Desarrollo Social*) shows an increase in the achievement of secondary education, which went from 21.8% to 29.9% during 1990–2013 period (see Figure 7).[37] The data also shows that the percentage of the population that completed higher education has more than doubled, going from 7.1% to 16.5% in the same period. According to the OECD (2011), this performance in coverage and attainment is partly explained by an increase in the number of private schools.

[36] The average number of years in education of people aged 15 or older went from 9.0 in 1990 to 10.8 in 2013 (Ministerio de Desarrollo Social, 2015).
[37] The CASEN is a household survey conducted at national, regional, urban, and rural levels (Ministerio de Desarrollo Social, 2016).

Figure 7: Population (higher than 19 years), by formal education level attained



Source: Own elaboration based on Ministerio de Desarrollo Social (2015).

The quality of Chilean education, however, is still lagging behind (OECD, 2011), as can be seen from its performance in international evaluations. For instance, results from the Programme for International Student Assessment (PISA) show that Chile performed below the OECD average in 2012 (OECD, 2015a). Furthermore, a study conducted by the Microdata Center (*Centro de Microdatos*, University of Chile) conducted in 2013 on the basic competencies of Chilean adults found that 50% of the population did not understand what they read (Martínez et al., 2014).[38] These results are similar to those found in the first version of the study carried out in 1998 (Martínez et al., 2014).

[38] The Microdata Center is Chile´s most distinguished research and data collection centre on microeconomic issues such as unemployment, education, poverty and income distribution (UCHILE, 2016).

The higher education system: stylised facts

In the 1980s the reforms introduced by the military regime allowed the creation of new self-financed private universities. At the same time, between 1980 and 1990, public funding for higher education fell by 41% in real terms (OECD and The World Bank, 2009b: 32). The reforms also introduced a new and diversified system of finance for the eight pre-existing universities, which transferred a considerable part of the universities' costs to students and their families. The number of universities in Chile rose from eight in the early 1980s to sixty in 2012 (OECD, 2012b).

In 1980, total enrolment in higher education was 116,962 students, which was about 7.2% of the 18–24 age group (OECD and The World Bank, 2009b: 32), in 1990 enrolment reached 245,408 (MINEDUC, 2002), and in 2013 it reached 1,184,805. This represents a more than ten-fold increase in 33 (see Table 10). In this relatively short period Chilean tertiary education has moved from an elite to a mass system (OECD and The World Bank, 2009b: 36).

Table 10: Number of enrolled students in higher education

	1980	1990	2010	2013
Number of students	116,962	245,408	987,643	1,184,805

Source: Own elaboration based on (INE, 2011b; 2014; MINEDUC, 2002).

With regard to the quality of research in Chilean universities, which is central for this DPhil because it provides information about R&D capacity, Chile only has two universities—UCHILE and PUC—in the top 500 ranking prepared by the Academic Rank of World Universities in 2015; both Chilean universities ranked below 300. In

2003 the same ranking reported only one Chilean university—UCHILE—in the list. The highest-ranking university from the Latin-American region is the University of Sao Paulo (Brazil), which is ranked in the 101-200 range. [39]

One reason that explains the limited international performance of Chilean universities is a lack of the skills needed to conduct research activities. The availability of a highly skilled pool of human capital allows universities to provide high quality training to their students who then help form a better qualified labour force. Also, highly skilled academics allow universities to carry out better quality research and to produce knowledge that can then be transferred to the rest of the economy.

International evaluations have claimed that Chile's education at this level, specially at the doctoral level in science, technology, and engineering, is quantitatively and qualitative insufficient (OECD, 2007). Recent data from the CRUCH reports that the number of graduates from doctoral programmes went from 92 in 2001 to 390 in 2010 (CRUCH, 2010). In order to increase the amount of highly skilled human capital in the country, in 2009, the Government established a national scholarship programme (*Programa Becas Chile*) to increase the number of postgraduates in the country (OECD and The World Bank, 2011). This programme replaced the President of the Republic's Scholarship programme, which between 1981 and 2008 was the main source of postgraduate scholarships in the country. The introduction of Chile's scholarship programme elevated the number of scholarships from 330 in 2008 to 3,300 in 2010 (OECD and The World Bank, 2011). Data from the universities belonging to the CRUCH shows that the number of academics with

[39] Data retrieved from website of the Academic Rank of World Universities on 19 August 2015 (ARWU, 2015).

doctoral degrees in these universities has increased from 3,229 in 2003 to 5,919 in 2013, which represents an increase of 27% to 39% of the total academic personnel in the period (see Table 11). This increase should lead to the improvements in the quality of the Chilean universities.

Table 11: Number and percentage of academic personnel with doctoral degrees in the universities belonging to the CRUCH

	2003	2010	2013
Academic personnel with doctorates degrees	3,229	4,725	5,919
Total academic personnel	12,054	13,573	15,068
Percentage	27%	35%	39%

Note: Numbers presented in FTE.
Source: Own elaboration based on data from CRUCH (2010; 2013).

4.3.1 Human capacities for R&D

In spite of these efforts to improve the amount of human capital, which is so central to the performance of the innovation system, Chile continues to have a lower level of researchers devoted to R&D than other OECD countries. Data from 2013 shows that Chile has 0.72 researchers (in full time equivalent, FTE) per thousand labour force, while on average OECD countries reported having 7.29 researchers (FTE) per thousand of labour force (2012 data). This means that Chile has ten times fewer researchers than OECD countries (see Table 12); four times fewer in comparison to Turkey, which has a similar GDP per capita; and its limited human skilled capacities on R&D are also lower than in other Latin American countries such as Argentina and Mexico.

Table 12: Total researchers per thousand labour force

Country/Year	2007	2008	2009	2010	2011	2012	2013
Argentina	2.14	2.28	2.38	2.59	2.71	2.74	2.71
Australia	..	8.23	..	..	..	..	..
Chile	0.8	0.83	0.67	0.7	0.75	0.83	0.72
Mexico	0.81	0.8	0.89	0.76	0.78	..	..
New Zealand	6.49	..	7.04	..	6.97	..	7.54
Turkey	2.1	2.17	2.29	2.46	2.65	2.95	3.09
OECD - Total	6.69	6.83	6.97	7	7.19	7.29	..

Source: Main Science and Technology Indicators (OECD). Data retrieved on 17 August 2015.
.. : Data not available.

The distribution of researchers across the economy also provides information about the capacity that each sector has to carry out R&D activities. Table 13 shows the sectoral trends between 2009[40] and 2013 and shows that, during the period of analysis, more than 50% of the total number of researchers in the country was concentrated in the higher education sector. This is not surprising considering that universities are the main source of knowledge creation in Chile. Firms accounted for less than a third (from 21% in 2009 to 30% in 2012) of the total of researchers in the economy.

Table 13: R&D researchers in FTE

Sector/Year	2009	%	2010	%	2011	%	2012	%	2013	%
Government	269	6	292	5	337	6	404	6	438	7
Higher Education	3,007	62	3,274	60	3,295	54	3,561	52	3,271	55
Private non-profit	570	12	576	11	631	10	738	11	735	12
Firms	1,013	21	1,298	24	1,752	29	2,027	30	1,448	24
Astronomical Observatories	..	..	..	..	64	1	67	1	52	1
Total	4,859	100	5,440	100	6,078	100	6,798	100	5,944	100

Note: Data not available for astronomical observatories in 2009 and 2010.
Source: (MINECON, 2014d).
.. : Data not available.

[40] There is no data available from before 2009 for Chile on this indicator.

Looking at the total available R&D personnel, which includes researchers, technicians and other support staff, Chile's performance is also low in comparison with other countries. Chile has 2.46 (preliminary data for 2013) personnel per 1,000 labour force for R&D, the lowest of the OECD countries, which reported an average of 12.31 in 2012 on this indicator (MINECON, 2015b).

4.4 Innovation performance and the institutional development of the National Innovation System

Since the 2000s the Chilean innovation system has been in continuous development with a view to helping the country become a knowledge society. The main indicator for measuring the total R&D effort of countries is their gross domestic expenditure on R&D (GERD), which covers all expenditure for R&D performed on national territory in a given year (OECD, 2002: 22). Although Chile country has reported increased investment on R&D in recent years, its rates are not only considerable lower than the average expenditure of OECD countries, but also lower than that of countries with similar GDP per capita (see Table 14). This difference is even maintained when comparing with other Latin American countries of similar income per capita, such as Mexico and Brazil.

Table 14: GDP per capita and R&D/GDP selected countries, 2014 or latest year available

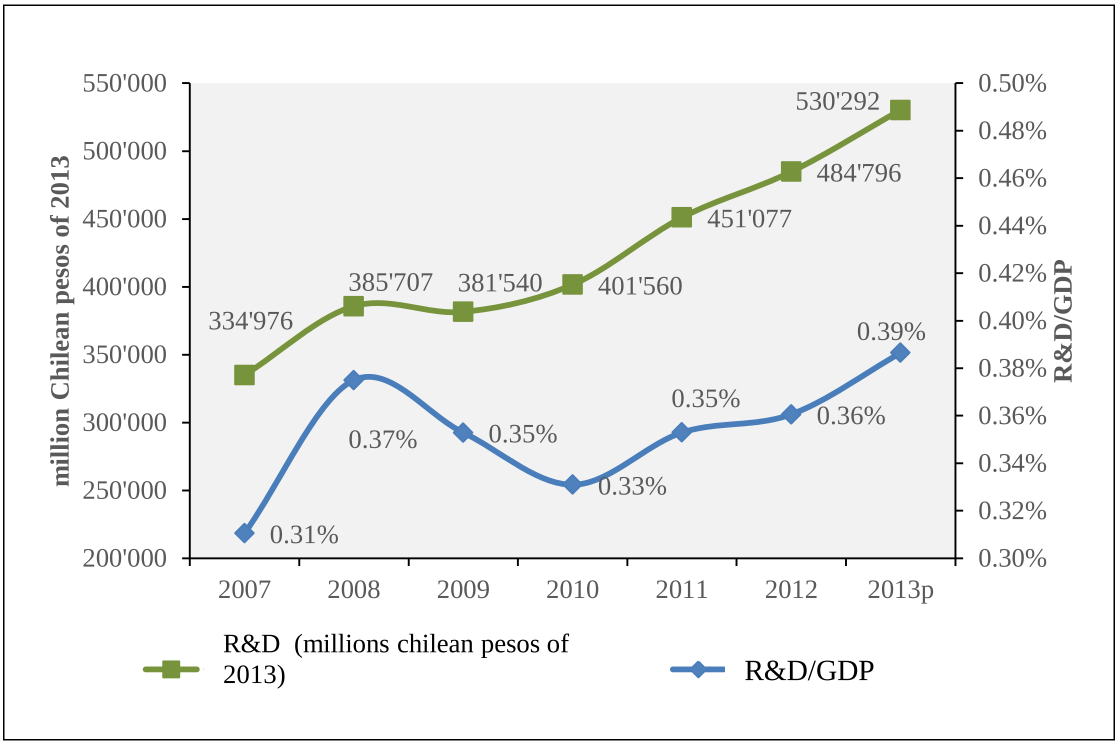
Countries	GDP per capita*	R&D/GDP**
Australia	43,219	2.99
Brazil	15,412	1.15
Mexico	16,496	0.54
Turkey	18,884	0.94
Chile	21,967	0.39
New Zealand	33,360	1.17
OECD countries	..	2.36

Notes: * Data for 2014. ** Data for 2014 Australia and Mexico (provisional), 2013 New Zealand, Turkey, Chile (estimated) and OECD countries, 2012 for Brazil, and 2011 other countries.
Source: World Development Indicators (Data retrieved on 4 August 2015), Main Science and Technology Indicators, OECD (Data retrieved on 4 August 2015) and MINECON (2015b).
.. Data not available.

According to the latest R&D indicators elaborated by the Ministry of Economy, in 2013 Chile invested 530,292 million Chilean pesos in R&D (approximately 1,071 million US dollars of that year), which represents 0.39% of GDP in that year (MINECON, 2015b).[41] Figure 8 shows the trend in the R&D expenditure of the country between the period 2007 and 2013[42] and reveals that national efforts in R&D have been growing in a sustained way since 2007. In real terms, the rate of growth of R&D expenditure during this period grew 59%. As a proportion of the GDP, however, the growth has been more moderate, reaching only 24%. This is because GDP has grown at a higher rate than national R&D expenditure.

[41] Using the average exchange rate from 2013 (495 Chilean pesos (CLP) to one US dollar) available from BCENTRAL (2016). Data retrieved on 11 June 2016. The indicators estimated by the Ministry of Economy are also submitted to international organizations such as the OECD to be included in international rankings.
[42] Because of changes in the methods used by the Chilean Government to estimate its R&D efforts, it is not possible to compare data from 2007 with data from previous years. Indeed, data from previous years is not publicly available from official government sources.

Figure 8: Gross National Expenditure on R&D in millions of Chilean pesos and as a percentage of the GDP, 2007-2013



Source: MINECON (2015b).

The public sector has played a significant role in supporting R&D funding 38% of the total of R&D carried out in the country in 2013 (see Table 15). During the same period, firms funded 34% and higher education organisations funded 11% of the total R&D carried out in the country. It is important to consider, however, that universities with the capacity to conduct R&D activities by and large belong to the CRUCH and receive public funding for their operations, which means their funding can be considered government expenditure on R&D. Overall, the data from Table 15 shows that the growth of R&D from 2007–13 has been largely due to a continuous increase in public funding (MINECON, 2012b). The Chilean government claims that its strategy is designed to follow the R&D funding strategies of today's developed countries, which have been widely credited with playing a significant role in the process of constructing knowledge economies

(MINECON, 2012b). The data also shows a significant reduction in the R&D funded by firms during the period 2009–2010 (see Table 15). This could the result of the effects of the global economic crisis of the period on investment by Chilean firms. The patterns in Chile's funding of R&D are contrary to those observed in the OECD overall, where the business sector provides the most funding for R&D in developed countries (OECD, 2010).

The composition of R&D by sector of expenditure during 2007–2013 is presented in Table 16. The data shows that the main sector in which R&D activities are carried out is higher education, which accounts for 39% of the total R&D in 2013. The second sector in importance in terms of performing R&D is firms. During the years analysed the percentage of R&D performed by firms has ranged from 35% in 2007 to 36% in 2013, with a peak of 40% of the total R&D in 2008. However, a comparison of the data from Table 15 and Table 16, taking into consideration that the main source of funding for university R&D is the government, it is possible to observe that the resources invested by firms in R&D are largely performed inside these organisations. For instance, in 2013 firms funded 34% of the total R&D and carried out 36% of the total R&D executed in the country.

Table 15: Chile's R&D by sector of funding, 2007– 2013, millions of Chilean pesos of 2013

Sector	2007	%	2008	%	2009	%	2010	%	2011	%	2012	%	2013	%
Firms	130,267	39%	168,662	44%	102,873	27%	102,166	25%	152,880	34%	169,415	35%	182,696	34%
Government	119,189	36%	130,221	34%	146,218	38%	162,063	40%	151,809	34%	174,334	36%	202,807	38%
Higher Education	62,461	19%	66,375	17%	53,276	14%	50,894	13%	43,235	10%	45,689	9%	58,117	11%
Private non-profit	9,063	3%	7,568	2%	6,493	2%	6,802	2%	7,228	2%	10,346	2%	6,368	1%
International Funds	13,996	4%	12,880	3%	72,679	19%	79,636	20%	95,925	21%	85,012	18%	80,303	15%
Total	334,976	100%	385,707	100%	381,540	100%	401,560	100%	451,077	100%	484,796	100%	530,292	100%

Source: Own elaboration based on MINECON (2015b).

Table 16: Chile's R&D by performing sector, 2007– 2013, millions of Chilean pesos of 2013

Sector/Year	2007	2008	2009	2010	2011	2012	2013
Firms	35%	40%	29%	30%	34%	34%	36%
Government	10%	10%	3%	4%	4%	4%	5%
Higher Education	43%	41%	40%	39%	32%	34%	39%
Private non-profit	12%	9%	10%	10%	10%	11%	8%
Astronomical Observatories	-	-	17%	18%	20%	16%	13%
Total	100%	100%	100%	100%	100%	100%	100%

Note: There is information available for the astronomical observatories only from 2009.

Source: Own elaboration based on MINECON (2015b).

Turning to innovation outputs, Table 17 presents the number of academic publications since 1990. The data shows an increasing trend in the number of academic publications since the 1990s. In fact, Chile outperforms other Latin American countries, which indicates higher productivity in academic research. Table 18, moreover, shows the productivity of the researchers (in FTE) in terms of the number of scientific publications. The data shows that Chilean researchers are more productive than in other countries from the Latin American region and even more productive than in Australia and New Zealand. The latest data available for Chile shows that Chilean researchers published 0.88 publications per researcher in 2013. This is followed by Australia and New Zealand with 0.4 articles per researcher. The second best performer from the Latin American region is Mexico, followed by Brazil, with 0.31 and 0.29 publications per researcher respectively. It is important to note, however, that productivity does not necessarily translate into quality. A study by Contreras et al. (2006) examined the international relative impact (measured as the number of citations publications and its relation to the world average) of Chilean scientific publications by discipline for the 1984-2013 period. These authors found that Chile is the only Latin American country that shows an international relative impact, higher than the world average for three disciplines (Economic and Business, Space Science, and Multidisplinary). Overall, the data shows that despite the low number of researchers, these are more productive that even some developed countries. Also, research has found that the impact of these publications is higher than the world's average for some disciplines.

Table 17: Scientific publications (per million inhabitants), selected countries and years

Country	1990	1995	2000	2005	2010	2011
Argentina	49.9	56.5	77.1	79.1	93.3	94.8
Australia	624.9	726.3	761.7	783.3	885.8	922.2
Brazil	15.9	21.2	36.7	53.2	64.2	66.8
Mexico	12.1	20.3	28.6	35.5	..	..
Turkey	13.9	29.3	55.2	115.4	110.2	114.0
Chile	62.8	61.5	72.2	95.4	108.9	114.3
Peru	3.5	2.7	3.0	4.8	5.0	5.5
New Zealand	668.8	664.9	739.0	722.6	781.7	791.9

Source: World Development Indicators (The World Bank, 2012). Visited on 4 August 2015.
..: Data not available.

Table 18: Scientific publications per researcher (FTE), selected countries and years

Country	2000	2005*	2010**	2013***
Argentina	0.16	0.15	0.16	0.16
Australia	0.31	0.32	0.40	0.40
Brazil	0.16	0.20	0.29	0.29
Mexico	0.22	0.19	0.31	0.31
Chile	..	..	0.77	0.88
Turkey	0.29	0.45	0.41	0.34
New Zealand	..	0.39	0.40	0.40

Source: Own elaboration based on data from UIS.Stat and World Development Indicators (Bank, 2017). Data accessed on 8 January 2017.

*Data 2004 for Australia.

** Data 2009 for New Zealand.

** *Data 2010 for Australia and Brazil. Data 2011 for Mexico
.. Data not available.

Table 19 shows the patents applications made by Chilean residents. The data from the table shows that Chile experienced an increase during 1990–2012 when the number of applications went from 12.8 to 19.3. However, Chile's performance is considerably less than that of developed countries, including those that also base their economies on natural resources, such as Australia and New Zealand (see Table 19). Table 19 also shows that Chile's performance of the country is considerably lower than countries with a similar GDP per capita, and even other Latin American countries. The level of patents applications can be considered as a proxy for the inventiveness of a country (Zuniga et al., 2009) but, at the same time, it is important to acknowledge that patents are not the only way to protect inventions. There are inventions for which alternative protective measures, such as industrial secrecy, are more suitable (Zuniga et al., 2009).

Table 19: Patents applications, residents (per million inhabitants)

	1990	1995	2000	2005	2010	2013
Argentina	29.3	19.4	28.8	27.3	..	15.5
Australia	..	98.7	100.7	125.3	109.3	132.4
Brazil	16.0	16.7	18.2	21.8	21.7	24.8
Mexico	7.7	4.5	4.1	5.3	8.1	9.9
Turkey	2.6	2.9	4.4	13.7	44.1	58.6
Chile	12.8	11.8	15.6	22.1	19.1	19.3
Peru	2.3	..	1.5	1.0	1.3	2.4
New Zealand	240.9	349.5	379.2	457.9	364.3	363.3

Source: World Development Indicators. Visited on 4 August 2015.
..: Data not available.

4.4.1 Development of public support for innovation

It is only in recent decades that Chile has advanced in the establishment of a national innovation system (CNIC, 2010). Before this, innovation policy initiatives were carried out by separate agencies and public research organisations in an uncoordinated way. Until the early 1990s, innovation policy tools consisted mainly of: (i) funding agencies, such as the National Commission on Science and Technology (*Comisión Nacional de Investigación Científica y Tecnológica*, CONICYT), which mainly supported academic research and financed scholarships; and (ii) a set of technological institutes that provided some basic technological services to a limited number of firms in the industrial and agricultural sectors (OECD, 2007: 14). Technological development was promoted through finance and technology transfer by the National Development Agency (*Corporación Nacional de Fomento*, CORFO) and, from 1976, *Fundación Chile* (CNIC, 2010).[43]

The first policy initiatives created to strengthen the innovation capacity of the country were only introduced in the early 1990s with the establishment of the Science and Technology Programme (*Programa de Ciencia y Tecnología*, PCT) by the Ministry of Economy. The purpose of the PCT was to incentivize technological innovation in Chilean firms and strengthen R&D activities (CNIC, 2010: 34). The implementation of the PCT led to the creation, in 1991, of the National Fund for Scientific and Technological Development (*Fondo Nacional de Desarrollo Científico y Tecnológico*, FONDEF), hosted in CONICYT.

Further, the National Productivity and Technological Development Fund (*Fondo National de Desarrollo Tecnológico y Productivo*, FONTEC) was created in 1991 and the Development and Innovation Fund (*Fondo de Desarrollo e Innovación*, FDI) in 1994. Both programmes were hosted in CORFO.

Since the 2000s Chile's innovation policy began to acquire national relevance and a series of new initiatives were implemented (CNIC, 2010). These included the Programme of Technological and Innovation Development (*Programa de Desarrollo e Innovación Tecnológica*, PDIT), created in 2000 with a loan from the Inter American Development Bank (IADB), and the Bicentennial Programme of Science and Technology (*Programa Bicentenario de Ciencia y Tecnología*, PBCT), created in 2003 with funds from the World Bank and the Chilean Government

[43] In 1982, *Fundacion Chile* created *Salmones Antártica*, initiating through the establishment of this firm the large scale salmon industry in Chile (Fundación Chile, 2015).

(CNIC, 2010). In 2005 the InnovaChile Committee (Comité InnovaChile de CORFO) was created within CORFO by the merger of the FONTEC and FDI-CORFO. InnovaChile's mission is to 'contribute to raising the competitiveness of the Chilean economy through the promotion and facilitation of innovation in firms, the stimulation of entrepreneurial development and the strengthening of the NSI' (CNIC, 2010: 34).

Table 20 shows the R&D budget allocated by the Chilean Congress through the Budget Law of the Public Sector (*Ley de Presupuestos del Sector Público*) for the period 2010–2013. The data provides a sense of the magnitude of the programmes and funds described in terms of resources, participation in the national efforts on R&D, and as a percentage of the Gross Domestic Product of Chile in the years selected. From the table it is possible to observe the importance of FONDECYT and of InnovaChile as the main fund and programme oriented to promote R&D and innovation in Chile. Table 21 shows the R&D budget from the funds and programmes of the NIS in terms of the total expenditure on R&D performed by the Higher Education sector. The data shows the importance of FONDECYT for this sector, since its resources represent 41.26% of the total R&D performed in this sector. It is important to mention that the resources from funds and programmes presented are not allocated exclusively to universities. Measuring the importance of the resources in terms of the total of R&D performed by the Higher Education sector may overestimate the importance of the fund for this sector. In the case of FONDECYT, however, more than 95% of the resources of the Regular Programme, which is the largest programme of the fund, were allocated to universities in 2013 (CONICYT, 2013a). This shows that the Higher Education sector is the main beneficiary of this fund.

Table 20: R&D Budget 2010-2013, selected programmes

Public Programme/Fund	USD constant prices 2013 (thousands)				%GDP				%R&D			
	2010	2011	2012	2013	2010	2011	2012	2013	2010	2011	2012	2013
Fondecyt	98,628	132,621	163,440	175,662	0.0429%	0.0511%	0.0617%	0.0634%	12.97%	14.45%	16.92%	16.22%
Innova Chile	96,159	122,456	120,966	142,967	0.0419%	0.0471%	0.0457%	0.0516%	12.65%	13.34%	12.52%	13.20%
Becas Chile	85,450	78,071	108,183	105,415	0.0372%	0.0301%	0.0408%	0.0380%	-	-	-	-
Programme of Associative Research	57,340	44,120	44,490	47,207	0.0250%	0.0170%	0.0168%	0.0170%	7.54%	4.81%	4.60%	4.36%
Fondef	28,819	36,019	41,374	33,697	0.0125%	0.0139%	0.0156%	0.0122%	3.79%	3.92%	4.28%	3.11%
Millennium Initiative	15,611	16,588	17,689	20,824	0.0068%	0.0064%	0.0067%	0.0075%	2.05%	1.81%	1.83%	1.92%
Fishing Innovation Fund	5,596	5,302	5,859	8,293	0.0024%	0.0020%	0.0022%	0.0030%	0.74%	0.58%	0.61%	0.77%
Regional Programmes of S&T	6,971	5,527	7,365	7,537	0.0030%	0.0021%	0.0028%	0.0027%	0.92%	0.60%	0.76%	0.70%
Bio Bio Innovation Fund	5,247	4,952	4,882	4,905	0.0023%	0.0019%	0.0018%	0.0018%	0.69%	0.54%	0.51%	0.45%
Total	399,822	445,655	514,249	546,508	0.1741%	0.1716%	0.1942%	0.1971%	41.35%	40.04%	42.03%	40.74%

Source: Own elaboration based on data from www.stats.oecd.org, www.bcentral.cl, www.fred.stlouisfed.org, MINECON (2015a); Ministerio de Hacienda (2010) (websites accessed on 7 January 2017).

Note: Following the guidelines of the Frascati Manual (OECD, 2002) funds aimed at support training (such as Becas Chile) are not considered in the estimation of national R&D investment. Therefore it is not pertinent to estimate its participation in the total of R&D expenditures.

Table 21: R&D Budget as a percentage of R&D performed by Higher Education Sector, selected funds and programmes

Public Programme/Fund	%R&D performed by Higher Education			
	2010	**2011**	**2012**	**2013**
Fondecyt	33.67%	44.57%	49.36%	41.26%
Innova Chile	32.82%	41.16%	36.53%	33.58%
Programme of Associative Research	19.57%	14.83%	13.44%	11.09%
Fondef	9.84%	12.11%	12.50%	7.91%
Millennium Initiative	5.33%	5.58%	5.34%	4.89%
Fishing Innovation Fund	1.91%	1.78%	1.77%	1.95%
Regional Programmes of S&T	2.38%	1.86%	2.22%	1.77%
Bio Bio Innovation Fund	1.79%	1.66%	1.47%	1.15%

Source: Own elaboration based on data from www.stats.oecd.org, MINECON (2015a); Ministerio de Hacienda (2010) (website accessed on 7 January 2017).

Since 2007, the governance of the national innovation system has been coordinated by the Committee of Ministers for Innovation (*Comité de Ministros para la Innovación*, hereafter CMI, comprising ministers from the ministries managing Chile's research and innovation resources and programmes: the Minister of Economy, the Minister of Education, the Minister of Agriculture, the Minister of Fishing, and the Minister of Planning. The Committee is in charge of designing the innovation policy and is also responsible for the allocation of the resources from the Innovation Fund for Competitiveness (*Fondo de Innovación para la Competitividad*, FIC). This fund was created in 2005 by Presidential Decree *(Decreto Presidencial*) to allocate the proceeds from the mining tax (OECD, 2007)—a royalty explicitly reserved by the government to promote innovation as well as activities that foster the creation of long-term capacities for the economy (CNIC, 2009).

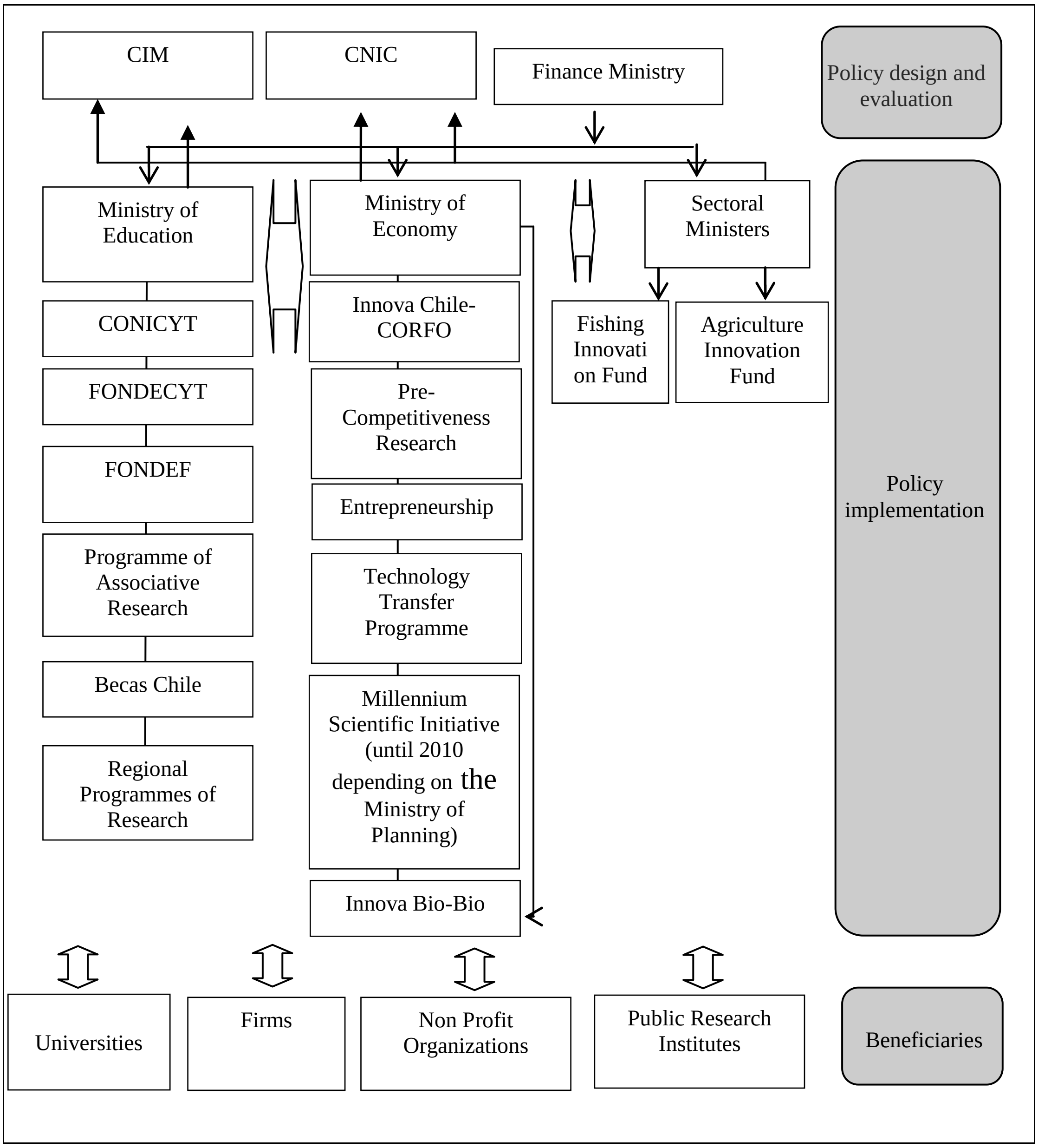
The CMI is advised by the CNIC (*Consejo Nacional de Innovación para la Competitividad*), which, like the FIC, was also created in 2005 by Presidential

Decree and was instituted as a permanent body in 2006 (CNIC, 2009). The Council was formed to meet the explicit objective of advising the Government on how to develop a holistic innovation policy to increase the GDP per capita fast enough to repeat the doubling of the previous fifteen years (CNIC, 2009:4). Before the creation of the CNIC, the activities of the national innovation system were entrusted to a range of different agencies associated with R&D and innovation of which the main ones were CONICYT and CORFO (Intelis, 2007). With the creation of the CNIC and the CMI, the government was able, for the first time, to formulate and implement an explicitly coordinated innovation policy. The system is designed to work in the following way: the CNIC evaluates and proposes innovation policy to the CMI, which then decides the policy and consequent allocation of the FIC among the different programmes and agencies. These then allocate the resources to the beneficiaries (firms, universities, non-profit organisations, and public-research institutes).

The creation of the FIC led to the establishment of additional matching grants and programmes to support innovation activities, including R&D. The evaluation of the national innovation system carried out by the OECD in 2007 identified more than thirty public programmes devoted to technological innovation (OECD, 2007). Of these, there were at least six public programmes designed to promote technological research and pilot development that regularly consider university-firm collaborative projects (OECD, 2007). Figure 9 presents the organisation of public funds to support research and innovation in Chile as of 2012. These agencies allocate the resources to the different types of organisation conducting R&D and innovation activities based on competitive grants (universities, firms, non-profit organisations, and public research institutes). The double-sided arrows between the ministries and their agencies show the linkages and interactions between these organisations. The double-sided arrows between the implementation and beneficiaries layers of the system are intended to reflect that the beneficiaries receive the funds from the agencies and programmes but that, through their sectoral representatives, they participate in the boards that select and even in some cases approve the projects. Also, through arrows from the ministries to the CMI and the CNIC, the figure reflects the fact that representatives from the ministries also are represented in the CMI and the CNIC. Table 22 shows the main milestones in the development of the national innovation system. From the figures it is possible to observe that the creation of funds to promote R&D started with the creation of the National Fund for Scientific and Technological Development (FONDECYT) oriented to support mostly basic science.[44]

[44] This fund plays an important role shaping the incentives of academics and universities towards research activities (See Chapter 5).

Figure 9: Organisation of the public structure for promoting innovation in Chile



Source: Own elaboration based on OECD (2007).

Table 22: Main milestones in public support for R&D and innovation in Chile

Year	R&D and Innovation Initiative
1981	Creation of the FONDECYT, the first fund oriented to promote research. It is granted directly to the academics in the universities.
1992	Creation of the PCT (funded by a loan from the Inter-American Bank of Development Loan). This loan allowed the establishment of the FONDEF, the FONTEC, and the FDI-CORFO. These programmes were intended to foster research and economic development. The FONDEF was the first matching grant established in Chile. It requires the participation of firms and is allocated to universities.
1996	Creation of the Programme of Technological Innovation
1997	Creation of the fund for the funding of Excellence Research Centres.
2001	Creation of the Chile Innova programme (funded by a loan from the Inter-American Bank of Development).
2002	Launching of the first programme to create technological incubators (at CORFO)
2003	Launching of the PBCT (funded by the World Bank and the Government of Chile). It had three main objectives: increasing university-firm linkages, promoting basic science, and fostering monitoring and evaluation capacity in innovation.
2005	Creation of InnovaChile de CORFO (ex FONTEC and FDI). Creation of the CNIC and the FIC (funded by royalties to the mining industry).
2008	Launching of the Associative Research Programme at CONICYT Launching of the R&D tax credit (managed by InnovaChile)
2009	Launching of the National Innovation Policy for Competitiveness
2010	Presentation of the Agenda for Productivity 2010–2020 Launching of the Strengthening of Technology Transfer and Entrepreneurships Programme (CITE) at InnovaChile.
2011	Dismissing of cluster policy
2012	Changes introduced to the R&D tax credit Introduction of the start-up programme

Source: Own elaboration.

In the view of the CNIC, the Chilean innovation system evolved towards a mature state with the creation of InnovaChile, the establishment of the FIC associated with the mining tax, and with the initial steps made towards new innovation institutions (the CNIC and the CMI) and the elaboration of an innovation strategy (CNIC, 2010: 34).

4.4.2 Institutional development

In this subsection I describe the processes behind the creation of the institutions that have shaped the national innovation system: the FIC, the CNIC, the CMI and the mining tax. These institutions all resulted from the same legislative initiative, which was sent to Congress in mid-2004. It had two objectives: to tax the mining sector and to create the FIC (Aninat et al., 2010: 60). The main argument behind the initiative was that a non-renewable resource was not generating enough assets to compensate for its exploitation and concomitant depletion (Aninat et al., 2010: 60). To re-balance this, the royalty, set at 5% of income (ad valorem tax), would raise resources that would strengthen and increase national innovation efforts (Aninat et al., 2010; Intelis, 2007: 5). Additionally, the initiative indicated that geographical considerations should be in place when allocating the resources, in order to benefit mining regions (Aninat et al., 2010: 65). The initiative also indicated the establishment of the CNIC and the creation of the CMI (Aninat et al., 2010: 65). The CNIC was intended. amongst other duties, to oversee the proper allocation of these resources, while the Council of Ministers was supposed to be a more executive institution oriented to overseeing the consistency of the proposed instruments and programmes (Aninat et al., 2010: 65).

The mining tax was approved in May 2005 (Law N 20.026 of 27 May 2005) and implementation began in January 2006 (BCN, 2005). Congress did not, however, approve the other parts of the initiative (Aninat et al., 2010). This means that the institutional reforms associated with the FIC and the CNIC are still under discussion (Intelis, 2007). In the view of Aninat et al. (2010: 65), two issues have impeded the official approval of the creation of these institutions. First, the composition of the CNIC, for which there is a consensus on that the interests of the regions should be represented but no agreement on how to implement this. Second, there is disagreement about what percentage of the tax revenues should be directly allocated at the regional level and the distribution between mining and the non-mining regions is particularly contested (Aninat et al., 2010: 65).

While the project of law proposing the creation of the CNIC is still under discussion in Congress, we have already seen that the CNIC was created, with the same duties and responsibilities proposed by the legal initiative, by presidential decree in late 2005. The Presidential decree further asked the CNIC to make a proposal on the use of the FIC, also already in place, to include allocating 35% of the resources to be decided at the local rather than national level (Aninat et al., 2010: 65).

The CNIC was also in charge of defining and designing a so-called National Innovation Strategy for Competitiveness for a 12-year horizon. This would separate the strategy from the short-term politics (Intelis, 2007: 6). The creation of the Council allowed innovation policy to be designed at a central level, which was a change from the decentralized design used up to that time (Intelis, 2007: 6). The first CNIC finished its work in March 2006 with the elaboration of the Final Report of the Council of Innovation for the Competitiveness (*Informe Final del Consejo de Innovación para la Competitividad*) (CNIC, 2007) . Later that year a second Council was established to design the long-term innovation strategy, elaborate policy proposals, establish allocation criteria of the resources, and evaluate the policies implemented by the Executive. The CNIC was formed of 17 members: 5 ministers (education, budget, education, economy, public works and agriculture);

representatives from the main actors in the NIS—the private sector, science, education, and innovation public policy; and 2 representatives from the main agencies implementing science and innovation policies (CONICYT and CORFO respectively) (Intelis, 2007: 6).

In 2007 another milestone in the development of the innovation system was achieved with the establishment of the CMI (CNIC, 2010) to act as the link between the policy proposed by the CNIC and policy decisions made by the Executive. That year, the CNIC also presented its proposed innovation strategy (*Estrategia Nacional de Innovación para la Competitividad, Volume I (2007) and Volume II (2008)*). Based on these proposals, in 2009 the Government presented the National Innovation Policy for the Competitiveness,[45] which included the following specific objectives (CNIC, 2010):

i. To promote an innovative culture throughout the society, including within the Government, firms, and especially in the education system;
ii. To strengthen public institutions related to innovation, linkages between the actors, and the provision of public goods;
iii. To strengthen the provision of factors and conditions for innovation, namely: human capital and R&D, entrepreneurship and technology transfer capacities.

Furthermore, the policy proposed the development of clusters with long-term (15 years) high growth potential. In 2010, the CNIC concluded the Innovation and Competitiveness Agenda 2010–2020 (*Agenda de Innovación y Competitividad*

[45] Política Nacional de Innovación para la Competitividad: Orientaciones y Plan de Acción 2009–2010 (CNIC, 2009).

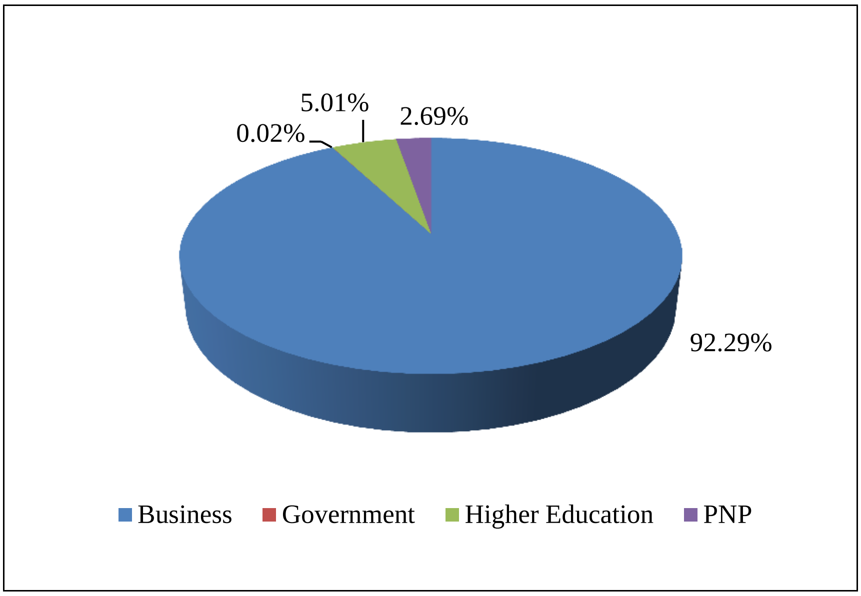
2010–2020), which was presented in March 2010, just before the end of the *Concertación* government and the start of the right-wing government that would lead the country from 2010 to 2014. The Agenda reviewed the advances in the implementation of the innovation policy proposed by the CNIC in 2007, and proposed the 2010–2020 innovation strategy (interview to Gonzalo Rivas, current president of the CNIC, in *La Tercera*, 15 June 2014). The cluster policy (*Política de Clusters*) designed and implemented during President Bachelet's administration was cancelled by President Piñera's administration (Crespi et al., 2014; Schneider, 2013b), which also reduced the CNIC's duties and budget considerably (Schneider, 2013b).

4.5 University-firm collaboration

As discussed in the introduction to this DPhil thesis, university-firm collaboration has been identified as one of the areas a country should improve in order to become a knowledge society. Chapters 5 and 6 discuss the incentives and factors explaining this interaction in Chile. This section, however, provides a brief description of the national trends in this area.

As shown in the previous section, firms contribute to the national R&D efforts by funding 34% of the total R&D expenditure while conducting 34% of the total R&D in 2013 (see Table 15 and Table 16). The percentage of the total R&D expenditure funded by firms and performed in universities provides an initial glimpse of the importance of universities as R&D collaborators for firms. Figure 10 presents the amount of R&D financed by firms by sector of performance. The figure shows that firms performed 92.29% of the total of resources they invested in R&D in 2013, while, of the remaining resources, universities performed only 5.01%.

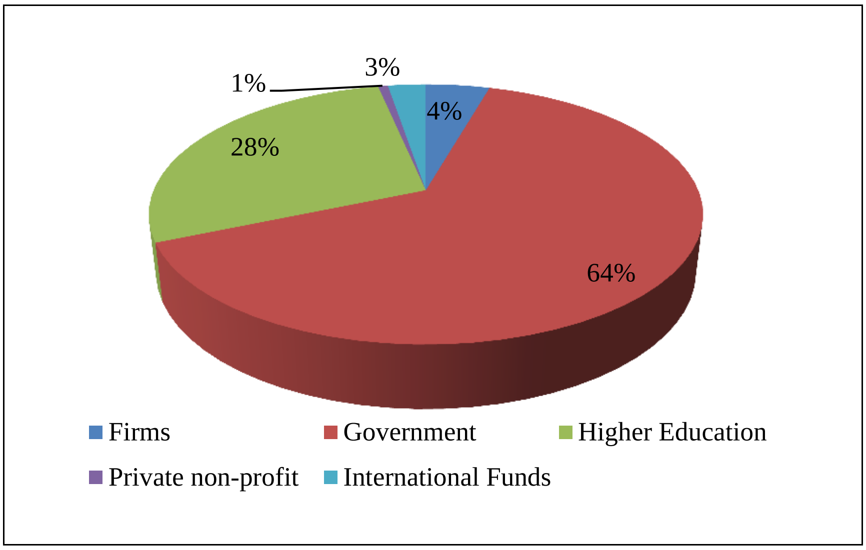
Figure 10: Business R&D funding by sector of performance, 2013



Note: PNP: Private non-profit organisations.
Source: Own elaboration based on MINECON (2015b).

On the other hand, government funding was the main source of R&D investment reported by universities in 2013 (MINECON, 2015b). After government funding, the main source of R&D funding for universities were their own internal resources. Firms provided only 4% of the total R&D resources performed in universities in this year (see Figure 11). Furthermore, as in many developing countries, in Chile the pattern of scientific spending is more biased towards basic research than in developed countries (CNIC, 2010). In the view of the CNIC this is partly explained as the result of the scientific elite having a great deal of control over funding allocation combined with a low level of demand or signalling from companies and other social actors about their needs (CNIC, 2010: 110). In Chile, most of the R&D financed by the government is carried out in universities with few connections to the business sector (CNIC, 2010: 110).

Figure 11: Percentage of R&D expenditure performed by universities by funding sector, year 2013



Source: Own elaboration based on MINECON (2015b).

University-firm collaboration is also measured to elaborate the Global Competitiveness Index prepared by the WEF, which in 2014—15 reported that Chile ranked 39 out of 144 economies in terms of university-firm collaboration.[46] In comparison with other countries from the Latin American and the Caribbean region, Chile ranks third after Costa Rica (33) and Puerto Rico (36) (WEF, 2014).[47]

4.5.1 Public support for university-firm collaboration

During the 1990s, the main programmes supporting university-firm collaboration were FONDEF (managed by CONICYT) and FONTEC (managed by CORFO). In the early 2000s, however, the increasing awareness amongst innovation policy makers of the importance of technology transfer meant that the PBCT was to

[46] The GII questionnaire assesses university-firm collaboration in countries by asking: In your country, to what extent do business and universities collaborate on research and development (R&D)? [1 = do not collaborate at all; 7 = collaborate extensively] (WEF, 2014)
2013–14 weighted average
[47] See Appendices for comparison with other countries.

explicitly include the promotion of collaborative knowledge creation in its goals. Among the resulting initiatives was the creation of the *Incentives to Patenting Programme* and the *Technological Consortia Programme*. This was the first initiative to promote academic patenting and it produced a breakpoint in the number of patents applications from universities. The *Incentives to Patenting Programme* is discussed further in the following chapter (Chapter 5), which analyses the universities' and academics' incentives to collaborate with firms and to transfer technologies to firms in Chile.

In addition to the creation of new public programmes to promote innovation, in 2008 the government established a tax credit for firms to promote R&D conducted in research centres (Minecon, 2012). The limited results of this instrument led to improvements to the law in 2012, which increased the R&D efforts of firms but have produced mixed effects in fostering university-firm collaboration. The performance and incentives produced by the tax credit are addressed in Chapter 7, which discusses the incentives Chilean firms have to innovate and collaborate with universities for this purpose.

Prompted by several governments and international reports claiming that there was limited technology transfer between universities and firms in Chile (see for instance World Bank, 2009), the government took action to strengthen these linkages. In 2010, CORFO created the Technology Transfer and Entrepreneurship (CITE) programme, which aimed to strengthen the technology transfer capacities of universities (Babish et al., 2009).

4.5.2 The limitations and constrains of Chile’s innovation system

In spite of its increasing importance in the design of public policies since the 2000s and the development that it has experienced in the last decades, Chile’s innovation system has several limitations that require attention.

An evaluation of the national innovation system carried out by the OECD in 2006 found that Chile followed the technology gap orthodoxy of the time to adopt imported technologies, but that there were limited efforts to develop domestic capabilities to unbundle, understand and further develop these technologies in firms, universities or indeed in the State (CNIC, 2010: 13). One of the consequences of this strategy, and of the lack of regulation, was the sanitary crisis in the salmon industry of 2007 (CNIC, 2010). This crisis dramatically reduced the production of salmon and contributed to the loss of around 20,000 jobs in the sector by 2009 (Iizuka and Katz, 2015).

Several national and international reports have noticed Chile’s low innovation performance (see for instance CNIC, 2006; 2007; OECD, 2010) and have recommended the promotion of strategies to strengthen firms' innovation expenditure. Policy initiatives such as the creation of the CNIC, attempts to foster the creation of local capacity, and the creation of an R&D tax credit, are just some of the examples of the efforts conducted by the country in the 2000s to increase innovation in firms. Despite the advances in the innovation system, especially those observed since the 2000s, in the view of an international evaluation of the system (prepared by the Growth Commission) Chile’s innovation system is ‘rudimentary’ compared to those of East Asia, (Kharas et al., 2008: 14). The evaluation argues that this could be explained by the comparatively low level of firms' R&D and lack of linkages, and the lower number of research workers. Further, according to the OECD (2009), the main challenges faced by Chile in attempting to realise its innovation potential are the low levels of national investment in R&D, the strong focus on research rather than on innovation activities, the lack of skilled human capital, and the absence of an innovation culture across the agents of the innovation system.

As the following brief summary shows, these weaknesess in Chile's innovation system can be grouped into three areas: low investment in R&D; poor institutional development and a lack of linkages among the actors of the system; and a shortage of human capacity for innovation.

Low investment in R&D

The limited R&D investment of firms is a widely recognised problem of the innovation system (CNIC, 2007; 2010; OECD, 2007). Indeed, in the view of the OECD, the feature that most distinguishes Chile's innovation system is the limited role played by the business sector in the financing and performance of R&D (OECD, 2007). As discussed in Section 2, the total R&D innovation expenditure is low in comparison with countries with similar GDP per capital. Moreover, most R&D research in Chile is financed by the public sector and the government has failed to invest the necessary resources in matching the level of expenditure seen in not only OECD, but also some developing, countries from the region. In this regard, the OECD and the World Bank claim that the 'Chilean research system is underfunded and lacking in coherent strategic focus' (OECD and The World Bank, 2009b: 16).

Institutional development and lack of linkages among the actors of the system

Overall, an international evaluation conducted by the OECD in 2006 found governance problems in the Chilean innovation system. In particular, they found a weak overall governance of the NSI and agency co-ordination, an unbalanced policy mix between basic and applied research, and fragmented and unfocused instruments (lack of critical size, duplication and blind spots, and a deficient articulation with sector-specific demand) (OECD, 2007). Also, the innovation policy fails to find an adequate balance between the support given to basic science and priority areas. There are too many research programmes, they are fragmented, and there is even duplication among them (OECD and The World Bank, 2009b). More efficiency could be gained if they were consolidated in fewer, but larger and more focused, programmes (OECD and The World Bank, 2009a: 17).

Shortage of human capacity for innovation

The system also has limitations in terms of human skills. As discussed in Section 4, there are few research workers and these are concentrated in the public sector, rather than in firms, which potentially reduces the commercial returns of R&D, as appears to have happened Chile where the returns are lower than in the OECD in general (Kharas et al., 2008: 14).

4.6 Conclusion

This chapter has described the main features of the Chilean innovation system with a view to providing the research settings for this DPhil thesis. The Chilean innovation system is characterized by an open-oriented, small economy whose productive structure is based on the exploitation of natural resources. Chile has experienced significant growth in recent decades and its public sector has devoted significant efforts to strengthening its national innovation system. Despite these efforts, however, the innovation and R&D efforts of firms are low in comparison to countries with a similar level of economic development. Chile's innovation system is also characterized by a shortage of skilled labour and a limited research capacity in its university system. Taken together these factors limit the absorptive capabilities of the country.

Despite the development experienced by Chilean NSI in recent decades, the institutional development of the system still has to overcome the challenges of the lack of coordination and linkages among the actors of the system and inefficiencies in programme design and complementarities. Against this background, the following chapter examines the incentives that Chilean academics and universities have to engage in collaborative R&D with firms with special emphasis on the incentives created by public policy.

Chapter 5: Incentives in universities

5.1 Introduction

In this, the first of three empirical chapters, I discuss the factors influencing academics and universities motivation for engaging in university-firm collaboration and technology transfer activities, with special emphasis on the effects of public funding on the development of organisational capacities in the universities. I will argue that the allocation of research funding to universities has produced inconsistent incentives for universities and academics in relation to the nature of research undertaken, collaboration with firms, and the organisational capacity for technology transfer. The combined effects of direct and indirect incentives have produced a negative bias towards university-firm linkages that produce changes within firms through technology transfer.

Research has emphasized the importance of the experience of technology transfer staff and the value of the social capital of the researchers in explaining the success of knowledge transfer activities (Geuna and Muscio, 2009; Siegel et al., 2003). The literature has also identified cultural clashes, poorly designed rewards systems, and ineffective management of university technology transfers offices as barriers to technology transfer (Siegel et al., 2003; Siegel et al., 2004). There are also many studies about the impact of public funds on university-firm linkages (e.g. Bozeman and Gaughan, 2007; Rasmussen, 2008; Sa and Litwin, 2011), but these have often limited their analysis to firms mostly operating in developed countries.

As discussed in the previous chapter, in Chile the demand for innovations from firms is limited and innovation capacity is to some extent determined by market failures (CNIC, 2007). By studying the dynamics of university-firm collaboration and technology transfer in the three most important Chilean universities in terms of knowledge creation, in this chapter I show that the allocation of public funds has produced inconsistent incentives for academics and universities in relation to their choice of mechanism for technology transfer (particularly publications and patents) and to engage in innovation collaboration with firms.

In addition, I argue that universities have created organisational capacity to transfer technologies in the form of patents, new businesses, and collaborative projects. My findings suggest that the main motivation behind the creation of these capacities has been a desire to secure shares of the newly available funding. In other words, universities that do invest in organisational collaboration capacity have done so primarily to exploit new sources of funding rather than to strengthen their collaborative linkages with firms and meet innovation targets.

Collaborative research projects with firms are seen, first and foremost, as a way to obtain public resources for research and only second as a mechanism for collaborating with firms or transferring technologies. The findings show that universities see the 'commercialization of knowledge activities' as a strategy for obtaining government matching grants to work with firms. The academic groups identify firms as potential partners in collaboration and align their proposals to the available sources of funding. After identifying a possible source of funding, they present the project proposal to the firms. If the firm agrees, they apply for the grant and the project only goes ahead if it is granted public funds. After a research project is finished, it is often the case that the outputs are not ready to be implemented by the company and the academics who had been working on the project often leave to begin a new project. This escalation stage in development is usually not funded by the government and may entail significant costs for the firm, depending on the field of research. The lack of funding to cover this gap in the development of innovation research limits the transfer that can occur from the knowledge created in the universities. Consequently, there is a specialization from academics and universities in making applications for patents and little effort to commercialize new inventions (Wright et al., 2008).

The main implication of this analysis centres on the systemic effects of innovation policy on the innovation system. The strong influence exerted by public policies on the aims and behaviour of universities makes the design of the innovation policy critical to the system's success. The agents in the innovation system react to the overall effects produced by the direct and indirect incentives available and, in Chile, the importance of public funding to the universities and academic, intensifies the effects of changes in the innovation policy.

The chapter is organized according to the main factors that influence the strategies of the universities and academics: these are university-firm links, applied innovation, patenting, and commercialization of knowledge. After this introduction, I briefly describe the settings of the analysis.[48] Then I examine the influence of the evaluation processes for public grants and their effects on the motivations of both academics and universities in relation to academic publications. This is followed by an analysis of how the establishment of matching grants has framed the creation of capabilities in the universities, and the effects of such public funding on the

[48] Please refer to Chapter 3: Methodology for a detailed discussion of the selection of cases.

motivations of academics to undertake research collaboration with firms. Lastly, I discuss the main findings of the analysis and review their implications.

5.2 Description of the settings

The case study presented in this chapter is based on an analysis of the engineering departments of the three most important universities in Chile—University of Chile, Catholic University of Chile, and University of Concepción. As well as receiving more public resources to conduct research than any other university, these universities also lead the field in terms of scientific publications and patent applications. As discussed in Chapter 3, the decision to focus on their engineering schools was driven by a desire to cover the academic fields most likely to interact with firms and to facilitate comparability across the different settings.[49]

These universities have received more grants from the FONDECYT—the oldest and most prestigious research grant in Chile—than any other university in the country (CONICYT, 2012b). Table 23 shows the allocation of resources from the Regular Programme, which is the largest programme operating within the FONDECYT umbrella. The universities selected for this study received in total 58.5% of all granted funds in 2010.

[49] Please refer to Chapter 3 for the rationale to focus the analysis on the engineering schools.

Table 23: Number of approved projects and participation in the total resources allocated, Regular Programme 2010 FONDECYT

Institutions	Number of Projects Approved	% of Total Resources Allocated
University of Chile	86	25.9
Catholic University	100	21.8
University of Concepción	41	10.8
University Austral	25	6.0
University of Santiago of Chile	21	4.7
Technical University Federico Santa Maria	19	3.6
Other Universities	103	21.0
Other Institutions	52	6.2
Total	447	100

Source: Own elaboration based on (CONICYT, 2012b).

5.3 Institutional incentives to collaborate with firms and transfer technologies

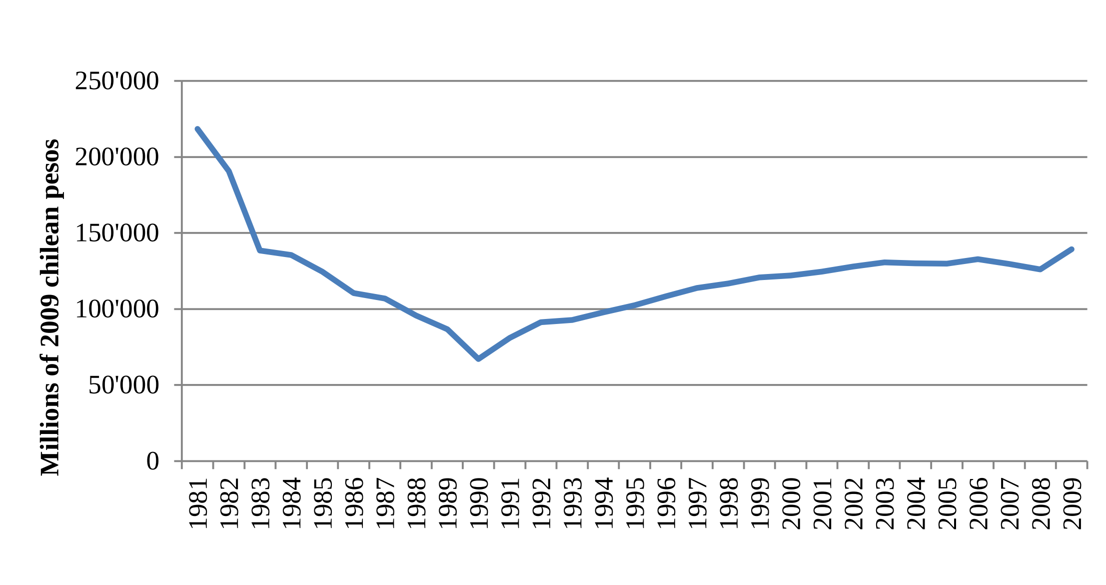
The criteria used by the Chilean agencies to allocate the research funds for R&D have produced uneven incentives with regard to universities' and academics' choice of technology transfer mechanism and motivations for engaging in collaborative innovation activities with firms. To demonstrate this, I focus the analysis on three different instruments and examine how they have influenced the behaviour of universities and academics regarding collaborative research with firms and patenting: (i) the block grants allocated directly to the universities; (ii) the competitive grants for research; and (iii) the patenting schemes that were first created by the PBCT. These were chosen because the block grants and the competitive grants are designed explicitly to promote basic and applied research activities while the PBCT's patenting scheme was the first public programme to systematically promote patenting and technology transfer activities.

5.3.1 Allocation of block grants to universities

As mentioned in Chapter 4, until 1981 the universities in Chile were largely funded by the public budget (Contreras and Katz, 2011). In that year, however, the Chilean Government promulgated the *Decreto con Fuerza de Ley N°4 de 22 de Enero de 1980* (law decree N°4 of 22 January 1980), which declared that the State would contribute only partially to the funding of the universities (BCN, 1981b). The law decree created two contributions calculated on an annual basis—the *Aporte Fiscal Directo* (Direct Fiscal Contribution, AFD) and *Aporte Fiscal Indirecto* (Indirect Fiscal Contribution, AFI).

Block grants, AFD and AFI, are all of free use by the universities and generally not linked to specific outcomes. The resources from the AFD (which is the largest block grant allocated to universities) are distributed annually among the 25 public and private state-dependent universities that belong to the CRUCH. Figure 12 plots the trend in AFD from 1981 to 2009 and shows that, during the 1980s, public expenditure on higher education was reduced incrementally until it reached 50% of the sum allocated for the same purpose in 1980 (BCN, 1982). Since the return of democracy to the country in 1990, there has been a consistent gradual increase in government investment in higher education (Figure 12).

Figure 12: Direct block grant to the CRUCH universities, 1980–2009. Data in millions of 2009 Chilean pesos



Source: Own elaboration based on Ley de Presupuestos (1990–2009) and Mendez (1996).

Table 24 shows the percentage of the total expenditure on tertiary education institutions that is financed by public expenditure. In the case of Chile, the data shows that private expenditure is the main source of funding for tertiary education. In recent years, the share of public expenditure has increased but it is still the lowest among the countries selected. Unfortunately, universities are not requested to publish data about their expenses by type of expenses (current versus capital expenditures; salaries; R&D, etc). Therefore, there is no data on the percentage of the total expenditure of universities devoted to R&D.

Table 24: Share of public expenditure on tertiary education institutions

OECD countries/Year	2000	2005	2008	2010	2011	2012
Australia	49.9	45.4	44.9	46.5	45.6	44.9
Chile*	19.5	15.9	14.6	22.1	24.2	34.6
New Zealand	n.a.	n.a.	n.a.	n.a.	n.a.	52.4
Turkey	n.a.	n.a.	n.a.	n.a.	n.a.	80.4
OECD average	72.7	70.7	69.1	70.2	70.4	69.7

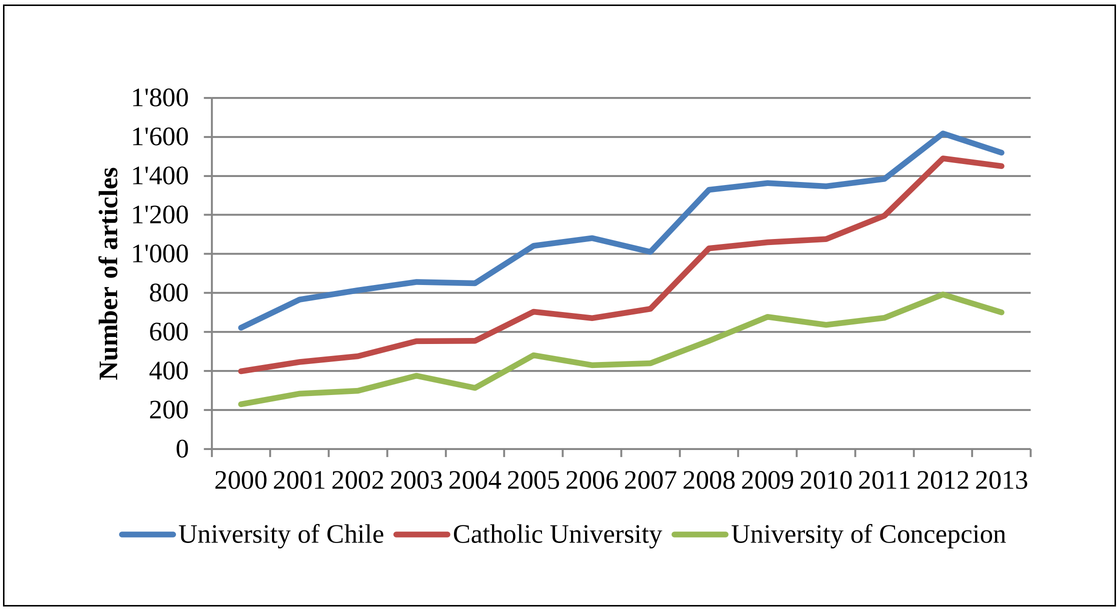
Note: * Year of reference 2013 instead of 2012.n.a. Data not available.
Source: Education at a Glance 2016 (OECD, 2016).

The resources from the AFD are allocated according to the criteria of historical continuity. As a result, a large proportion of these resources (95%) is not linked to any performance criteria. Only 5% of the AFD is allocated annually based on specific performance factors. The amount of resources allocated to each university within this 5% is calculated according to the evaluation of a set of performance indicators (BCN, 1982) that include: the number of research projects granted to the universities from the FONDECYT and other public programmes; the number of academic publications in internationally reviewed journals; and the share of high skilled academics (holding a PhD or Master's degree) out the total number of academics in the institution (BCN, 1982). The AFI is available to all the universities and is allocated according to the number of students belonging to the 27,500 highest-scoring students in the University Selection Test who have enrolled in the university (Holm-Nielsen et al., 2004).

The universities add the incremental resources—5% calculated every year—to their historic base for future calculations of the AFD. This means that the *only way* by which universities can increase their share of AFD resources is by improving the performance indicators used for the allocation of the 5% of the AFD. The allocation criteria used by the AFD make explicit the requirement that universities will receive resources according to their performance in the above-mentioned variables. The evaluation criteria of the AFD have thus created incentives for universities to focus on the factors influencing these performance indicators. In particular, academic publications appear to be a key objective of academics' research activities and the number of publications from the universities studied has seen an overall positive trend over the last decade (Figure 13). There has also been a positive trend in the ratio of academics with doctorates to the total number of academics (Figure 14).

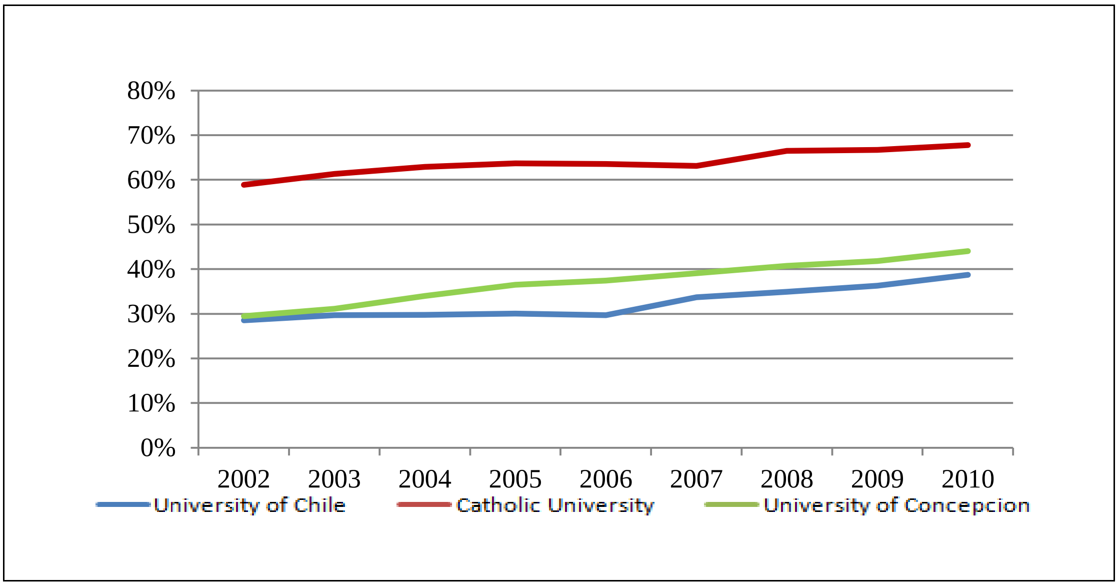
Since these indicators are part of the way that the AFD is calculated, improvement in their performance has directly influenced the amount of AFD allocated to the three universities during the period 2002–2010.

Figure 13: International Scientific Indexing (ISI) articles selected Chilean universities (2000–2013)



Source: Data retrieved from (CONICYT, 2016) on 14 June 2016.

Figure 14: Ratio of academics with doctoral degrees to total academics



Note: The number of academics is measured in FTE.
Source: Own elaboration using CRUCH (2002–2010).

However, because the evaluation criteria for the allocation of block grants values publications as the main indicator of research performance, there is a negative indirect incentive to engage in other mechanisms of technology transfer, such as collaborative research, consultancy projects, and commercialization of property rights. The interviews carried out with academics and managers of technology transfer units within these universities revealed the misalignment of objectives between block grants that promote basic research—later published in academic articles—and competitive grants that are oriented to the promotion of applied research and experimental development.[50] Supporting this statement, one of the respondents of the interviews said:

> There is a misunderstanding in FONDEF [public programme to promote R&D and Technology Transfer] about the interest that the universities have in making money by commercializing their research. These organisations seem not to care about making money. Universities have other interests such as obtaining funds from the AFD (Academic N°3, UCHILE).

The same researcher continues:

> The universities do not have an interest in creating technological businesses. They prefer to maintain their leadership, to recruit good academics.

The importance of the number of publications for the allocation of the block grants means that the universities also consider the number of publications as very relevant for the evaluation of their academics. In turn, this creates a bias among the academics themselves towards choosing academic publications as the main

[50] Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed (OECD, 2002: 30).

technology transfer mechanism. We can see from the following quotations from two academics:

> The academic that does not publish obtains very low academic qualification, and every two years yellow or red card. If is a red card, you have to leave straight away; you have to leave if you obtain two yellow cards in four years. If you did not do well in terms of publications, you [have to] leave (Manager and Academic N°4, UCHILE).
>
> We are evaluated by the level of publications, patents are not considered now. There is a lot of talking about that patents are considered, but in practice I still have not seen any document stating that patents will be considered in my evaluation… If I do not publish, I cannot be promoted (Academic N°21, UDEC).

The evaluation processes used for the allocation of research grants have also used the number of publications as an effective yardstick for measuring the research capacity of academics. Academics need to respond not only to universities, but also to the agencies from which they receive research grants. Consequently, the mechanisms for the allocation of research grants among academics can also influence their research behaviour. The next sub-section discusses the characteristics of the main research grants in Chile, their influence on the type of research undertaken by academics, and their impact on the behaviour of academics and researchers.

5.3.2 Access to research funds and academic standing

The FONDECYT, Chile's oldest and most prestigious programme for the development of science and technology, has exercised a powerful influence on the behaviour of academics and universities in relation to technology transfer activities and the type of research undertaken. This influence, when combined with the other features and regulations of the fund, promotes scientific publications as the main mechanism of technology transfer, to the exclusion of others.

National Fund for Scientific and Technological Development (FONDECYT)

As mentioned above, the first competitive grant to promote research in Chile, the FONDECYT, was created in 1981. This initiative is one of the most important programmes for national scientific and technological development and has a very good standing in the scientific community for its quality and status (Fondecyt, 2011a). This means that every academic hoping for peer recognition and significant career development must receive a grant from FONDECYT:

> There has been a glorification of the FONDECYT; everyone has to have a FONDECYT; anyone who does not have one will be poorly evaluated (Academic N°22, UDEC).
>
> In the academic world, FONDECYT it is like a quality test [‘test de la blancura’] (Academic N°28, PUC).

The FONDECYT only funds scientific and technological research projects that lead to new knowledge or applications developed from hypotheses set out in the original project application (CONICYT, FONDECYT Regulations 2011.P.1).[51] Since the purpose of this programme is oriented towards the promotion of basic science, it does not encourage interaction with firms. The FONDECYT has three paths: Regular Programmes, Initiation to Research (directed at young scholars), and post-

[51] The FONDECYT comprises several types of funds for academics. Its main line, the *Fondecyt Regular*, gives grants for projects between two and four years and it grants a maximum of 50 million Chilean pesos per year (approximately 100,000 USD) to cover all the expenses of the projects; it also allows universities to claim 17% for overheads to cover the indirect expenses of the projects (FONDECYT Regulations 2011.P.6).

doctoral research grants. Through these, the FONDECYT aims to support academics at different stages of professional development (CONICYT, 2013c).

The evaluation process of the FONDECYT assesses the projects according to the quality of the proposal, the potential impact, scientific novelty, viability of the projects, and, most importantly, the capacity of the responsible researcher. This last item accounts for 40% of the total score for the projects (FONDECYT, 2011b:13). Below is an extract of the evaluation criteria from the call for applications to the Regular Programmes in 2008 (CONICYT, 2013b):

> Capacity and productivity will be evaluated. Capacity considers leadership defined as the first author of publications or correspondent author of publications that have editorial committee, has experience as a responsible researcher of a FONDECYT project in the last five years, and has guided pre- and post-graduate thesis. To evaluate productivity only ISI publications will be considered (CONICYT, 2013b).

The extract from the FONDECYT's regulations shows that the evaluation process of this programme considers publications as the main indicator of the productivity of academics. If an academic wants to be granted a FONDECYT project, she/he must have a competitive number of academic publications. The accent on publications, however, produces negative incentives towards other types of technology transfer mechanism. To make matters worse, the programme has a legal constraint on the granting of property rights to the academics and universities that may significantly reduce their interest in applying for patents. The law decree that regulates the FONDECYT (D.F.L № 33 Ley №3.541 de 1980 y D.F.L № 1 de 1980) states the following:

> If in the course of a technological development project, there follow inventions, technological innovations, or procedures which need the protection of property by the issue of patents or other mechanisms, the institution or individual seeking to protect their inventions should apply to the

> Superior Council of Technological Development. The Council is empowered to authorize the property of the invention on the repayment of the grant, according to the conditions established in the regulations of the programme. (D.F.L № 33 Ley №3.541, BCN, 1981a)

This means that when an academic would like to obtain a patent arising from a FONDECYT-funded project, then he would have to reimburse the funds granted by the FONDECYT. This requirement limits the technological development of FONDECYT projects, from basic and applied science to the elaboration of prototypes that may become innovations. This aspect of the regulation can often be shown to discourage universities and academics from applying for intellectual protection for the results of their research. A former senior civil servant claims in this context:

> Thanks to the FONDECYT there was little incentive for any sort of patenting. This programme limits aspirations even before the application process has begun (N°39, former civil servant).

The very opposite occurs in the United States. Since the passing of the Bayh-Dole Act in 1980, US universities have been permitted to claim the intellectual property rights of knowledge obtained from research undertaken with public funds (Siegel et al., 2004). This measure resulted in a direct increase in the number of patents for academic inventions, which rose from 390 in 1980 to 2,681 in 1998 (Powers, 2003:26).

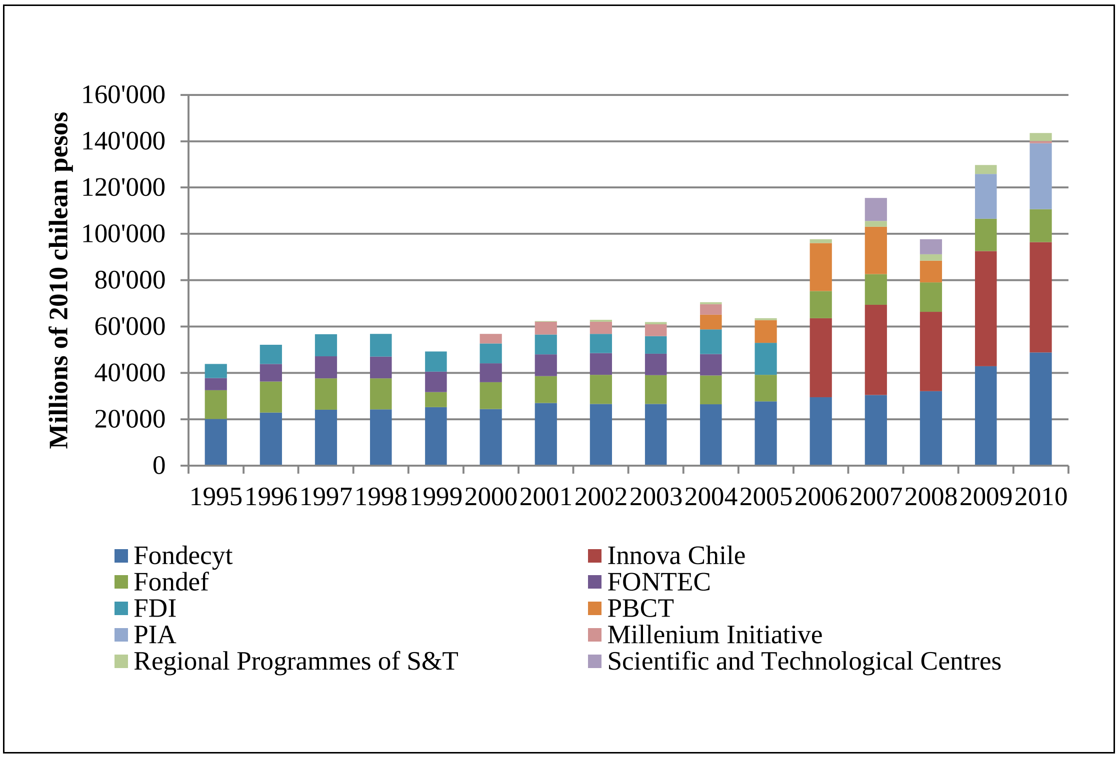
Matching grants as sources of research funds

As already mentioned, the AFD and the FONDECYT were the main sources of funding for academic research in Chile in the 1980s. There was no innovation policy in Chile country until the mid-1990s. As a response to this shortcoming, several programmes were launched during the 1990s and the budget for scientific research increased by a factor of three between 1995 and 2010 (Figure 15). The main objective of these public efforts during the 1992–1996 period was:

> to incentivize innovation in the Chilean firms and to strengthen the R&D activities through horizontal funds [this means without giving preference to particular productive sectors], oriented to institutionalize innovation as an activity, and to promote stronger interaction between government-firms and research centres-firms (MINECON, 2009:11).

In 1992 a new type of mechanism for fostering technological development was sponsored by a grant from the Inter-American Bank of Development (IDB). This new source of funding financed the creation of the Programme of Science and Technology (*Programa de Ciencia y Tecnología*, PCT) by the Ministry of Economy. The initiative was intended to create and strengthen the scientific and technological capabilities of the nation as a whole, as well as to promote technological innovation in firms (Fernandez, 2010). The PCT was organized into three funds, which were in turn assigned to selected institutions within the national system of science of technology. Part of the resources were devoted to strengthening the FONDECYT and two new funds were created: the National Fund for the Technological Development (FONDEF), which was managed by the CONICYT, and the National Fund for Technological and Productive Development (FONTEC), which was administrated by the National Development Agency (CORFO) (Fernandez, 2010). The FONDEF was oriented to support university-firm collaborative research and sustain competitiveness within the main sectors of the Chilean economy, whereas the FONTEC was intended to share the risk and benefits of technological innovations by allocating grants to firms investing in innovation (Fernandez, 2010).

Figure 15: Main programmes promoting R&D, innovation and entrepreneurship in Chile. Yearly budget 1990–2010 (millions of Chilean pesos 2010)



Source: Ley de Presupuestos (1996–2010), Academia Chilena de Ciencias (2006), Banco Central de Chile (2012).

The main benefits created by these programmes were a sizeable and significant increase in funding for researchers and universities and greater incentives for larger and more ambitious research projects. The establishment of matching grants that began with the creation of the FONDEF and the FONTEC produced an increase in the availability of funds for researchers. However, I would contend that the establishment of matching grants to promote university-firm research collaboration served first and foremost as a source of funding for academics to pursue research rather than as an effective mechanism for promoting collaboration between academics and firms.

The requirement for academics to participate with firms has resulted in a greater dependence on firms as additional agents in research programmes. The demand for academics to secure the commitment of firms was aimed at ensuring that the research being funded would reach a more advanced stage of research rather than remaining at the basic level. As a former evaluator of the FONDEF says:

> The idea was to do applied research, let's say research that was closer to development research than was otherwise being done, and they [the FONDEF Committee] kind of just gave the resources to the universities, and the participation of firms has never been important. The commitment of firms was useful to validate the research conducted. If the project had firms participating, then it was supposed to be closer to development rather than to research. (N°39, former senior manager CNIC)

With the creation of matching grants, academics were required to look to the industrial sector to identify possible partners with whom to present their project proposals to the funding agencies. A senior academic from UDEC recalls the creation of FONDEF:

> When the FONDEF programme was launched, we were very aware of what was about to happen. It was a great opportunity because those are long-term projects that require large investments. Firms are willing to listen to us, but they are not keen to invest large amounts of resources in this. We saw the FONDEF as a very valuable tool, and it is valued for the development of more ambitious, big technologies, such as the ones that we are developing now (Academic N°17, UDEC).

However, the requirement to find a collaborative commercial partner in order to apply for funding had unforeseen consequences on the attitudes of academics towards collaborative programmes: they began to look for partners mainly to access the funds. This creates a problem for matching grant initiatives, such as the FONTEC and FONDEF; the relationships originate with the academics and this influences the level of the firms' interest in the projects:

> With the creation of the FONTEC we began to have a relationship in which firms were looking a bit more to the problems of the mining companies and not the solution of immediate problems. The relationship

> was based on access to funding. That was the problem. For example, I had around five FONTEC projects since the first call for proposals in 1991. We had our interests and we proposed those projects and the firms kindly sponsored us but it was not that they had any precise interest in those projects. It was only because the government was putting pressure on firms to fund these research projects that they were moved to sponsor them in the first place (Academic N°17, UDEC)
>
> The requirement for fresh resources does make firms want to commit more, but they are always reluctant to invest resources. For us to get money is like asking for a miracle (Academic N°18, UDEC).

A quotation from a researcher from the University of Chile claims that:

> According to my experience, I prefer that the firms fund the project in its totality. I believe there is a design flaw in the FONDEF. When the idea comes from the university, and the university goes to the firm and tries to get them on board, then the firm says: fine, let's support them [but they do not have real interest] (Academic N°10, UCHILE).

Even though academics have complained about 'having to beg for funding from firms' and about a general lack of interest from firms in long-term projects, the number of applications to FONDEF has been growing constantly since its launch in 1991 (see Figure 16). An academic granted a second FONDEF-funded project after a bad experience with the first one explains his motives for applying again:

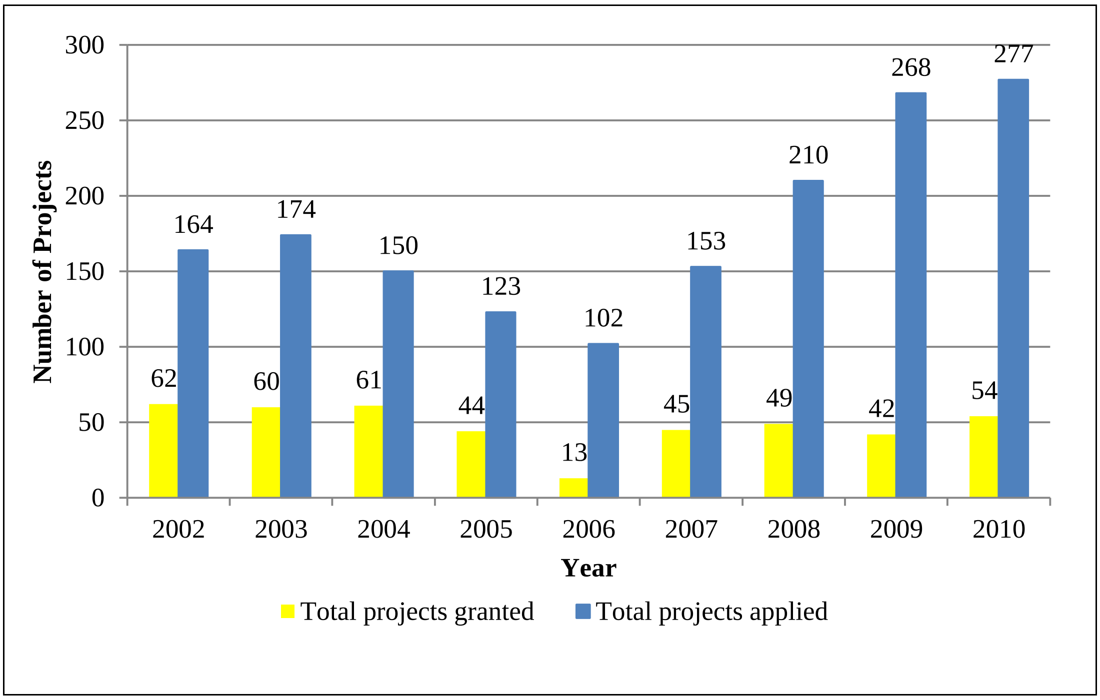
> Despite the bad experience with the first FONDEF, we went for the second one for two reasons: first, it is important funding; second, since we recognised that the problem came from the firm and since they now too see the problem, now it will work (Academic N°7, UCHILE).

While academics recognise important benefits accruing from the FONDEF grants, such as the training of young professionals and investment in research equipment, they are none-the-less aware that the number of projects that attain the development stage where research outcomes can be transferred to firms—either by creating companies or producing change in firms—is very few.

> The [funds from] FONDEF are a significant amount and that has allowed me to buy a lot of equipment, to prepare very good people, and the times are longer and without pressure. Also, academics can have good economic incentives in the FONDEF. All of these [reasons] create an interesting scheme for the academics (Academic N°22, UDEC).

> In reality, when considering the direct benefits of the FONDEF, there are several that can be observed. First, it allows us to employ young people that are engineers and are trained to a very high level. These people are then able to transfer development to firms, as the engineers who have worked on my project have done. This has had a very positive impact. I have been able to recruit these people because I can pay them competitive salaries. Second, the equipment acquired with the resources from FONDEF stays in the university. This means after the projects are finished we are still able to work with other students using equipment that we would not have been able to acquire without the FONDEF resources. Those are positive outcomes; the research activities do work; and we are very happy for that. But the percentage of those projects that reach the transfer stage and that is able to create a spin off or produce changes in firms is very limited (Academic N°21, UDEC).

Figure 16: Applications versus projects granted funding, FONDEF. 2002–2010



Source: Own elaboration based on CONICYT (2013d).

A recurrent explanation for this is that, the when the project finishes, the innovations are not yet ready to be implemented in the firms and most of the time there is no funding to cover the prototyping and development stages of the innovation process. This limits the possibility to develop and complete the projects and introduce innovations in firms.

In sum, it is clear that academics consider matching grants as an important source of funding and they are willing to contact firms and to work with them despite the problems associated with this type of funding. Despite the lack of interest from firms, academics keep applying for the FONDEF fund because it produces benefits not only for the research groups but also, in terms of the training of personnel, and for firms in general.

5.3.3 Patenting and commercialization of inventions

As mentioned in the Literature Review Chapter, commercialisation of intellectual property rights (such as patents) has been found to be less relevant than other forms of university-firm linkages in both developed and developing countries. For instance, in the case of Argentina, Brazil, and Mexico, Dutrenit and Arza (2010) found that that commercialisation of intellectual property rights (through patents, licences, spin- offs) are the least important mode of linkage despite their prominence on the innovation policy agenda. This underscores the importance of acknowledging the limited role of patenting as a mechanism for transferring knowledge between universities in firms. This section explores these trends in terms of patenting in our selection of universities and the role of the public policy in promoting patenting in these organisations.

The evidence from Chilean academics shows very limited patenting activity during the 1990s, which may reflect the fact that the academia was generally reluctant to value this area of activity (see Figure 17). In this subsection I argue that the requirement to patent the outcomes from FONDEF-funded projects and the creation of the PBCT's patenting scheme produced not only positive incentives for academics to protect their research but also precipitated a cultural change in the outlook of academics and universities on the value of patenting activities. However, since public efforts have been concentrated on promoting patenting, there has been little evidence of the effective transfer of the inventions through the commercialization of property rights.

It is important to note, however, that this section does not assess the value of patenting for the effectiveness of technology transfer between universities and firms in Chile. Figure 17 plots the trend in the number of patent applications in the universities analysed. The chart shows very limited patenting activities until 2002. The relative lack of patent applications can partly be explained by the general lack of awareness among the agents (academics and universities) about the possibility to apply intellectual property rights for knowledge created at universities and by the limited resources available for making patent applications. A former manager of PBCT and FONDEF comments on the lack of knowledge about patenting and the creation of the patenting programme at the PBCT:

> From 1995 to 2003 we were just talking and doing nonsense about patenting. When the PBTC was created [2003], a patenting programme was established because there was an understanding about the importance of technological development and also the national indicators of the time showed that in terms of its size and level of development the country was lagging behind in terms of patenting activity (N°40, former civil servant).

He continues:

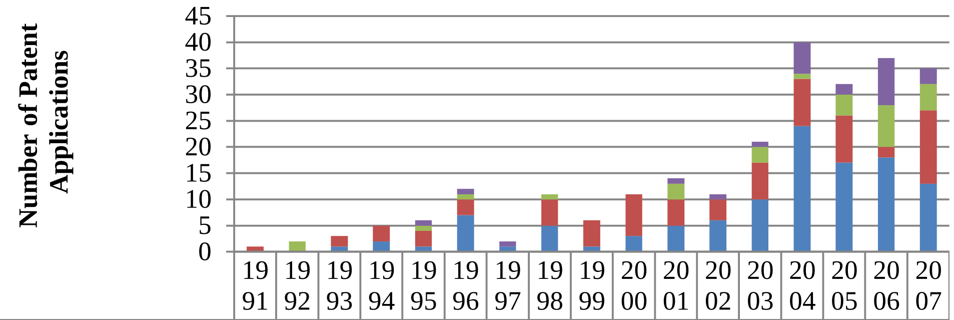
> Around 1998 there was some patenting activity, produced by some efforts at diffusion and by pressure from the funding bodies. Only from

2000 did there begin to appear a real interest in patenting projects and a positive return to doing so (N°40, former civil servant).

When asked about his first experience of patenting in Chile, a researcher also commented about the general lack of knowledge and awareness about intellectual property rights and the possibility to apply for the protection of inventions created through public funds:

In 2003–2004 no one had any idea of patenting. In fact, no one at this School had any idea about patenting. Anyone who talked about patents would have been condemned as a heretic. It was culturally not approved (N°8, academic UCHILE)

Figure 17: Number of patents applications Catholic University, University of Chile, University of Concepción, and other universities. 1991–2007



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Catholic University					1	1	1				1	1	1	6	2	9	3
University of Chile		2			1	1		1			3		3	1	4	8	5
University of Concepción	1		2	3	3	3		5	5	8	5	4	7	9	9	2	14
Other Universities			1	2	1	7	1	5	1	3	5	6	10	24	17	18	13

Source: Own Elaboration based on INAPI (2010).

The information displayed in Figure 17 (and expressed in the above quotations) establishes that, prior to the mid-1990s, patenting in Chile was largely unknown and unvalued by researchers and universities. This situation began to change after the FONDEF required the applicants to apply for patents as the final output of their projects. This encouraged some project managers to apply for patents in order to comply with the demands of the public programme:

> Around 1995–1996 patents began to have a reality of their own but most of the effort in Chile was simply copying what the developed countries were doing but without really knowing the rationale behind it. Then the FONDEF began to require the claiming of patents as an indicator of the successful conclusion of projects and, as a result, some projects began to apply for patents (N°40, former civil servant).
>
> We patented because it was possible to patent and also because there is pressure to claim patents. FONDEF says it is good to patent, so fine, we patented (N°10, Academic, UCHILE).

The PBCT's patenting programme was created as a natural step in the development of the national innovation system. Patenting was not promoted until the creation of public programmes supporting these activities.[52] The existence of this trend is clear from the statement of a senior figure within the R&D establishment at UCHILE; the statement, significantly enough, was made during a speech on the launching of an internal grant from the PBCT aimed at covering the costs of patenting, and to some extent reflects the attitude held by the university and by his academic peers. Clearly, the quotation reflects the lack of cultural awareness in universities about the value of patenting during the early years of the patenting programme:

> In general, our university publishes more than a thousand ISI articles every year, while the annual number of patent application is ten … To patent is not something we look for, is not something that is valued, is not something considered an academic achievement … This programme is intended to change that perception and to recognise the value of creativity (Extract from discourse, UCHILE (2007).

[52] The number of patents applications per million of inhabitants is generally used as a proxy to measure the innovation performance of countries (OECD, 2005b).So it may be possible that the promotion of this activity was aimed at increasing the quantifiable innovation performance of the country rather than at responding to evidence from developing countries that university patenting contributes to innovation in firms.

The patenting programme operated by granting funds to universities and non-profit organisations with the resources to implement their own patenting schemes. These organisations were then required to allocate the granted funds to projects working on inventions engaged in the formulation of novel and patentable solutions to technical problems in a particular sector (University of Chile, 2011). The programme also funded diffusion and training initiatives to promote the protection of inventions (CONICYT, 2013e).

In each of the three universities studied, the programme directly contributed to an increase in the number of patent applications. PUC and UCHILE applied for more patents during the period 2005–2007 than they had applied for in the previous fourteen years (1991–2004) (see Figure 17). UDEC has continued its steady trend of patenting activity from the 1980s. The difference in patenting activity between PUC and UCHILE, on the one hand, and UDEC, on the other, may be explained by the differences in culture and path development between these organisations. The existence of researchers at UDEC who were familiar with patenting from experiences abroad, may have encouraged others to apply for patents as a way to protect their inventions, over time, may have helped create an environment that facilitated and valued patenting activity. The importance of this international experience is clear from the words of a senior academic from UDEC:

> I began to patent around twenty five years ago, because of personal interest. Here it was almost unknown to patent. I began because I had experience in Canada where I worked and where several of the developments in which I participated were patented. I saw that the patents were sold, but since I was only an employee, I had to sell the patents to the company for one dollar. Yet, I saw that some of them could actually have real value (Academic N°18, UDEC).

Table 25 compares the total number of patent applications that were the product of projects funded by the FONDEF and with the total number of patents applications from universities. Since the FONDEF is one of the several programmes to foster technological development, and yet represents close to half of the patent applications, it is not unreasonable to draw the conclusion that universities mainly— if not only—undertake research and apply for patents when their researchers have secured public funding.

Table 25: Patent applications created from FONDEF projects versus total patents applications from universities in Chile, 1993–2008

Period	Patent Applications FONDEF's Projects			Total Patent Applications			Participation Patent Application FONDEF on Total Applications		
	UDEC	UCHILE	PUC	UDEC	UCHILE	PUC	UDEC	UCHILE	PUC
1993–2002	16	3	5	38	6	5	42%	50%	100%
2003–2008	20	10	11	49	24	23	41%	42%	48%
Total Period	36	13	16	87	30	28	41%	43%	57%

Source: Own elaboration from INAPI and FONDEF databases, and UDEC (2010).

The creation of these additional and novel mechanisms to fund research produced an opportunity for universities to strengthen their organisational capabilities to promote and support patent applications. As will become clear in the next section, the patenting programme was very well received by the recently created units managing technology transfer in the universities, which saw this new type of funding as a mechanism for consolidating and increasing their activities. According to a former civil servant:

> There was a new interest in the patenting programme, but only because the units [inside the organisations] wanted to have more work to do, not because universities as organisations were interested in patenting ... It was not necessary to convince the university administrations to participate, because it became fashionable to be awarded a patenting grant. These patenting grants are related to innovation and that it is what

> the universities are perceived as doing, therefore it became a platform for universities to broadcast their quality. The same applies to the academics ... it was not necessary to convince the universities to participate, since it was read as a message from the government . . . something along the lines of 'either you [universities] patent or there are no more projects' (N° 40, former civil servant).

The patenting programme produced an important shift in attitudes towards patenting and encouraged the view that it was necessary to foster this activity in order to continue to receive public funding. The former civil servant already quoted, continues: ‘it [patenting] became a topic on the agenda of the research programmes and on the agenda of the government’. However, the programme did little to promote the transfer of these inventions to firms and, consequently, universities once again proved reluctant to do anything without public support.

Commercialization of patents

In terms of patenting activity, the University of Concepción has been the most active among the universities of Chile. However, in regard to the licensing of these patents, the university has achieved limited results. Table 26 shows the trend in the number of license agreements negotiated by the university since 2007. These results mostly represent license agreements secured by academics, working on behalf of themselves. A manager of the newly created TTO comments:

> Most of the licenses agreed by the university have been [granted] to start-ups [created] by our academics. It is a natural process: the academic gets interested, the incubator supports him, and so the academic and the university negotiate an agreement to have everything in order (N° 38, technology transfer officer UDEC).

Table 26: Number of licensing agreements UDEC 2007–2012

Year	Number of licensing agreements
2007	0
2008	0
2009	3
2010	1
2011	2
2012	1

Source: Unidad de Transferencia Tecnológica, UDEC (2012).

If we only consider those factors that have hindered the commercialization of licenses within universities, the two most important are the lack of experience of working with patents and the limited organisational capacity for commercialization of the inventions. Both factors are especially relevant when observing UDEC's oldest patents. The lack of a professional vision and experience is clear from the practice (pursued by many other universities as well as UDEC) of sharing property rights to the inventions. This practice severely limited the possibility of any commercialization activities. As one manager comments:

> If you look at the oldest patents, you will find that the university used to share the property [of the inventions] with the academics or the firms. Some years ago, a decision about this was made because we realized that [sharing the property of the inventions] was detrimental to the management of technology transfer, because you would possess a patent of which you were not the entire owner. This at least in the Chilean legislation required you (in practice) to have to agree with all the partners. Therefore, some years ago, it was established that everything that a research project develops and produces with clear protectable results should be completely owned—and I do mean, the entire 100%—by the university without any sharing with academics or firms. (N°38, TTO manager, UDEC)

The limited commercialization of inventions produced at UDEC may also be a consequence of the paucity of the organisational structure for managing technology transfer activities. In fact, tellingly, it was not until 2012 that a unit dedicated to these activities was finally established at the university. Before then, the technology transfer activities of the university were managed by an employee working half-time on them. As the manager of the university's recalled:

> We did have licenses and we still have, but it was all very sporadic; there were few efforts on that front, indeed there was not a single person dedicated full time to that [commercialization] (N°38, TTO manager, UDEC).

In PUC's case, even though the monitoring data about this type of activities is extremely limited, there are nevertheless a few successful cases of patents being licensed. However, the commercialization of property rights in this university should not be credited to any coordinated or systematic organisational efforts but to the personal efforts of particular, entrepreneurial academics. This view is supported by the following quotations from an academic and a manager of the university's research incubator:

> So far all the developments that have been created up to this year [2011] have occurred without much planning. What successes have been achieved belong to the natural entrepreneurial inclinations of academics who have developed their own businesses and created spin- offs when the opportunity was suitable. (N°31, Manager, Technological incubator PUC)

> It is very difficult to commercialize the outputs of the projects when these conclude. Universities are not good at doing that (Academic N° 28, PUC).

An example of this trend is supplied by the case of the Dean of PUC's school of engineering. In the early 2000s he founded and created a company that designs, produces, and implements solutions to protect the structures of buildings from earthquakes. Since 2001 he has been supported by a renowned external international entrepreneurship organisation and his company is currently valued at $300 million (ASECH, 2013). His achievements, as well as the commercialization activities of his colleagues, nevertheless remain exceptional cases that highlight the importance of personal interest, professional expertise, and serendipity.

In the case of UCHILE, technology transfer through the commercialization of property rights remains a non-institutionalized activity. While there are independent efforts in individual departments of the engineering schools, these remain uncoordinated and the process of commercialization continues to be rudimentary:

> The theme of commercialization is not institutionalized at the university, it does not exist. What we can say is that there are particular efforts in some research centres where there are units devoted to technology transfer... in order to make the patent work someone needs to try to sell it… It [individual commercialization efforts of patents] is a big financial effort if there is no one devoted to exploiting the patent, trying to commercialize it, then nothing will happen (N° 2, Academic and Manager of a research centre, UCHILE).

So far we have explored those factors *within* universities that inhibit the commercialization of inventions. But there are also issues directly related to the innovations themselves. Even after the patent is granted, the gap between applying for the patent and developing an innovation can be implemented in firms can be a long one. This delay often increases the difficulties in the process of commercialization, as is made clear in the following:

> Claudia: So what happened after you applied for the patent [produced by a FONDEF project]?
> Interviewee: Nothing happened. I am happy having protected the invention with a patent.
> Claudia: Do you have plans for the patent?
> Interviewee: I believe it requires a lot of investment to make it a saleable product; it is not so easy (Academic N°5, UCHILE)

> In this area [materials engineering] when you create a new material, eventually you create a new application. The escalation process is, however, very expensive. (N°4, Technology transfer manager, UCHILE).

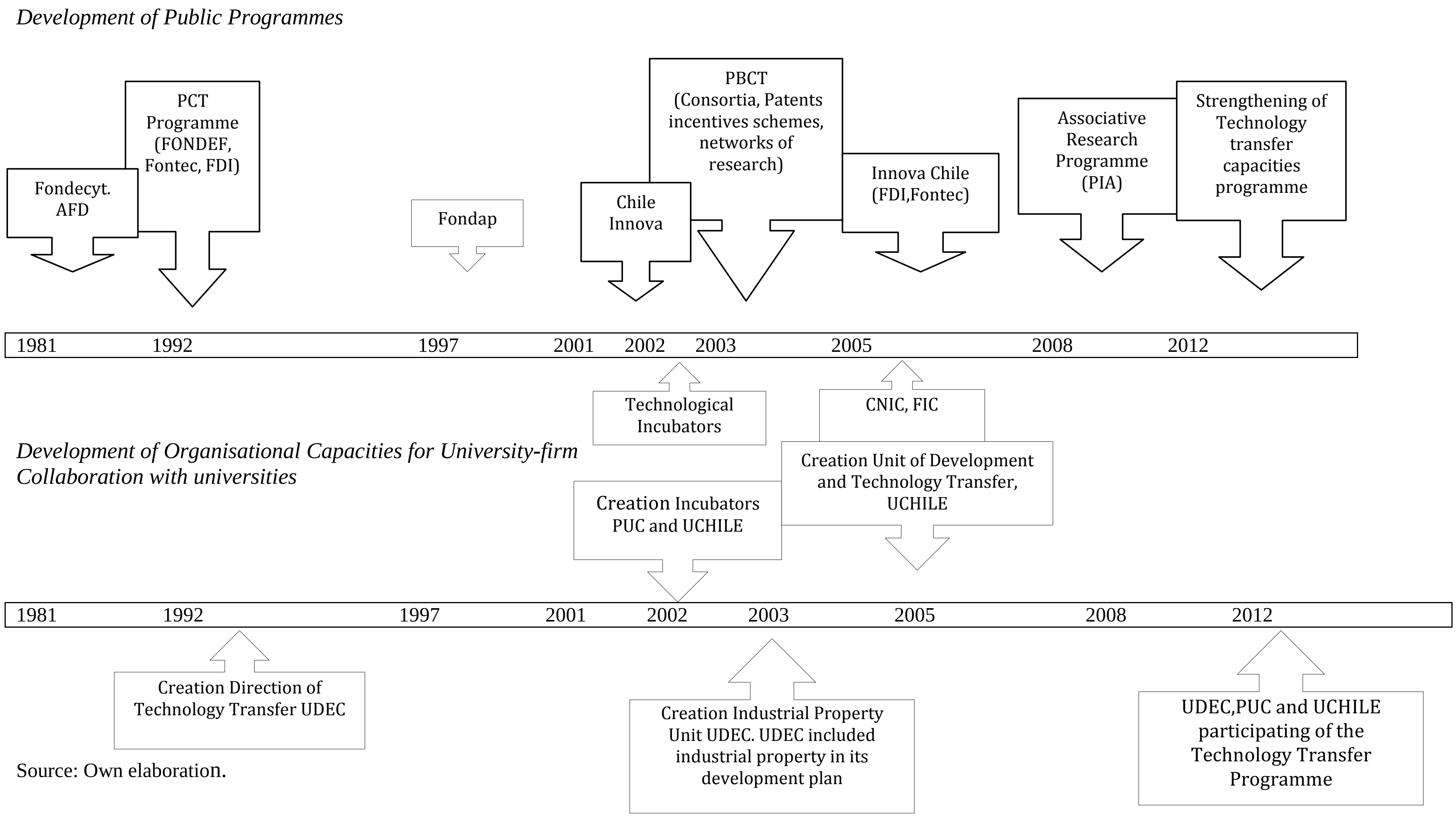
> Now, there is the patent, I do not think it has a lot of potential, it is so basic" (N°5, Academic UCHILE)
> Since in order to patent, you need results, at the end of most projects, the maximum that is achieved is to apply for the patent. Afterwards, however, most of the academics forget about the application and they move on to other projects. (N° 40, Former civil servant)

We can see from the quotations above that patenting does not necessarily mean that there is transfer of technology. Two explanations for the lack of commercialization and technology transfer from the university may be advanced. First, if patenting is pursued solely to comply with the grant regulations and without an interest in commercialization, then it is difficult to continue developing the research without the necessary resources. This clearly diminishes the likelihood of future development of innovations produced in the universities. Second, the technologies developed are usually not ready to be implemented in firms and since academics have no further responsibility, other than applying for a patent, for transferring their technologies, the project often finishes with the application for the patent rather than with the transfer of research outcomes to the firms. These conclusions, however, need to be put in the context that patenting is less important than other mechanisms to disseminate technologies to firms (Agrawal and Henderson, 2009), and that is unlikely that university led activities of commercialisation intellectual property rights drive technological change in firms if these have low absorptive capabilities, such is often the case in developing countries.

5.4 Creation of organisational capacities in the universities

Throughout this section I argue that the creation of organisational capacities for technology transfer in the three universities has been largely driven by trends in the innovation policy. This means that, as public funds have become available, the universities have created new roles and units, and developed better project managerial skills but, since there is limited funding to promote the commercialization of inventions, there has been limited organisational development in this area. Figure 18 shows the timeline of the creation of public programmes to promote technology transfer and the related organisational development of the three universities. From this figure it is possible to observe that the creation of organisational capacity to support technology transfer in the universities has largely occurred in response to the creation of public funds.

Figure 18: Timeline of the Creation of public programmes promoting innovation



Source: Own elaboration.

The new capacities are designed to support academics in two main areas: (i) to facilitate the work of academics by providing administrative and managerial support for the execution and successful realisation of projects; and (ii) to increase the likelihood of academics receiving the applied-for grants by building expertise in applying for public funding. Universities have developed from offering basic support services, such as organizing the diffusion and management of individual projects (FONDECYT), to providing more advanced support to applications for, and management of, larger collaborative research projects (FONDEF and other matching grants). Indeed, universities have moved from running programmes in which proposals were entirely prepared by the academics and where their role was largely confined to authorizing applications, to taking a more active role in the management of multi-purpose projects, preparation of complex business plans, and formulation of potential commercialization strategies for the products created by the research.

The analysis shows, however, that the growth in funding to promote technology transfer resources has meant that the universities have specifically developed organisation capacity to take advantage of these new resources and appear to have made little effort to commercialize the inventions, so that their capacities in this area remain relatively undeveloped. This is clear when analysing the organisational structures dedicated to technology transfer within these three universities.

Catholic University (PUC)

The Catholic University has devoted specific personnel to the management of basic science projects (FONDECYT) and applications for collaborative research projects

(FONDEF and other matching grants programmes). It has also established an Intellectual Property Unit. However, this is the limit of support provided by PUC's central administration; as soon as the contractual arrangements have been set up and the project begins, support from centre comes to an end (PUC, 2013). A manager of the research unit at PUC explains the role of his department:

> The calls for applications are transmitted to the academics, we organize workshops and we establish an internal calendar. That calendar basically serves to manage the timing of the applications to comply with the internal requirements of the proposals, such as the creation of the business model, the development of the exit strategy, and the options available to the university concerning intellectual property, business rights, and a sustainability strategy" (N° 27, Manager PUC).

PUC owns an independent firm (DICTUC S.A.) that is in charge of the consultancy projects, the matching grants of the engineering school, and the technological incubator for the whole university. DICTUC manages each academic's project as an independent business line, as mentioned by one academic:

> We do consultancy through DICTUC ... Usually we respond to calls for proposals or we get contacted directly. So, we prepare the proposals and the management of the project is done by DICTUC (Academic N° 29, PUC).

The webpage of PUC's technological incubator (IncubaUC[53]) reveals that the university's main efforts on technology transfer are conducted through the use of public funding. The following information appears on the website of IncubaUC under the heading, *What we offer*:

> Funding: IncubaUC gives you access to public funding to move your idea to the market through grants from CORFO, as well as private funding through CORFO's network of Angel Investors and several national and international Venture Capitalists (Incuba UC, 2016).

[53] IncubaUC is part of DICTUC S.A.

This appears to be in line with the expected general functions of an incubator. However, in its internal call for projects to join the incubator, there is the following statement:

> The winning projects will be accepted onto the IncubaUC High-Tech Programme, and they will be incubated, supported, and presented to the *available public grants* [emphasis my own] with the purpose of fostering the technological packaging of these technologies or securing the commercial initiative in the market through the Seed Capital available in InnovaChile-CORFO.

The above statement shows that despite the fact that IncubaUC defines its role as promoting technology transfer between different types of possible investors, in practice its technology transfer efforts are performed through public funding.

University of Chile

A similar organisation of roles occurs at UCHILE. Support for academics and departments in this university is primarily expressed through administrative assistance in orchestrating the details of projects involving the university and firms, and continues throughout the life of the project, especially when different funding bodies require periodic reports. At this university, the Directorate of Development and Technology Transfer is in charge of managing intellectual property rights, technology transfer activities, and university-firm interactions. The mission of this Unit is, as the UCHILE website declares:

> to link the University of Chile with [organisations from] the private and public sector, particularly [with] firms, with the purpose of promoting the identification of opportunities for interaction with the university system, government, productive sectors, and with the national and international community (UCHILE, webpage, 2011).

The Unit was created in 2005 and until at least 2011 was staffed by only two professionals paid from the university budget (director and secretary); the rest of the professional team (approximately five people) was paid from leveraged overhead funds from projects and other sources. A former senior manager of the Unit states:

> I began by myself in 2005, now I have six people with leveraged funds, this is what frustrates me. I paid one girl using resources from the FONDEF; another one is paid with money from the European Union, while another person is paid with the overheads of the patents, and so on. Everyone is hired as consultants. Therefore there is a high rotation of personnel. All of this is immensely frustrating (N°6, former senior manager UCHILE).

At the engineering school of UCHILE there is an independent unit in charge of managing consultancy and FONDEF projects in the engineering school: the *Fundación para la Transferencia Tecnológica* (UNTEC) (Foundation for the Technology Transfer). This non-profit organisation was created in 1989 'to promote and perform all type of activities that lead to a better utilization of technology in the social, cultural, and economic development of the country' (UNTEC, 2013). In practice, this organisation has two main roles: first, to facilitate the management of consultancy projects by reducing organisational bureaucracy by allowing academics to sell consultancy projects as part of UNTEC rather than as part of the university. Its second role is to oversee the management of large matching grants—such as the *Technological Consortia Grants (InnovaChile-CORFO).* A senior manager of UNTEC describes the organisation's role in the following way:

> In practice this is an administrative office that facilitates the management of the projects ... The team is formed by seven people, all managers. They manage the CORFO projects and the private consultancy projects (N°11, senior manager UNTEC).

University of Concepción

At UDEC the technology transfer activities are managed by the Unit of Industrial Property and the Directorate of Innovation and Development. These units depend on the Vice Directorate of Research and Development (*Vicerrectoría de Investigación y Desarrollo*), which was created in 2011 (UDEC, 2011). Since 1987, UDEC has demonstrated its commitment to its stated policy to promote university-firm links.[54] One academic had this to say about the support provided to academics UDEC:

> The university provide us with a project engineer, because these projects [FONDEF] have lots of bureaucracy, so it is often necessary to pay a guarantee and do lots of other things. This is managed by the university's project engineer. We only have to concentrate on doing our research—and about nothing else. And he [the engineer] has to deal with all the related bureaucracy. For instance, he is in charge of the expenditure of money and we are only required to send regular reports about the research advances of the projects. Because of the bureaucracy of the projects, the university provides project engineers who are usually industrial engineers, and each of the engineers manages a small portfolio of projects (Academic N°25, UDEC).

In 2009 UDEC established an intellectual property section to support the patent application process for its inventions. The creation of this unit has facilitated more effective applications to public programmes. A researcher at this university declares:

> Now there is a patent office in the Research Directorate. This confirms the idea that patenting has real relevance for the university (Academic N°18, UDEC)

[54] This policy is revised every five years within the framework of the university's five-year strategic plan (Santibañez, 2004).

This new unit complements the role of the innovation unit, which is in charge of supporting applications for the FONDEF and other matching grants. A manager of the UDEC says:

> Now that we have the intellectual property unit, we are in a better position. This constitutes an important change for us, because if we have any doubts about anything we invite an intellectual property expert to the meetings (N°20, Manager UDEC).

UDEC also manages the consultancy projects of their academics through the Institute of Technological Research (*Instituto de Investigaciones Tecnológicas*), whose objective is ‘to promote, coordinate, and manage the provision of services to third parties in the field of research and technology transfer, technical assistance, and continuing education’(UDEC, 2013).

The three universities examined share some similarities but they also present important differences. In all three cases, there is an established *unit* in charge of the management of property rights. All three universities have incubators, which were created through the funds of a public programme. Additionally, the universities have independent organisations in charge of managing the consultancy and non-research relationships with firms. These organisations have been in existence at the universities for a long time. In the case of UCHILE and PUC these offices are also in charge of the management of the FONDEF and matching grants. In practice, the units identified as TTOs are used by the universities and academics as a bridge for working with firms on projects that mainly involve consultancy and laboratory testing activities. These types of university-firm linkages are typical in the universities studied and they are focused on short term projects.

In 2012 the *Fortalecimiento de Oficinas de Transferencia Y Licenciamiento* programme (Fortalecimiento de Oficinas de Transferencia y Licenciamiento) was created by InnovaChile (CORFO). The programme was designed to 'improve the institutional management and practices for an efficient and dynamic system of management of intellectual and industrial property' (InnovaChile, 2011) and it constituted a bold public strategy to strenghten the technology transfer capacities of Chilean universities. Again our three universities applied for these newly available funds and were accordingly granted projects that allowed them to strengthen their technology transfer capacities. The projects were timed to begin in late 2012, and by early 2013 training was underway. In the UDEC's case, 'they [the personnel from the Technology Transfer Unit] are just beginning their training in the formation of technology transfer capacities' (N°38 manager TTO, UDEC). Before the establishment of this programme, the universities made limited efforts to create technology transfer capacities. As the same manager states:

> Now in this new unit, if before I would devote 20% of my time to this [technology transfer activities], now I devote 100% of my time to technology transfer. I have even have hired an additional person (Manager, UDEC).

Although commercialization of the universities' projects' outcomes has so far been limited, UDEC is the university with the highest organisational development in this area. Its technology transfer activities are more institutionalized than in the other two universities. Despite the fact that UDEC is still creating capacity in technology transfer and has only limited experience in the licensing of patents, there are individual, institutional, and environmental factors that distinguish it from UCHILE and PUC.

The university has been working with firms since the 1980s, especially in technical assistance programmes. About these linkages with firms a senior academic recalls:

> During the 70s, there was not a lot of contact with firms, and so interactions with firms were sporadic. During the 80s, the number of contacts with firms increased and all the academics were already trained, and then we had important linkages with firms. The relationship with the industry was oriented to consultancy and the solution of immediate problems (i.e. technical assistance). Until the late 80s the mining industry would not fund long-term research. It was during the 90s that—through the funding from CORFO and CONICYT— the mining companies began to look at non-immediate problems in their industry (Academic N° 17, UDEC).

The presence of several industries in the region has been identified as a reason for the university's relatively long history of collaboration with firms. A manager of the technology transfer unit recalls comments from the Vice Dean of the R&D:

> The presence in our region of forestry, fishing, petrochemical, and iron and steel industries helped create closeness with firms . . . The researchers created linkages and conducted many projects of technical assistance to the firms . . . In August 1976 there was a Direction of Technical Assistance, and this changed its name to the Division of Technical Assistance in 1983. In October 1993 this became Division of Technology Transfer. This unit then took over management of the FONDEF projects. Today this is the Directorate of Innovation and Development. (N°20, manager UDEC)

About this team’s experience of managing the linkages with firms, a Directorate manager states:

> I have been in this position since 2003 and most of the team has plenty of experience in their roles because they have been there for a long time. We get excited with the applications and we get happy when our projects win (N°20, manager UDEC).

Despite the fact that UDEC had been working with firms for a long time, its interactions mostly focused on the solution of immediate problems and did not involve the transfer of novel technologies. It was the creation of new sources of funding requiring additional capacities at the universities, as well as the promotion of property rights by the government, which proved decisive in encouraging universities to create organisational capacity in this area. The programmes created by the PBCT—directed to promote university-firm interaction and technology transfer—offered universities opportunities for development in technology transfer. The creation of institutional awareness of the potential value of intellectual property rights has moved universities to allocate resources to the creation of work in technology transfer activities. This organisational development has been largely financed by public funding; when public funds have not been available, only very limited efforts at technology transfer have been made. However, the case of UDEC shows that the technology transfer expertise created with internal resources gave this university its unique experience in this area and allowed it to use the public funding to expand rather than create technology transfer capacity. In time, this experience and deployment of resources may help UDEC to establish a platform from which to enhance its technology transfer performance.

5.5 Discussion and implications

This chapter has analysed how public policy incentivizes academics and determines their choices between different mechanisms of technology transfer, and how it influences university-firm collaboration and technology transfer capacity in universities. The main findings from this analysis show the following.

(1) Since the number of publications is the most important indicator in the allocation criteria of the AFD (which is the largest governmental source of

funding for higher education), universities value academics publications more than any other mechanism of technology transfer and evaluate their academics accordingly.

(2) Academics are required to secure FONDECYT funding to be considered successful in their respective academic fields. At the same time this programme's evaluation criteria consider academic publications as a proxy for research productivity. This programme requires that funds be reimbursement if an academic chooses to protect their invention and this regulation appears to have undermined interest in patenting.

(3) Collaboration with firms through matching grants is recognised by academics primarily as a mechanism for accessing research funds and only secondly as a way to access new sources of ideas and to contribute to economic development. In addition, academics perceive a lack of interest and commitment from firms, which produce inconsistent incentives for academics but do not seem to influence the level of collaboration.

(4) R&D collaboration does not necessarily translate into technology transfer. A key reason behind the growth in the application for patents since 2003 is the creation of public programmes to support this activity.

(5) The technology transfer capacity of the three universities is in an early stage of development; but this development has been almost exclusively a response to the growth in the public funding for such work. The technology transfer strategy of the three universities is focused on obtaining public funds.

Table 27 summarizes the public instruments studied and the impact of the incentives on the technology transfer mechanisms analysed and the direction of the incentives.

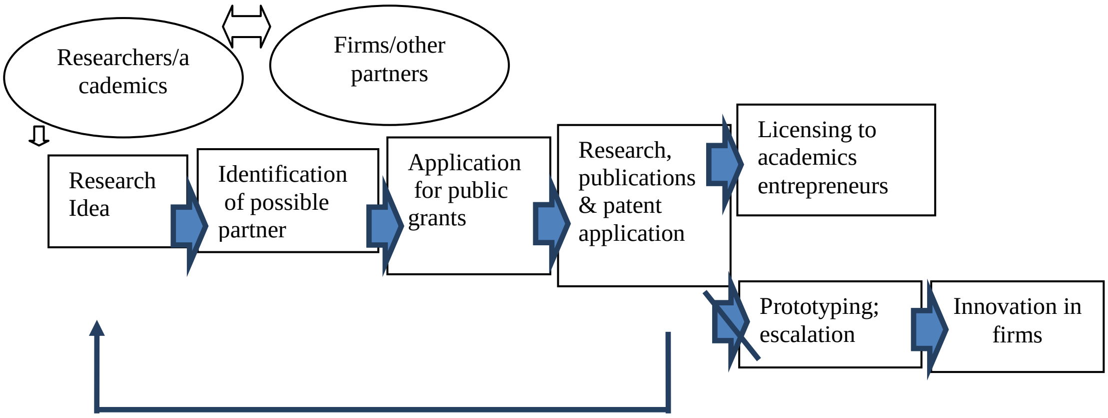
Table 27: Public policy instruments and the incentives they produce in selected technology transfer mechanisms

Public policy instruments	Academic publications	Patent applications	Collaborative projects with firms	Commercialization of knowledge
AFD	positive	negative	neutral	Neutral
Matching grants	positive	positive	positive	Neutral
Patenting programme	neutral	positive	neutral	Neutral
Academic standing (reputation)*	positive	positive (just in recent years, previously it was negative)	positive (mostly in UDEC)	Neutral

*Academic standing is not a public policy instrument. However, I have included it here because its effects on academics and universities are closely related to the effects produced by public grants mechanisms on these agents.
Source: Own elaboration.

The growth in the type and number of public programmes has contributed to the consolidation of the national system of innovation in Chile, but it has also created new demands on the universities. These organisations are required to provide effective organisational structures to manage the relationship between the different sources of funding and their particular mechanisms of administration. However, the evaluation system of the public grants may also have produced incentives for the universities in terms of research orientation and a public dependency on the government to fund their activities. The government is aware that the incentive structures within universities have not favoured university-firm linkages (World Bank 2009:11), yet it has not paid attention to the impact of its own incentive systems on the attitude and activities of academics and universities in relation to university-firm linkages and the relative importance of public grants.

From the foregoing analysis it is possible to advance the following model of R&D collaboration between universities and firms. The figure shows that an academic has an idea, contacts a firm to apply for a public grant, conducts the project, applies for the patent if and when it is possible, and then returns to another research idea. The process thus begins all over again. If the academic identifies a potential entrepreneurial opportunity and if he is interested, then he may license the patent for his invention from the university. Since there are no resources to implement and realise the subsequent stages of development, this is where the process of technology transfer finishes. The creation of knowledge through matching grants occurs in the following way:



This model offers an appropriate response for academics and universities according to the features of the innovation system in Chile, where there is limited demand for research from firms and where the public sector is the main source of funding for research. The research funding is designed to produce research of quality, whether or not it is oriented to industry. In order to reduce the asymmetries of information about the research capacity of a researcher, the use of the number of scientific publications serves as an adequate signal of quality and originality. But excessive attention on this indicator may hinder other mechanisms for transferring technologies, such as patenting. At the same time, public policy should not concentrate its technology transfer efforts exclusively on the promotion of patent applications because, if the indicators are misperceived as the goals of technology transfer, universities and firms may engage in counterproductive activities and produce outcomes not expected by the public programmes (Langford et al., 2006).

It has been argued that knowledge transfer is a significant source of funding for universities because they will obtain resources from commercializing technologies (Geuna and Muscio, 2009). Technology transfer is, in fact, used as a source of research funding, but not because of the income generated by patents but because of the public funds granted to promote the transfer of knowledge and university-firm linkages.

The technology transfer process is far from finished or secured by applying for patents; inventions still need to be licensed to firms and organisations. Despite the fact that universities have policies around sharing the benefits of inventions with researchers, academics are not encouraged to sell the patents and to commercialize their inventions. Therefore, the 'perceived potential income of academics' is almost non-existent. This undoubtedly explains why academics find it more profitable to apply for a new research project rather than pursue commercialization rights on their own. The licenses in our three universities were, on the whole, granted to exceptional academic entrepreneurs.

In addition, the lack of commitment from firms participating in matching grants also appears to influence the interest of academics in working with firms. This finding is in line with the work of Barbolla and Corredera (2009) on the factors influencing successful technology transfer in universities in Madrid. These authors found that the firm's interest in a project is a decisive factor in the success of the technology transfer. The authors claim that one sign of a firm's interest is the distribution and allocation of its own resources and they found evidence of lower rates of success for subsidised projects. Therefore we might expect that a lack of interest may reduce the potential success of the technology transfer. The lack of interest from the firm in a matching grant project may give additional control of the project to its academic directors, who may re-orient the project according to their own research interests instead of those of the firm. This could further reduce the potential transfer of technologies to the companies.

At the same time, my findings show that most of the innovations produced from collaborative research projects are not ready to be implemented by the end of the project and that firms are effectively not prepared to carry on with the prototyping and escalating process. This produces a gap in the potential transfer of technologies, which is not covered by public resources or firms.

In conclusion, if public funding for innovation and technology transfer is to produce the desired changes in universities and firms, it is necessary to: (i) evaluate carefully the expected goals of the research programmes (considering the essential characteristics of the agents involved) and (ii) align the incentives accordingly.

Chapter 6: Incentives in Chilean Firms

6.1 Introduction

So far I have discussed the development of Chile's national innovation system and the efforts the country has made to reduce the market failures related to innovation since the 1990s via innovation and industrial policy. In the previous chapter, I examined the effects of public policy on the incentives for universities and academics to collaborate on R&D projects with firms and to transfer technologies. This analysis concluded that public policy had created incentives that lead academics to interact with firms in order to access to R&D funding, rather than to increase technology transfer and strengthen the linkages between these two worlds.

In this chapter I focus on the other side of these interactions—the firms—and analyse the macro, meso and microeconomic incentives that they have to conduct R&D collaborative projects with universities. The chapter aims to contribute to the understanding of how firm-level strategies and innovative activities interact with the macro environment in which they operate (Chang et al., 2006). Throughout the chapter, I argue that negative complementarities between the productive structure of the economy, the type of capitalism present in Chile, and a lack of absorptive capabilities in the firms themselves, have created an environment in which R&D is not critical to growth. Furthermore, the lack of capabilities of these organisations, combined with the coordination and information costs associated with collaboration, has made universities a potential partner for only a few firms.

The arguments presented in this chapter draw on in-depth interviews with representatives from industrial sectors in Chile, academics from the universities studied in the previous chapter, official reports and quantitative information produced by national and international organisations, and aggregate data from two surveys—the EIT and the National Survey on R&D[55]—which have been developed by the Ministry of Economy (MINECON) to collect data on R&D and innovation activities in Chile.

The chapter is divided into seven sections. Following this introduction, in section 2 I consider the productive structure and type of capitalism in Chile and the consequent lack of macro-pressure on firms to innovate or upgrade. In section 3 I characterize the innovation efforts of Chilean firms, the relevance of R&D to firms, the role of universities as research partners, and how the innovation capacity of firms has limited the benefits to be gained from open innovation strategies involving universities. In section 4 I discuss the factors influencing the relevance of universities as collaboration partners to firms. In section 5 I examine barriers to university-firm collaboration, which include the poor understanding of firms' innovation demands, the timeframes for innovation, and the coordination and information costs. In section 6 I consider the role of the tax credit as a policy to foster R&D linkages between firms and universities. Lastly, section 7 discusses the main findings and conclusions from the analysis.

[55] In order to follow the guidelines from the OECD, in 2007 the Chilean Government separated the collection of data on innovation from the collection of data on R&D activities. The R&D survey is not a representative survey but its sample is built based on a directory of firms that could potentially have been engaged on R&D activities (MINECON, 2014c). This survey collects detailed information about the R&D activities of firms and other sectors in the country.

6.2 Productive structure and competitive pressure for innovation and upgrading

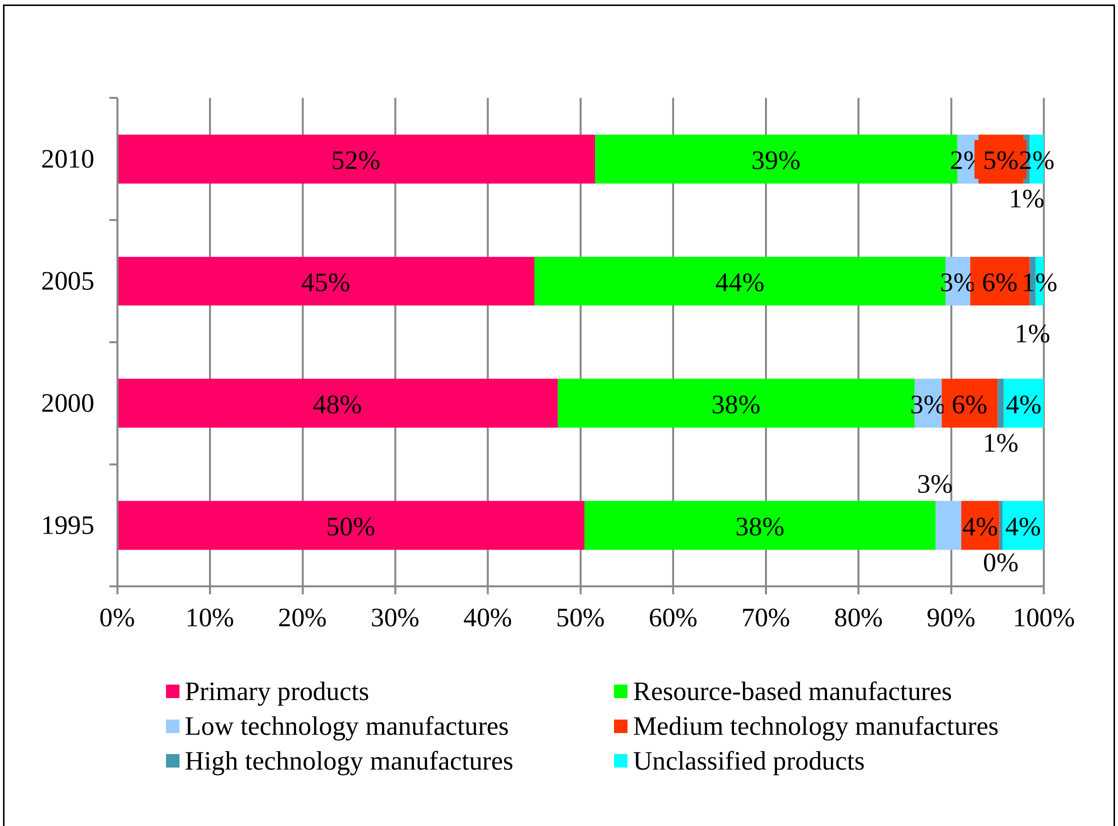
As discussed in Chapter 4, Chile's comparative advantages in natural resources, have framed the productive structure of the country. In this section I argue that the present productive structure of the country—which has the qualities of a hierarchical economy—helps to explain the type of innovation efforts made by Chilean firms and the lack of importance given to R&D activities in their innovation strategies, which has directly influenced the selection of universities as innovation partners by firms.

The market reforms carried out in Chile since the 1970s, and throughout the region, have meant that Latin American economies have specialized in the production of goods based on natural resources and unskilled labour (Katz, 2012). Chile's exports are largely concentrated in primary and resource-based manufactures (see Figure 19). Indeed, the new exports created since the reforms, were almost exclusively from the forest and food sectors.[56] This means that the diversification of Chile's economy has taken place mainly within natural resources. By contrast, exports of medium or high technology products have gone from just 4% to 6% between 1995 and 2010. According to the OECD (2011), however, the specialization of the exports reflects not only the pattern of comparative advantage that this country has in natural resources, but also a strategy of trade liberalization and export-led growth existing in this country since the 1970s. The work of Agosin and Bravo-Ortega (2009) argues that the fact that growth has been driven by the consolidation of

[56] These include wood products, pulp and paper, fruits and vegetables, fishmeal, other ocean products, cultivated salmon, pork meat, poultry, milk products, and wine (Agosin and Bravo-Ortega, 2009: 4).

comparative advantages in natural resources, and manufacturing as been practically absent, marks a clear distinction between Chile and the Asian countries whose export growth has been driven by the creation of new comparative advantages in manufactures.

Figure 19: Exports composition Chile by technological categories 1995-2010



Source: Own elaboration based on data downloaded from unctadstat.unctad.org on 4 February 2016. *Exports in thousands of dollars. Products categorized according to Standard International Trade Classification, Rev.3 (SITC rev.3) and technological categories (based on Lall, 2000).

The significance of primary products (mainly copper) and resource-based manufacturing was increased by the commodity boom of the 2000s, which produced a concentration of exports not only in Chile but also in the Andean area (Devlin and Moguillansky, 2012). In Chile, the boom saw copper rise to a peak of 57% of the total of exports in 2006 and an average of 52% during the 2004-2014 period (COCHILCO, 2016). This increase, however, was not due to increased production but was chiefly the result of price effects (Meller and Simpasa, 2011: 17).

Table 28 presents the participation of the economic sectors in Chilean GDP. The data shows that the financial and business services sector has increased its participation from 5.2% in 1970 to 19.1% in 2014. In the same period mining has gone from 8.8% to 11.2%. In contrast, manufacturing has reduced its participation in GDP from 25.56% in 1970 to 11.3% in 2014.

Table 28: GDP by sector, 1970–2014

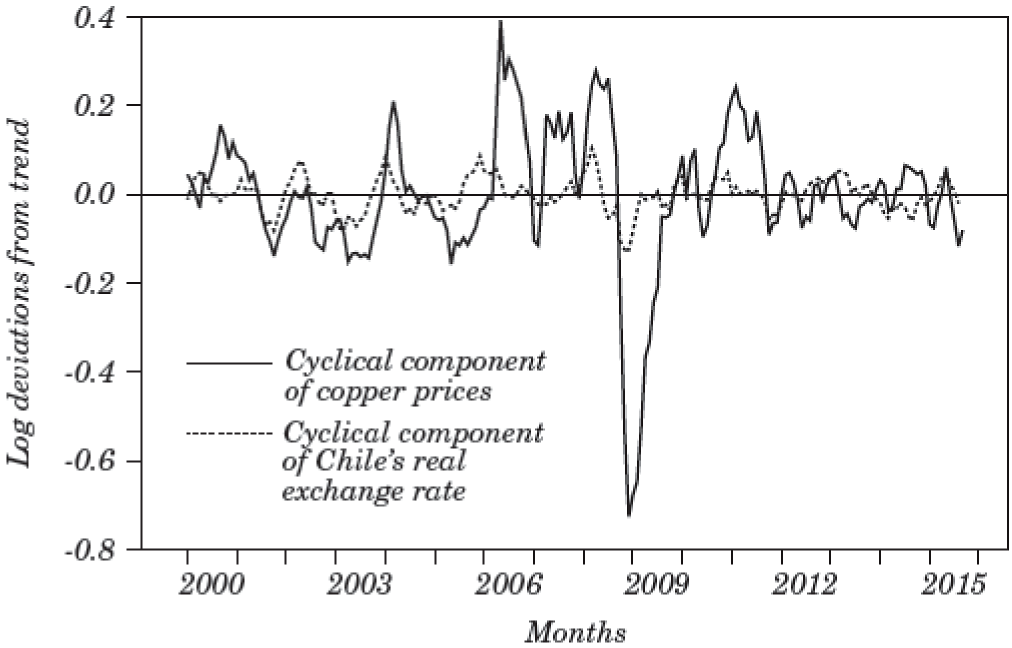
Sector	1970	1980	1990	2000	2010	2014
Other services	22.9%	24.5%	22.1%	31.2%	27.8%	30.0%
Financial and business services	5.2%	9.5%	9.8%	14.9%	16.9%	19.1%
Manufacturing	25.5%	21.4%	18.5%	16.2%	10.8%	11.3%
Mining	8.8%	8.6%	12.6%	6.4%	16.0%	11.2%
Trade, restaurants, and hotels	18.6%	16.4%	13.9%	9.9%	9.4%	9.7%
Construction	5.1%	5.2%	5.6%	6.0%	6.8%	7.3%
Transport and communications	5.2%	5.1%	6.7%	7.8%	6.3%	6.0%
Agriculture, Hunting, Forestry, and Fishing	6.8%	7.2%	8.2%	4.9%	3.2%	3.0%
Electricity, gas and, water	2.0%	2.1%	2.6%	2.8%	2.8%	2.3%

Source: Database Central Bank of Chile (www.bcentral.cl). Data retrieved on 16 February 2016.

Effects of commodity boom

In Latin America, exchange rate fluctuations have been intense with pronounced appreciation peaks. According to the OECD, both these factors have harmed training and productive transformation (OECD, 2015b). Given the significant contribution of copper to Chile's export basket, fluctuations in the price of copper can, amongst other macroeconomic factors, create pressure on the exchange rate (Meller and Simpasa, 2011). Empirical research by Caputo and Chang (2014) has shown a positive correlation between the cyclical variability of copper prices and that of the real exchange rate (Figure 20). Furthermore, the relation between commodity prices and exchange rates appears to be quite robust in Chile and other emerging countries, suggesting that commodity price shocks have significant economic effects on real aggregates (Caputo and Chang, 2014: 5).

Figure 20: Copper prices and real exchange rate over the cycle



Source: Caputo and Chang (2014: 2).

The increased demand for copper produced in Chile by the commodity boom or super cycle[57] that started in 2003 may have reduced the need to reduce costs, and this may have, in turn, reduced the relevance for mining companies of introducing innovations. In the words of Gustavo Lagos, a highly recognised Chilean academic expert in mining:

> the less significanft degree of innovation of mining firms may be linked to a particular situation of the industry at that time. Particularly the high prices of the metals in the year 2006 help explain why firms did not have a

[57] Heap (2005: 2) defines super cycle as a prolonged (decade or more) trend rise in real commodity prices, driven by urbanization and industrialization of a major economy. The super cycle started in 2003, the price of copper reached a peak price of $4,60 USD/lb in 2011 in December 2011, and by December 2016 its price was a 57% lower (Flores, 2016).

> significant pressure to reduce costs. The pressure was on increasing production. This strategy may have lessened the pressure on mining suppliers to introduce innovations. (Lagos, 2013: 18).

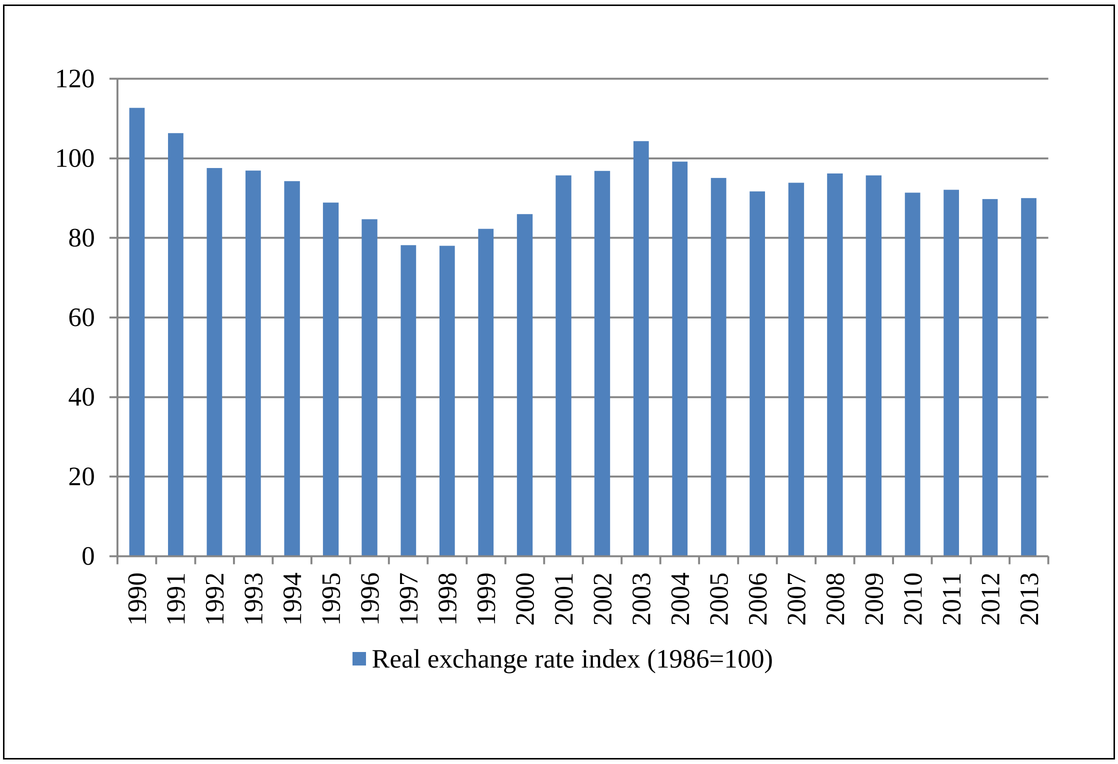
Further, according to Lagos (2013: 18), the super cycle contributed to the modification of the productive structure of the country. This is because the attendant weak dollar and strong Chilean peso produced a significant contraction in industries working with tradable goods and an important increase in the number of industries offering services and goods for mining.

It is important to note, however, that there is no agreement about the existence of episodes of Dutch disease in Chile over the last decade. On the one hand, the work of Meller and Simpasa (2011: 29) has found that since 1985 the exchange rate in Chile has not shown high sensitivity with respect to the copper price. In fact, according to these authors the exchange rate did not increase significantly during the copper boom (Meller and Simpasa, 2011: 29). They argue that in Chile's case the macroeconomic policies have been fundamental in dealing with the high copper prices and its pressures on the peso. In contrast, Katz and Bernat (2013) have argued that the inflation targeting scheme implemented in Chile during the 2000s was not capable of dealing with issues of international competiveness in the context of the boom in commodity prices and high inflow of investment. These authors argue that the high interest rates introduced in Chile during the 2000s, which aimed to curb inflationary pressures derived from the evolution of international prices, acted through two mechanisms. First, a higher interest rate negatively affected aggregate demand, lowering pressure on domestic prices. At the same time, it induced capital flows, which reduced the domestic nominal exchange rate, expanded imports, and further reduced the rate of domestic absorption of goods and services. It also increased the financial return to foreign investors, which produced the appreciation of the exchange rates (Katz and Bernat, 2013: 41). These authors found evidence that boom phases in the prices of natural resources determine the appreciation of real exchange rates and that the increase in exports related to natural resources decreases non-traditional exports (Katz and Bernat, 2013: 41). They argue that the preservation of the real exchange rate not only provides incentives to close the gap with the international technological frontier but might even do the opposite (Katz and Bernat, 2013: 54). This means that it can even weaken the sustainability of the growth process and the rate of diversification of the production structure (Katz and Bernat, 2013: 54). They argue that the appreciation of the real exchange rate can have a negative impact on the production structure, as well as on international competitiveness, if it is maintained for a long time, discouraging investment in new plants and innovation (Katz and Bernat, 2013: 54).

Exchange rate instability and incentives to invest in R&D

The exchange rate is a ‘determinant’ variable for the productive development of exporters and imports competitors (Ffrench-Davis, 2014). Rodrik (2008) has shown the existence of a positive correlation between a competitive exchange rate and economic growth in emerging economies. This is because a stable and competitive real exchange rate strengthens export competitiveness while its stability favours productive investment in tradable goods and activities with higher value added (Ffrench-Davis, 2014). Moreover, an exchange rate that favours exports is likely to stimulate more innovation (Fu, 2015). When analysing the real exchange rate in Chile during the 1990–2013 period it is possible to observe periods of volatility and depreciation (see Figure 21). The characteristic volatility of the floating exchange rate systems produces important problems when instability occurs in the mid-term cycles. This is what has happened with the incorporation of emerging economies, such as Chile, into the international markets in recent decades (Devlin and Moguillansky, 2012).

Figure 21: Real exchange rate index 1990–2013 (average index 1986=100)



Source: Own elaboration based on data from Central Bank of Chile (www.bcentral.cl). Data retrieved on 17 February 2016.

Under such circumstances, the periods of intense exchange rate appreciation, created by the significant influx of capital funds, produce perverse consequences in the allocation of resources. In the context of massive and unstable flows of capital and an unstable exchange rate, the free exchange rate suffers from the intense ups and downs of capital flows. This instability in the real exchange rate heightens risk and thereby depresses investment in the production of tradable goods and services that can be exported or used as import substitutes (Ocampo, 2011: 30). In addition, the work of Ffrench-Davis (2014: 503) has shown that exchange rate instability reduces the incentives for the creation of value added to natural resources and the incorporation of small and medium enterprises (SMEs) to the national export effort. It also reduces the survival of a competitive national industry and its employment and the productive investment in tradable goods. Moreover, according to Ffrench-Davis (2014: 503) exchange rate instability not only reduces the scope to take advantage of the opportunities created through trade agreements but actually stresses its costs and risks.

In conclusion, the market reforms implemented in Chile since the 1970s led the country to specialize in the sectors around its natural resources and influenced the significant reduction of the importance of manufacturing in the local GDP. Chile's specialization in natural resources has been regarded as an important reason explaining the lack of business innovation investment (OECD, 2007). The productive structure of the country can help explain its limited efforts in R&D (see Chapter 4) as Chile is specialized in industries with a low propensity for patenting worldwide and successful exporting industries rely on imported technologies, showing innovativeness in non-patentable know-how, such as business models and marketing (OECD, 2007: 98).

However, according to Maloney and Rodriguez-Clare (2007), Chile's specialization in natural resources is one, but not the only, reason explaining Chile's low investment in R&D; factors related to the lack of human resources, labour market rigidities, among others, may also help explain this innovation shortfall.

6.2.1 Chilean capitalism and firms' behaviour

In this sub-section I argue that the varieties of capitalism view, in particular the *hierarchical capitalism* institutional variation developed by Schneider also helps explain the lack of incentives for Chilean firms to invest in technology upgrading initiatives and the limited role they give to R&D collaboration with universities in these activities. In particular, the negative complementarities between large groups, multinational corporations (MNCs), and the labour market present in Chile have reduced the relevance of R&D for firms.

6.2.1.1 Varieties of capitalism

According to Katz (2012: 5), countries' institutional environments contribute to explaining why they achieve different results. In particular, the various types of capitalism present in the world, each characterized by their country-specific institutions and dynamics between the agents, require case-by-case analysis that considers the specific nature of the instructions and incentives framing the behaviour of the agents.

The varieties of capitalism approach developed by Hall and Soskice (2001) focuses on corporate governance and employment relations to explain the interactions between firms and employees. These authors claim that two prevailing types of capitalism prevail among countries: liberal market economies (LMEs), exemplified by the United States; and coordinated market economies (CMEs), exemplified by Germany (Hall and Soskice, 2001; Schneider and Paunescu, 2012: 731). Under this approach, firms in LMEs mainly rely on market institutions to organize their interactions with suppliers and workers, and to secure their financial and human capital. In contrast, in CMEs, non-market institutions, such as business organisations and trade unions, mediate these interactions. It is further argued that LMEs support radical innovation whereas CMEs support incremental innovation and that, therefore, the institutional setup of each type of capitalism produces its own, industry-specific technological and comparative advantages (Schneider and Paunescu, 2012: 731).

Building on the varieties of capitalism approach, Schneider developed the concept of hierarchical capitalism as an institutional variation that responded to the institutional features of Latin American countries (including Chile), which are neither CMEs nor LMEs (see, for instance: Schneider, 2010; Schneider, 2013a; b). Hierarchical capitalism is based on the argument that organisations are not only reflections of the rules-as-incentives structure but also vary independently from rules, and thus have direct, independent impacts on political economic outcomes such as equity, innovation, skills, and political representation (Schneider, 2013a:6). This approach argues that the particular characteristics of organisations in Latin America, ranging from the Church, to state-owned firms and business groups, have always been hybrid, synthetic, complex, interrelated, and politicized, and that understanding them requires a full analytic toolkit from comparative institutional analysis (Schneider, 2013a:5).

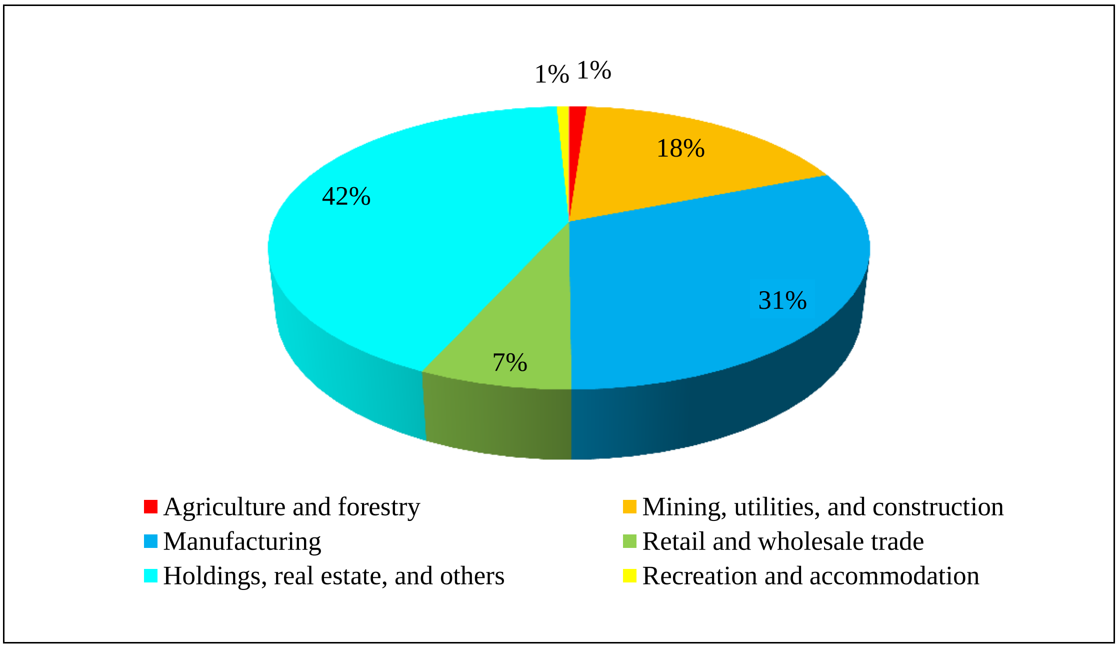
Schneider claims that the four core empirical features of hierarchical market economies (HMEs) in Latin America are: diversified business groups, MNCs, atomistic labour relations, and low skills (Schneider, 2009: 555). He argues that it is necessary to understand the type of firms, labour markets, corporate strategies, and skills regimes that constitute the institutional foundation of capitalism in Latin America in order to understand why firms do not invest more in R&D in this region (Schneider, 2013a:4).

Schneider’s model helps to explain why Latin America economies may be stuck in a low-skills equilibrium in which both large domestic groups and MNCs have little incentive to upgrade (Sánchez-Ancochea, 2009: 63). The atomized and short-term character of the labour market amplifies this negative effect since workers have little opportunity to acquire new skills and firms face little cost pressure to innovate (Sánchez-Ancochea, 2009: 69). This perspective has brought several major innovations to the study of the Latin American political economy. Most importantly, it has incorporated labour regulations and workers’ skills into analyses of business strategies; shifted the attention from states to firms; and shifted the empirical focus away from recent policy changes towards the enduring, underlying institutional features of capitalism in the region (Schneider, 2009).

Diversified business groups

In Chile, as in other Latin American countries, the dominant corporate form among large private firms is family-owned diversified business groups (*grupos económicos).* Many Chilean business groups were formed in 1974–1978 and 1984–1987 during two large waves of privatization (Larraín and Urzua, 2016). Only a few private agents and no foreign investors were able to participate in the first wave of privatization because of the on–going economic crisis of the mid-1970s. Consequently, the privatization process led to the concentration of ownership and the formation of business groups (Meller, 1993). The second wave of privatization took place after the crisis of 1982–1983, in which many companies were re-nationalized. It included firms that, until then, had been considered strategic in sectors such as energy, communications, steel production, and airlines. The groups that dominated the Chilean economy by the late-2000s were already in control of their flagship companies by 1990 (Larraín and Urzua, 2016). The Chilean business groups cover two main areas of activity: large, more diversified family-controlled groups tend to exploit and export natural resources, while a few successful family-owned retail chains have evolved into business groups with operations in several countries of Latin America (Lefort, 2010: 389). Figure 22 shows the industrial affiliation of group firms as of 2009. From the figure it is possible to observe that most group firms are in the holding sector (42%), in the manufacturing sector (31%), and to a lesser extent in the mining, utilities and construction sector (18%).

Figure 22: Industry affiliation of Chilean firms belonging to business groups, 2009



Source: Larraín and Urzua (2016).
Note: The sample covers all non-financial firms in Chilean groups listed in 2009. A business group is defined as a set of two or more listed firms with the same ultimate controlling shareholder. A business group can be family or non-family controlled.

Chilean business groups are characterized by a lack of separation between ownership and management. This means that affiliated firms are generally not only controlled, but also effectively managed, by the group's owners (Lefort, 2010:390). Data for 2009 shows that nine of the most important business groups represented 30% of the Chilean GDP (Larraín and Urzua, 2016), meaning that a small number of hierarchies controlled a large proportion of economic activity.[58] Business groups also have significant market share in some sectors (see Table 29). This significant concentration of economic power potentially also reduces the incentives for firms to take the risk of introducing innovations. Among the obstacles to innovation, the results from the 8th EIT, which reports on 2011-2012 innovative activities of Chilean firms, show that 63% of Chilean firms report that the market being 'dominated by established firms' is of medium or high relevance (MINECON, 2014a).

Table 29: Market Concentration and Business groups in selected sectors

Business group	Sector	Domestic Market Share
Angelini	fuel distribution	64%
Luksic	Beer	86%
Angelini & Matte	Forestry	60%
Concha y Toro, Santa Rita, San Pedro y Tarapacá	Wine	85%
Briones	Cement	30%

Source: (Schneider, 2013a).

Even in developed countries, business groups can provide access to internal financial markets, and can, therefore, contribute to overcoming financial market limitations. However, the interactions between firms and local institutions may

[58] Larraín and Urzua (2016) measure size as the ratio of the group's assets over Chile's GDP. The groups considered in this estimation are: Angelini, Matte, Luksic, Enersis, Claro, SQM, Sigdo Koppers, Concha y Toro, and Urenda.

reduce the potential benefits of business groups. As the former president of the CNIC already claimed in the early 2000s:

> Business groups reduce these imperfections [lack of developed capital market] by creating an internal capital market. However, one can ask if traditional business groups are those who have the highest orientation to innovation. In addition to the distributive effects, market power, and distortion of the political system, the pre-eminence of this form of business development has without a doubt, long term effects regarding the innovation capacity of the economy (Bitran, 2002: 262)

It is important to acknowledge that largely business groups produce commodities such as pulp and paper, copper, and petrochemicals—all industries in which, although technological progress tends to be 'embodied' in new equipment, firms carry out a significant amount of 'in house' engineering efforts to adapt equipment to the local raw materials and production environment (Katz, 2001a: 8). However, unlike large industrial commodity producers in developed countries, the large Latin American conglomerates engaged in raw material processing industries do not undertake significant 'in house' R&D or develop research capabilities (Katz, 2001a:8).

Multinationals corporations

The considerable presence of MNCs is also a characteristic of hierarchical capitalism. In the case of Chile, and as shown in Chapter 4, the evidence shows that an open investment regime and a robust regulatory and institutional environment have supported foreign direct investment (FDI) in Chile and made it an important driver of economic growth, as reflected in the tripling of FDI stocks over the past decade (OECD, 2015d). Furthermore, strong macroeconomic performance, strong and stable institutions and a generally friendly regulatory framework have enhanced the attractiveness of Chile as an FDI destination. As a result, Chile boasts one of the highest ratios of FDI to GDP in the OECD.

FDI can play a role as a channel of knowledge flows, and local networks often arise around or involve foreign companies (OECD, 2007: 60). However, in Chile FDI remains heavily concentrated in natural resources, potentially limiting beneficial spill-over effects on the broader economy in terms of innovation and productivity (OECD, 2015d: 5).[59] Additionally, MNCs often carry out their R&D at their headquarters, which limits the potential for subsidiaries to be involved. According to Schneider and Soskice (2009:40) 'MNCs have little incentive to conduct research in Latin America, since it is generally more efficient for them to bring technology with them.' As a representative from industry mentions:

> …firms here are multinationals. They support selected research centres in Australia, Canada and they bring that technology. This does not mean, however, that we do not do technological developments here (N° 46, industry representative).

A similar situation occurred in an important MNC company in the mining sector where, until 2008, headquarters would manage their large projects:

> There are two sources of technology; one is internal that you call it, it is the engineering department, and they are very competent people, very capable, and doing engineering, design, and in some cases doing a bit of research. It is always a mix [between internal and adapting]. The other thing, the traditional thing that we used to do, is that for the big breakthroughs, alliances with large international suppliers were made. These are done by headquarters. Everything was done abroad, except the local component that is the counterpart [of the project] (N° 48, senior executive mining company)[60]

[59] Data on FDI is presented in Chapter 4.
[60] Since 2008 the Chilean subsidiary of this company design and implements its own large projects. These are usually carried out in collaboration with international and national suppliers (Interview N° 48, senior executive mining company).

Broadly, it also appears that mining MNCs carry out only limited research that produces patents:

> In the copper mining industry in Chile, almost the totality of the innovation is produced by Codelco [state owned copper company] .... On the other hand, foreign companies have not joined in a significant way to the innovation process in Chile. It should be noted, however, that almost all foreign companies are implementing process innovations mainly directed at reducing costs and improving the use of energy, water, and other resources. But those innovations are most of the time, made internally and they do not produce patents (Lagos, 2007: 24)

> Most firms subcontract their basic engineering technology under turnkey conditions with major international contractors ... One of the few exceptions in this respect is the leaching technology developed recently by Codelco; the firm has even had a degree of success selling the leaching technology internationally (Katz, 2001b: 95)

Indeed, in the early 2000s Katz had already recognised the reduced incentives for MNCs to engage in local technological developed:

> Foreign firms that have recently entered the region's mining sector show little interest in engaging in the development of a strong local technological infrastructure. These firms operate mostly on the basis of foreign know-how and equipment, and given that they normally exploit new, high-grade mines, they do not need to undertake in-house technological efforts (Katz, 2001b: 96)

According to Schneider (2013a: 13), over the course of the second half of the twentieth century, the existence of MNCs in higher technology manufacturing reduced the returns from investments made by domestic groups in these sectors and increased the returns to business groups that invested in other area, such as, natural resources, commodities, and services that used lower skills and technologies. Neither of these groups has significantly contributed to R&D. This may be produced by the concentration of the first group on natural resources and simple manufacturing, while the second group concentrates on services (Schneider, 2013a). In Schneider and Soskice's view:

> Few groups have any incentive to undertake the risks of substantial research and development since they are not in innovation-driven export markets, nor is product development crucial for success in the oligopolistic markets that the business groups dominate (Schneider and Soskice, 2009: 40)

Labour markets and skills

Other characteristics of hierarchical capitalism are segmented labour markets and low labour skills (Schneider, 2013a). The particular manifestations of these in Chile may also have reduced the incentives to innovate as they reduce the incentives to invest in human skills capacities in firms and have also fostered the use of low-skilled labour. Chilean labour markets are characterized by weak unions, which can only negotiate salaries and short-term job tenure, and this has reduced the incentives for firms to train workers (Schneider, 2013a). In turn, this may have limited the absorptive capacities of firms not only to innovate internally but also to engage in more radical innovations involving universities.

At the same time, Chile lacks the human skills that are needed to carry out the level of R&D required by its income levels. Despite investment in education in Chile, which reached 6.9% of the country's GDP in 2011 (higher than the OECD average of 6%), it is still below the OECD average when measured in terms of investment per student. In 2011, Chile devoted USD 5,522 per student while OECD countries devoted, on average, USD 9,487 per student (OECD, 2014a).[61]

[61] It is important to note that 40% of this expenditure is funded by private sources, the highest proportion of all OECD countries. The expenditure in education per student has more than double in the last two decades (OECD, 2014a). This has placed this country among the OECD countries that most increased their financial commitment to education (OECD, 2014a).

In terms of quality, Chile scores the highest among Latin American countries in the PISA 2012 mathematics test, however its performance is still 71 points behind the OECD average (see Table 30). This equates to a socio-economic difference of more than two years of schooling (ECLAC et al., 2014: 166) between the lowest and highest income quintile.

Table 30: PISA 2012 score in mathematics, Chile, OECD and Latin American Countries

	Chile	OECD	LAC
PISA 2012 score in mathematics	423	494	397

Note: PISA test (Programme for International Student Assessment)
Source: (ECLAC et al., 2014)
LAC: Latin American Countries

So far in this chapter I have analysed Chile's productive structure and described the characteristics of hierarchical capitalism and how these have reduced the incentives to upgrade and to invest in innovations that require investment in R&D. As declared by Juan Rada (former Vice President of Oracle and new President of the Chilean Council for Competitiveness) in an interview with the Chilean magazine, *Política y Economía* in 2014 (Moguillansky, 2014):

> If we have a production model using cheap labour, little training, and precarious jobs, there is no stimulus to do things better or to sophisticate the production. The requirements are low... While there is no obligation that creates a demand for innovation demand and change, this will not change, and anyway it will be a process of many years.

Neither MNCs nor business groups focused on commodity firms invest much in R&D, higher-technological ventures, or related innovation that would generate abundant jobs for very skilled workers (Schneider, 2013a). Moreover, the interest in collaborating and preferences for partners in industrial policy are affected by the structure and strategies of big domestic business-mostly diversified, family-owned business groups (Schneider, 2013a). Consequently, public policies aimed at using public subsidies to change firms' behaviour, for instance towards R&D, may find resistance because business groups can find 'very profitable diversification projects that emerge for business groups abroad or in commodity sectors rather than the riskier, high-tech activities likely to be targeted by industrial policy' (Schneider, 2013b: 45).

6.2.2 Effects of competitive pressure on firms' collaboration with universities

So far I have shown that the country's strong specialization in natural resources helps explain the low national efforts on R&D and the role of universities as research partners. In addition to specialization in natural resources, I have argued that the hierarchical capitalism present in Chile has produced negative complementarities to the need to innovate in firms. For example, the strong presence of diversified business groups and MNCs and the lack of skills complement each other to reduce the need to engage in innovation efforts involving R&D that may be conducted in collaboration with universities.

In the view of the OECD, rent-seeking behaviour in Chilean firms is pervasive throughout the country's economy. This is explained by the strong dependence of Chile on exports of natural resources, a sector in which technology and innovation are often seen primarily as a tool that can easily be imported to appropriate these rents (OECD, 2007). The OECD also concluded that the fact that the rents from the exploitation of natural resources exceed those that can be expected from most innovations is one of the weaknesses of Chile's innovation system (OECD, 2007: 26).

In particular, competitiveness is a key factor to understanding the innovation needs of firms. As long as firms are able to continue participating in their respective markets by engaging in innovation activities that do not require R&D—either internally or in collaboration with universities— they will continue doing the same. In the words of a representative from the construction sector 'I do not believe that in this sector the one that does not innovate dies' (N° 50, construction sector representative). As another representative remarked:

> There are [innovative] developments in Chile, but they are not systematic. It is not that you say 'in Chile the mining technology of the world is being developed', which is how it should be... I believe there is a lot missing in terms of linkages between the industry and the universities... I believe this responds to the needs of the market. Mining in Chile is a case of open market, such as the rest of the economy in Chile. Thus, if it is cheaper to obtain [the innovations] abroad, then we bring them from abroad. That is my perception. It [copper production] is still cheaper in Chile than in other countries. We are a little higher than the average world costs, but we still have advantages in terms of political stability... Then, everyone is saying we need technology and we need to improve productivity, but you need to invest to do that, therefore, incentives are needed that go further because firms' look for return, and while today it is rentable to continue investing in producing in the same way in Chile, they will continue producing in the same way in Chile (N° 45, mining sector representative).

At the same time, the main markets for Chile's manufacturing exports are other Latin American countries that also may not require radical innovations in firms. In the words of Andrés Rebolledo, General Director of Foreign Commercial Relations at the Ministry of Foreign Affairs, 'the regional surroundings represents 22% of Chilean foreign trade, being the main market for our manufacturing industry, in which SMEs participate the most'(DIRECON, 2015: 5). Table 31 shows the distribution of exports by technological content and region. Data for 2004–2008 shows that the Latin American region was the main destination for Chilean manufactures; 47.1% of non-manufactures based on raw materials and 72% of manufactures with high technological content went to this market. These markets are already substantially behind Chile in technological development, as recognised by representatives from those exporting industries:

> The industry has realized that the neighbouring countries are 20 years behind Chile in terms of technology and product innovation, therefore it is very easy to enter in those markets. (N° 47, industry representative)
>
> The natural markets for Chile are South and Central America, which are mainly our neighbours and therefore there are many more opportunities to export perhaps with less value added. I mean if we think of demanding markets [in reference to European markets] for sure there is a need for research, development and innovation (N° 46, industry representative).

Firms have to balance short-term versus long-term pressures from the market. However, the environment in which manufacturing Chilean firms operate, in general, is not as dynamic as those serving more developed markets. Innovation is required, but adapted to the Chilean reality:

> I believe Chilean firms are as innovative as it is adequate to the business which they are in. In an open economy such as the Chilean one, where you have to run a lot to stay in the same place and that necessity means innovation. That means process innovation, a few product innovations as well as innovation in new business, that is because the environment in which firms are does not require more than that... It is another thing if you are in a dynamic environment, such as biotechnology, information and communication technologies (N° 41, industry representative).
>
> Yet, in Chile, the thing will start to get tighter, and it will begin to change, but today you do not need to be so competitive (N° 47, industry representative).
>
> I believe that there is already consciousness [in the Government] that Silicon Valley is not the only North we can have. I mean we have to do innovation according to Chile’s characteristics (‘*Innovación a la escala Chilena*’) (N° 46, industry representative).

Table 31: Geographic distribution of Chilean exports by type of technological content, 1983–1989 and 2004–2008

Period	Categories	Percentage of total exports	Latin America (33)	European Union (15)	United States	Asia (10)	China	Japan	Others
1983–1989	a. Primary goods	77.4	10.6	40.8	22	5.4	1.8	12.8	6.5
	b. Manufactures based on raw material	17.4	26.4	26.4	13.5	8.5	4.7	8.2	12.1
	c. Manufactures and others	5.2	44.4	11	21	1.7	2.1	1.8	17.9
	Low technology	1.2	42.3	10.2	37.8	1.5	0.1	0.6	7.5
	Medium technology	2.6	56.2	13.6	17.7	2.7	3.3	3.3	3.3
	High technology	0.3	39.8	19.6	35.7	0.8	0	0.3	3.8
	Other transactions	1.1	25.9	0.8	1	0.2	0	0	72.1
	d. Total	100	14.9	36.8	20.8	5.6	2.3	11.5	8.1
2004–2008	a. Primary goods	71.9	10.9	26.2	12.5	12.4	14.7	13.8	9.4
	b. Manufactures based on raw material	18.6	29.1	22.1	20.4	7	8.3	6.5	6.6
	c. Manufactures and others	9.6	47.1	14.8	10.5	6.1	0.6	1.3	19.7
	Low technology	1.6	70.9	5.4	17	1.7	0.9	0.1	3.9
	Medium technology	5.1	49.6	22.7	9.7	10.4	0.7	2.2	4.7
	High technology	0.4	72.3	6.4	16.8	0.8	0.3	0.3	3.1
	Other transactions	2.5	22.2	5.6	6.4	0.9	0.2	0.4	64.3
	d. Total	100	17.7	24.3	13.8	10.8	12.1	11.3	9.9

Source: Ffrench-Davis (2014) .

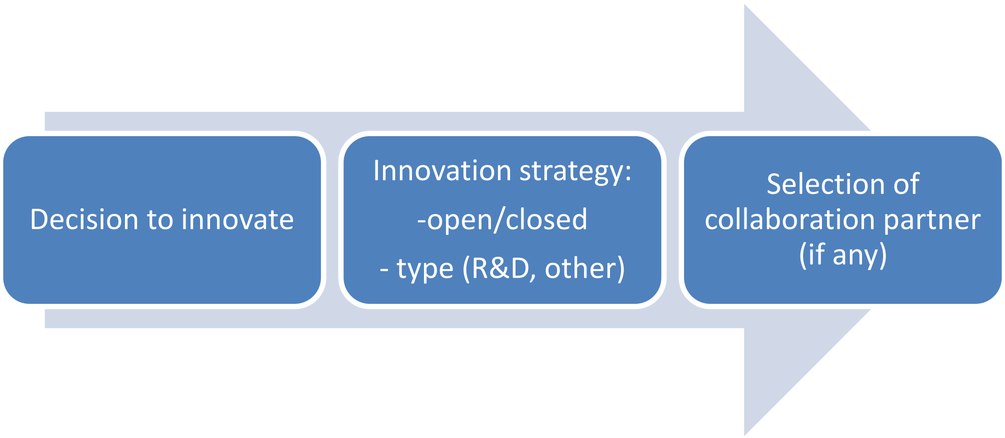
6.3 Innovation in Chilean firms

> In Chile our firms do little innovation. We are very far from the OECD standards, there is even a declining trend... technological and R&D innovations are not part of the business strategy of our firms' (Interview with Eduardo Bitrán, Vice-president of CORFO in Chilean newspaper *La Tercera* 22 June 2015[62]).

This section examines the innovation activities that are carried out by firms in Chile. Understanding these activities allows us to gain a sense not only of their innovation strategies and capacities but also of the role of universities as innovation partners. In this section I argue that Chilean firms' innovation activities are mainly oriented to technological upgrading and their strategies are aimed at creating the skills to carry this type of innovation activities. Therefore, innovation strategies in Chile are less oriented to introduce new products or processes that require R&D efforts. It also appears that Chilean firms do not consider R&D activities as relevant or necessary, so their efforts in this area are further limited. This attitude towards R&D activities in general, hinders the potential role of universities as innovation partners.

In order to understand firms' incentives to conduct R&D is it necessary to understand firms' incentives to innovate at all. First, firms decide if they are going to include innovation in their strategies. Second, they decide their innovation strategy, which considers, amongst other things, R&D activities and potential collaborators. Only then they decide if universities are a good fit as innovation partners. The workflow below shows a basic representation of this process.

[62] León Salamanca (2015).



Source: Own elaboration.

According to the MINECON (2014a) Chilean firms have reached innovative activity levels similar to those of OECD countries when considering both technological and non-technological innovations. The data from 8th EIT survey carried by this Ministry show that 23.7% of Chilean firms introduced some type of innovation.[63] The main effects of these product and process innovations introduced by firms were to improve the quality of goods and services and to increase the capacity and/or flexibility in their production (MINECON, 2014a).

Focussing specifically on technological innovations—which are central to this thesis because they allow us to explore the role of universities as innovation partners on R&D and technology transfer—Table 32 shows that 18.8% of Chilean firms introduced product or process innovations, the latter being the most important type of innovation. In mining industries, for example, 35% of the technological innovation was process innovation while only 11.7% was product innovation.

[63] This ministry is in charge of collecting data on R&D and innovation activities in Chile. Aggregate data is then reported to international organizations such as the OECD and others.

Table 32: Rate of innovation of Chilean firms by economic sector 2011–2012

Sectors	Technological Innovation			Non-Technological Innovation			Total innovation
	Product	Process	Sub Total	Organi-zational	Marke-ting	Sub total	
A: Agriculture, Hunting and Forestry	15.80%	18.60%	21.10%	10.70%	3.50%	12.70%	27.10%
B: Fishing	4.30%	4.70%	6.40%	9.30%	6.40%	14.10%	16.50%
C: Mining and Quarrying	11.70%	35.00%	40.00%	26.70%	10.00%	26.70%	45.00%
D: Manufacturing	19.30%	22.80%	28.80%	18.40%	17.10%	23.60%	33.80%
E: Electricity, gas, and water supply	15.70%	30.60%	34.70%	37.20%	20.70%	42.10%	49.60%
F: Construction	11.10%	22.50%	23.30%	20.60%	9.90%	20.80%	25.70%
G: Wholesale and retail; other	9.50%	14.40%	17.30%	11.20%	10.20%	14.90%	21.40%
H: Hotels and restaurants	13.90%	18.50%	21.60%	21.70%	20.00%	25.20%	28.30%
I: Transport, storage, and communications	9.00%	7.90%	12.30%	6.50%	5.20%	7.40%	14.40%
J: Financial intermediation	8.70%	10.20%	10.60%	6.90%	10.80%	12.50%	14.10%
K: Real estate, renting, and business activities	12.30%	14.60%	19.20%	18.20%	12.70%	20.60%	28.30%
N: Health and social work	19.40%	18.30%	26.50%	20.50%	12.30%	23.30%	30.90%
O: Other community, social and personal activities	18.10%	21.60%	24.90%	23.40%	16.50%	25.10%	30.00%
Total	11.60%	15.60%	18.80%	13.80%	10.00%	16.40%	23.70%

Note: An *organisational* innovation is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations. A *marketing* innovation is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing (OECD, 2005a)

Source: (MINECON, 2013b).

Data from the 8th EIT shows that the rate of innovation among large firms is almost double that of small firms (see Table 33). A possible explanation for this could be that large firms have more resources, larger absorptive capacities, access to funding and other advantages that facilitate innovation. However, with regard to external collaboration strategies, it may be that size negatively influences external partnerships, because large firms may internally access to a large pool of resources (Lowe and Taylor, 1998).

Table 33: Percentage of firms introducing technological innovations by size, 2011–2012 period

Type of firms	Technological Innovation		
	Product	Process	Total
Large	17.60%	24.90%	30.00%
Medium	13.30%	23.50%	26.80%
Small	10.90%	13.80%	16.80%
Total	11.60%	15.60%	18.80%

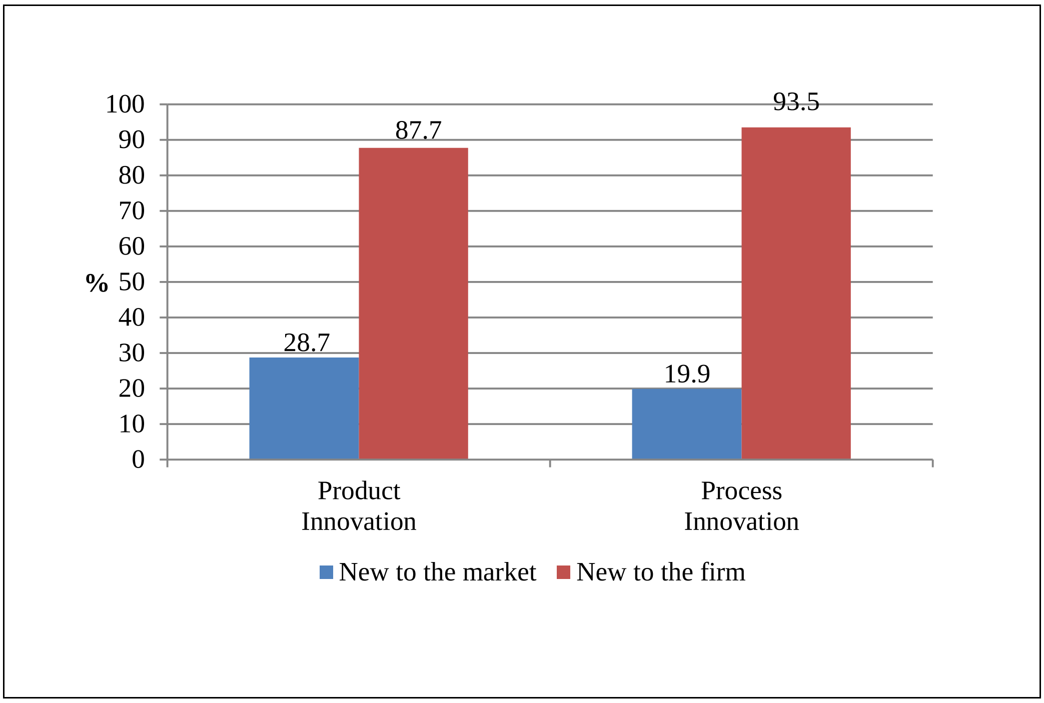
Source: (MINECON, 2013b).

Figure 23 shows the degree of novelty of the technological innovations introduced by firms and reveals that most of the innovations are new-to-the-firm but not-new-to-the market. Most of the innovations were, thus, produced by firms acquiring and adapting already available technologies and processes. This is not surprising given, what we already know about Chile having an economy based on natural resource commodities with very limited value added, which is one of the characteristics of hierarchical capitalism.

The capacities of firms can also help explain the type of innovations they are able to introduce. This is confirmed by a representative from the construction sector:

> I believe that it is [limited innovation in the construction sector] because of the technological or performance frontier of the firms from the construction sector. There are too few [firms] that are there on that frontier and that can generate more radical innovations. Most of the firms are far away from reaching their own potential performance, they are only a little bit productive, reluctant to change (N° 50, construction sector representative).

Figure 23: Rate of technological innovations of innovative Chilean firms by degree of novelty, 2011–2012 period



Note: Firms can introduce product, process, or both types of innovations. These innovations can be new-to-the-market or new-to-the-firm. This explains why the percentages do not necessarily add up to 100.
Source: (MINECON, 2013b).

If this is a problem in the construction sector it may well affect other sectors of the economy. It is also necessary to acknowledge that product innovation does not necessarily mean that new to the world innovations are developed in the country. Innovation in products is recognised as such when it involves the introduction of innovation to the country, as representatives from the manufacturing and plastics industries explain:

> We are a multisectoral association, therefore firms from approximately fourteen [subsectors] coexist and there is a quite a lot of product, containers, and process innovations. Perhaps not leading innovations but there are a lot of continuous improvements, which if looked at from a practical perspective, is indeed innovation when you do it in a systematic way. Therefore, there is a lot of continuous improvement, a lot of process innovation, incorporation of technologies (N° 46, industry representative).

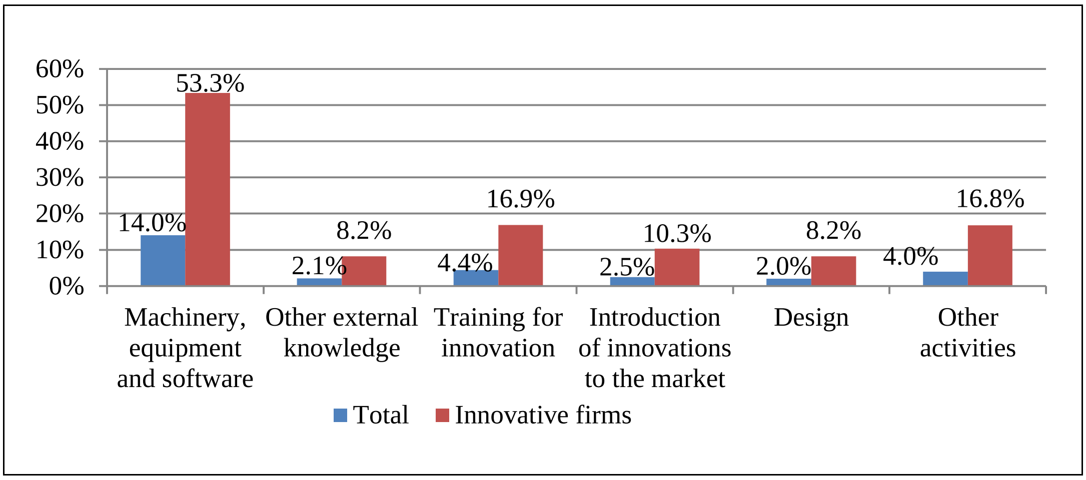
> Innovation in this industry is 100% in product. . . . They are mostly innovations new-to-the-country (N° 47, plastic industry representative).

The representative from the manufacturing sector and one of the academics who works with firms also underscore the importance of understanding the type of innovations produced in the industry in the local context, when trying to understand the needs and potential of Chilean firms:

> We need to start by considering that in Chile we do not have net exporters, with the exception of some sectors, but when we talk of manufacturers we do not have net exporters and [this country] continues exporting products probably with a couple of process of value added and not more than that... [...]...there is not much value added (N° 46, industry representative).
>
> The problem of Chilean firms is that for a long time they learnt to produce cheaply and to be competitive, which is very relevant and important, but not to produce in a differentiated way (N° 14, Academic UDEC).

By far the most innovative activities of Chilean firms are centred on the acquisition of machines and software for their productive processes (see Figure 24).

Figure 24: Type of innovative activities conducted by firms, 2012–2013



Source: (MINECON, 2013b).

Despite a larger share of innovative firms focussing on adapting imported technologies and know-how, the vast majority of Chilean companies purchase capital goods as the main means of technology adoption (OECD, 2007). This incorporation of available technologies has been observed by several of my informants, including a senior manager of a private fund providing research grants to natural-resource-based applied research projects and industry representatives:

> In reality, the firms what they do is that they buy technology that is ready and they adapt it to the local conditions (N° 49, senior executive private R&D fund)
>
> This is a very competitive industry, it is an industry of volume, and therefore the margins are very small. That makes you introduce new products, innovations in a very short period.... this industry is very exciting, with a lot of innovation and it had few linkages with academia when I arrived.... [innovations] were all imported. This is an industry that goes a lot to international fairs and these are an important source of knowledge and since the machinery is not produced in Chile either... The machinery for the industry of plastics is all imported, there is no local manufacturing... to build a machine in the plastic industry you need highly superior technology, even the machines that the UDT [R&D centre, UDEC] and CIPA [R&D centre, UDEC], the ones that are in the laboratories are imported (N° 47, industry representative)
>
> Since the innovation is in process [in the mining sector], an important part of the technological changes are made by the producers of plants and equipment, which in Chile, are largely imported (Arellano, 2012: 28)

Evidence from developed countries shows that is not necessarily bad to acquire and adopt external technologies as an innovation strategy if firms' have the internal absorptive capacity, and if it leads to learning. In order for this to happen, however, it is necessary to combine the external technology with complementary R&D and human resources efforts (Crespi et al., 2014: 69).

In conclusion, the analysis of the innovation performance of Chilean firms has highlighted three features: (i) few firms innovate; (ii) those that innovate concentrate on process innovation; and (iii) innovation is primarily done through machinery and software acquisition.

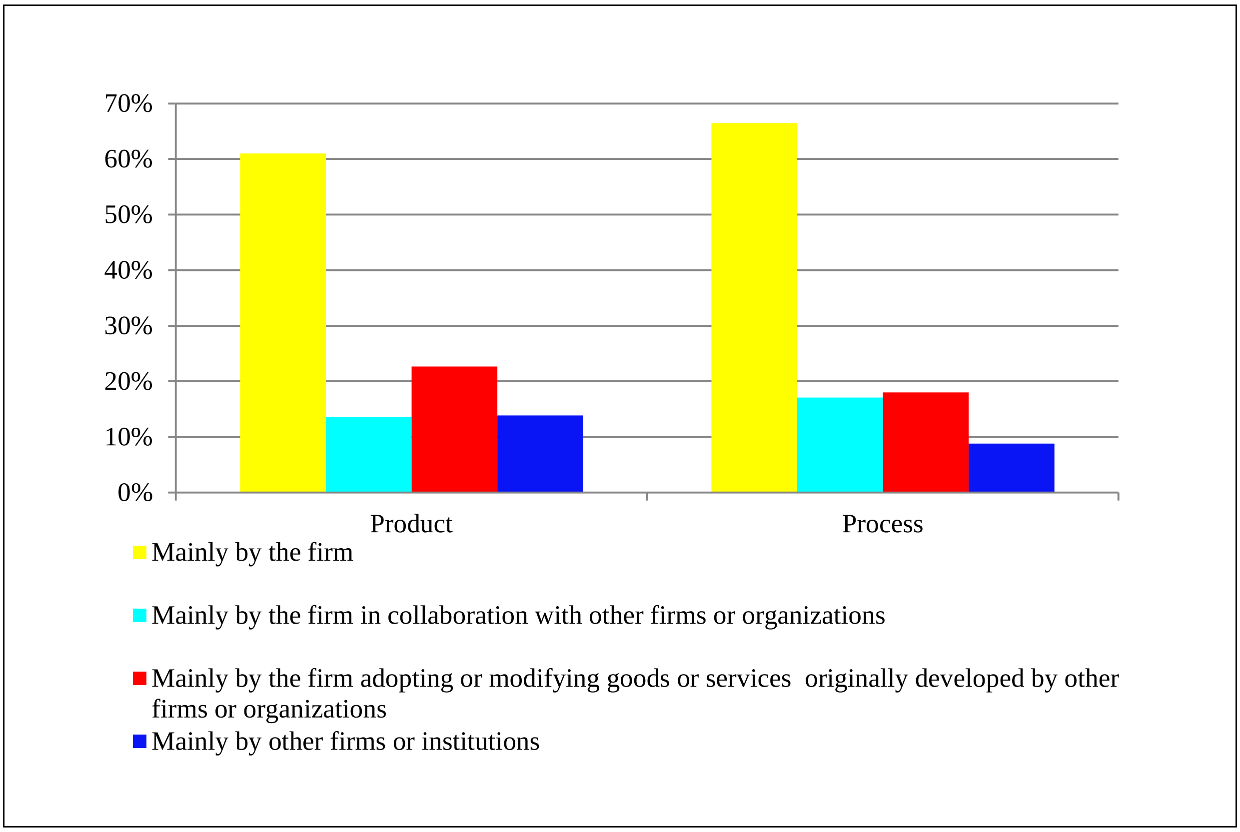
6.4 Factors influencing the relevance of universities as R&D collaboration partners for firms

In the previous section I have argued that firms have limited incentives to carry out innovation activities and that, within these, R&D is not reported as relevant to firms. This lack of incentives is partly explained by the combination of an economy based on natural resources and a competitive environment dominated by diversified family business groups in which there is limited capacity to undertake R&D activities. There are, however, firms that *do* innovate. The problems that these firms face in engaging in collaborative activities with universities are explored in this section. Throughout I argue that the limited R&D collaboration with universities is largely explained by two related factors: lack of relevance of R&D to firms, and lack of firms' capacity to engage in these interactions.

Universities are just one of the types of partner that firms may decide to interact with on innovation. The intensity of a firm's open innovation strategy and the type of partner it chooses to work with are affected by various factors such as the firm's sector, size, financial capacity and technological capabilities, and the life cycle of the industry. Intensity is also influenced by factors related to the universities and research centres such as research interest and capabilities, as well as the direct and indirect incentives produced by the innovation policy (see Chapter 5). Of course, we have also already seen that the effects on the type of capitalism on the importance of R&D to firms altogether, with inevitable effects for the importance of universities as R&D partners.

The results from the 8th EIT show that only 7% of the Chilean firms that introduced technological innovations in the period 2011–2012 cooperated with other organisations (MINECON, 2013b). This means that 93% of firms' innovative activities were carried out using closed innovation strategies. Figure 25 shows the development of innovations by type. From the figure, it is possible to observe that more than 60% of the firms introducing product and process innovations developed them internally. Only 13.8% of the firms introducing product innovations and 8.8% of the firms introducing process innovations reported that these were elaborated by third parties (MINECON, 2014a).

Figure 25: Development of the innovations by type



Source: 8th EIT, MINECON (2014a).

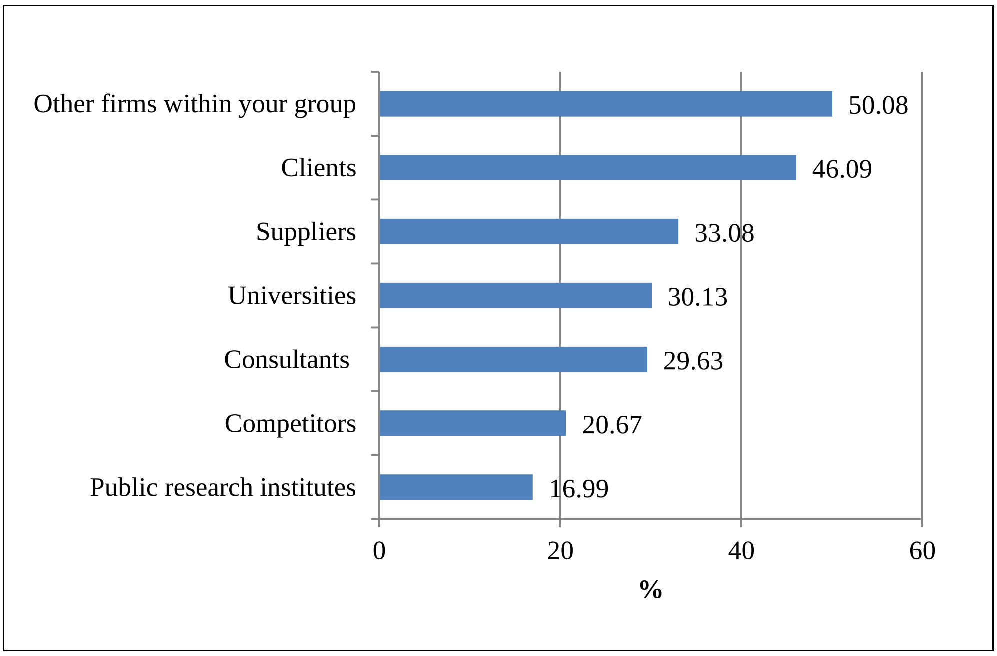
One possible reason explaining the fact that innovation activities are largely conducted using closed innovation strategies could be found in the type of activities that firms are interested in and the potential role of universities in this regard. As a manager from CORFO and representatives from industry and mining explain:

> Many firms would tell me that they largely conduct more development than research, using their own capacities though. In Chile what we do most is development and not research...[...] In general, most firms go straight to development, either developing or improving what they have based on the experience they have. I am talking about the majority of the cases. There are some that take the whole process more seriously and they use external support and see in advance if the solutions available today really can solve problems or if is necessary to develop something, and it is in these cases that I am not sure if they may work with universities, experts or research centres. (N° 44, senior civil service)
>
> There is no reason for Chilean firms that are influenced by market needs not to be as innovative as others [firms in other countries]. Chilean firms are as innovative as their competitors. However, much of that innovation does not come from local academics... because the horizons are too different. This, however, does not make Chilean firms less innovative, otherwise they would not exist (N° 41, industry representative)
>
> Here we do it [technology] in the Chilean mining industry and the mining engineering is very good at international level, and things are made and very interesting things are made, but it is not that we depend on the university, no (N° 43, mining sector representative)

Data from the 8th EIT show that universities are fourth out of six potential collaboration partners in terms of importance. Where firms engage in open innovation strategies, other firms from the same group or clients are their most important collaborative partners (see Figure 26). The relatively low importance of universities as collaboration partners in comparison to other partners is a regular finding in the literature. Similar results have been found in other developing countries such Nigeria (Kruss et al., 2015a) and also in developed countries such as the United Kingdom (Coad et al., 2014) and other European countries

(Fagerberg, 2015). This consistent trend in the data remind us that collaboration with universities is not a broad innovation strategy for firms and that only a minority of firms actually works with these organisations (considering that only 23.7% firms introduced innovations). Other types of partners appear to be more relevant for the majority of firms. This may reflect a range of issues that need to be examined further in order to understand the potential that university-linkages offer for Chilean firms. For instance, it may reflect a capability gap between firms in which only a few have the capacities to absorb the knowledge created in universities. The type of firms that interact with universities need to be identified in order to design and implement effective innovation policies and also to estimate the development impact of these tools. This issue is discussed further in Chapter 8.

Figure 26: National collaboration rate by type of partner, innovative firms



Note: Consultant includes private laboratories and research centres
Source: Own elaboration based on 8th EIT.

However, it is important to keep in mind that, although 30% of innovative firms declared that they collaborated with universities, this does not necessarily mean that they collaborated on

R&D projects. In fact, the analysis shows what appears to be regular interaction related to conducting laboratory testing, certifications, and other non R&D activities, which can also be carried out by suppliers and other partners:

> … the relationship with the universities that is relatively recurrent is associated with testing and analysis to feed internal processes, then they [the company] say ‘let's send this sample to the laboratory of X university and see what happen... but you can see that is a consultancy service, it is not that the academic is moving the frontier of knowledge. We see that a lot. Something [some knowledge] may be there but not much (N° 48, senior executive mining company)

> ...[on where to source technology from] Then what many times happened is that for specific needs, the design was done internally....and then you would ask the engineering people [suppliers] ‘why don't you help me make the engineering of the model?’ and then you are hiring that service... most of the terms of reference were internal and there were small interactions [with suppliers]. It was a contract to hire engineering services, but you would not buy technology transfer (N° 48, senior executive, mining company)

> The laboratory [university laboratory] of containers and packing is one of the most *pro* [meaning high-tech], I would say that it the one that has the most technology and more reputation regarding certification of containers... the firms always send their containers to them for certifications, and also for measurement (N° 47, industry representative)

> They [engineering academics] because of their area are permanently in contact with a series of firms. Researchers here have contact with the industry, they have their own networks. So I would say that in 50% of the companies that they work with, they have done consultancy projects for them or they already know them [for other reasons], the other 50% may be new or public organisations (N° 27, senior manager, PUC)

Understanding the type of activities that Chilean firms conduct as part of their innovation and development strategies could allow universities to develop their own strategies for becoming more attractive as innovation partners. This could entail, however, changes in their research focus towards the development of incremental innovations:

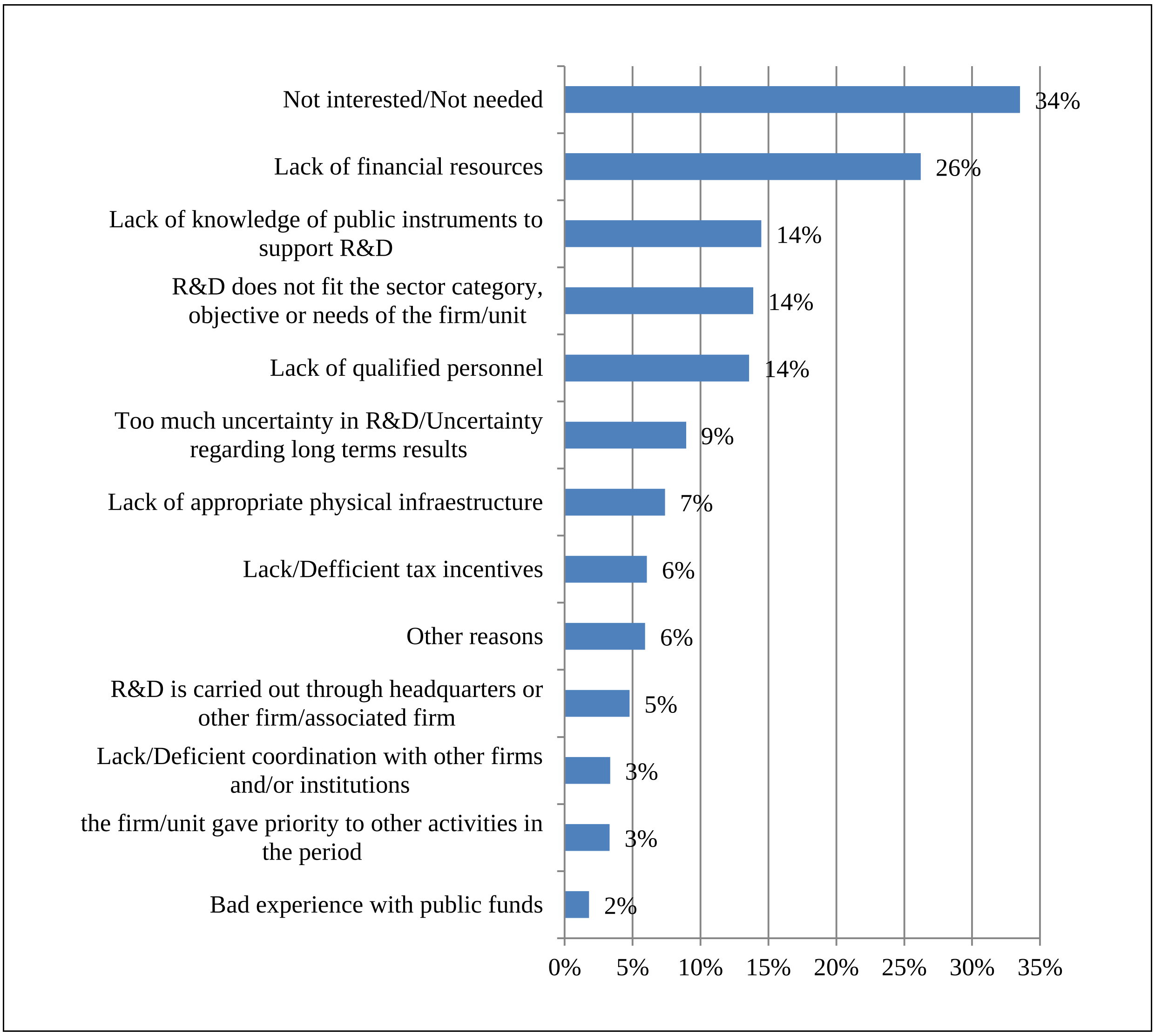
> ... there is, logically, a trade-off [between doing radical and incremental innovation]. But you have to bet on something (N° 47, industry representative)

6.4.1 Relevance of R&D activities for firms

One of the reasons that can explain the low level of R&D collaboration in firms is the limited relevance that firms give to R&D activities. As discussed in Chapter 4, the latest results from the 4th *Survey of Research and Development (R&D) in Firms* report that Chilean firms invested 34% of the total of R&D efforts of the country in 2013 (MINECON, 2014d), less than other OECD countries. At the same time, results from this survey show that 57% of the firms reported that they did not carry out R&D activities. From these, 34% did not carry out these activities because they do not need to or are not interested in them (see Figure 27). A further 14% of the respondents claimed that R&D did not fit in the sector category, objectives or needs of the firm. Figure 27 shows the reasons given by firms to explain their lack of R&D efforts. These can be grouped into at least three categories: factors related to the market; factors related to the firm; and factors related to the innovation environment and its coordination. The following reasons can be grouped among the factors related to the market: (i) lack of interest or need; (ii) R&D does not fit in the sector category; and (iii) the presence of uncertainty about long-term results. These results are in line with those presented in the first section of this chapter in which the characteristics of the environment of firms do not put pressure on them to engage in R&D activities. The reduced importance that firms, in general, give to engaging in R&D activities reduces their interest in collaborating with universities.

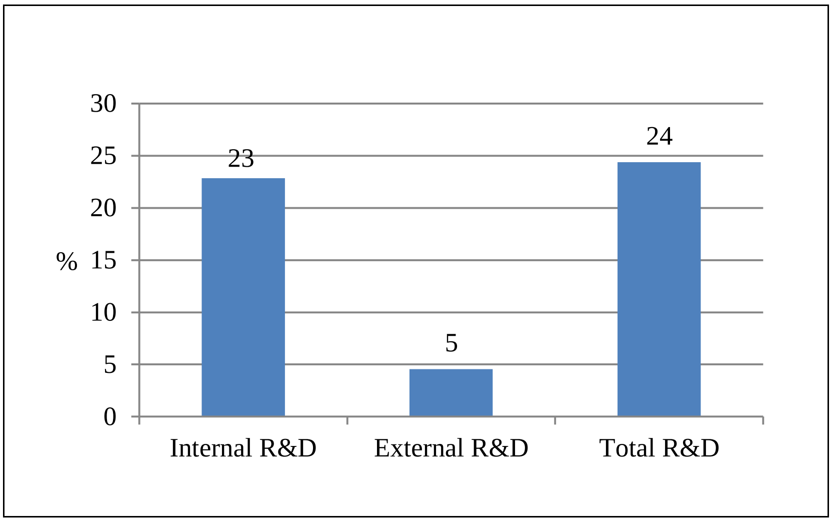
By analysing the data from the 8th EIT, it is possible to obtain representative information about the R&D rates of Chilean firms. The available data shows that only 5.8% of the total of Chilean firms conducted R&D activities (MINECON, 2013b) in the 2011-2012 period. Among the innovative firms, 24% conducted R&D. However, only 5% of innovative firms carried out external R&D. It is not possible to say that firms that did not pay for R&D did not collaborate with other organisations. However, this number provides a sense of financial interaction, which could be related to formal collaboration arrangements, suggesting their importance for firms (see Figure 28). Of the firms that engaged in external R&D, 21% collaborated with universities. This number rises to 36% when considering firms that conducted external or internal R&D.

Figure 27: Reasons declared by firm for not carrying out R&D activities



Source: Own elaboration based on 4th R&D innovation survey database (MINECON, 2014b).

Figure 28: Percentage of innovative firms that conducted R&D activities, 2011–2012 period



Source: Own elaboration based on 8th EIT.

It seems that the limited efforts that Chilean firms devote to R&D reflect the limited relevance that firms place on this type of activity. However, at the same time, low efforts on R&D also signal low R&D capacity, which could hinder R&D collaboration and technology transfer from universities. Firms do not need R&D therefore they do not invest in R&D capacities, and do not invest in R&D.

6.4.2 Firms' capacity to innovate as a factor hindering collaboration with universities

In the view of Giuliani and Arza (2009:906) a firm's knowledge base is a key driver of 'valuable' university-industry linkages. The innovation capabilities of firms depend on their ability to recognise the value of new, external information, assimilate it, and apply it to commercial ends (Cohen and Levinthal, 1990: 128). According to Cohen and Levinthal (1990: 131) the ability to evaluate and utilize outside knowledge is largely a function of the level of prior related knowledge. In the view of the OECD (2007) the lack of innovation in firms also reflects a deficit in training in the advanced management skills and business leadership required for incorporating innovation into firms' strategies (OECD, 2007). Indicators measuring the internal R&D efforts (such as expenditure on R&D and the existence of R&D departments) of firms have widely been used in the literature as a proxy for the absorptive capacity of firms (Aschhoff and Schmidt, 2008; Cohen and Levinthal, 1990; Negassi, 2004). Chile's firms report low levels in these two indicators; only 5% of the Chilean firms conducted R&D activities and only 2% of Chilean firms have R&D departments (MINECON, 2013b). Low investment in R&D can signal a lack of financial resources to carry out R&D activities. In this regard, more than 60% of Chilean firms report factors related to financial resources, such as the costs of the innovation and the lack of funding, as obstacles to innovation (see Table 34).

Table 34: Obstacles to innovation reported by Chilean firms

Factor or disincentive/ Level of importance	**High**	**Medium**	**Low**	**Not an obstacle**
1. Factors related to costs:				
Lack of own funding	44%	24%	8%	23%
Lack of external funding	38%	25%	10%	27%
Cost of innovation	47%	23%	8%	22%
2. Factors related to knowledge				
Lack of qualified personnel	33%	26%	13%	27%
Lack of information about the technology	29%	29%	13%	28%
Lack of information about markets	29%	29%	14%	29%
Difficulty in finding innovation partners	35%	25%	13%	27%
3. Market factors:				
Market dominated by established firms	43%	20%	11%	26%
Uncertainty about the demand for innovative goods or services	35%	28%	12%	26%
4. Other factors:				
Not needed because of previous innovations	17%	22%	22%	39%
Not needed because of lack of demand for innovations	20%	23%	20%	37%
Regulatory difficulties	18%	23%	20%	40%

Source: Own elaboration based on 8th EIT database.

Another proxy for firm's capacity to absorb and recombine knowledge is the quality of their human resources. We can see that 59% of Chilean firms regard the lack of qualified human resources as of medium or high importance in deterring their innovation activities (see Table 34). As discussed in Chapter 4, the lack of qualified human resources has been identified as a significant problem of the Chilean innovation system. According to the CNIC, although Chile has made advances in terms of access to education, the quality of its education remains deficient, making it difficult to achieve knowledge-based growth (CNIC, 2006). In Chile, there are 2.46 R&D personnel per 1,000 workers while there are 12.31 in OECD countries (MINECON, 2015b). In addition, the proportion of R&D personnel in firms is also reduced and under skilled (see Table 35). According to the latest available data, only 6% of the total of doctors (holding a PhD) work as researchers in Chilean firm in 2013 (MINECON, 2015b).

Table 35: Researchers working in Chilean firms, data for 2013

R&D personnel*	2009			2013		
	Firms	Total	%	Firms	Total	%
Doctorates (PhDs)	119	2,180	5%	179	2,810	6%
Masters	161	1,014	16%	331	1,548	21%
Professional and Licentiates	1,212	3,649	33%	1,957	5,532	35%
Higher Education Technicians	507	1,615	31%	561	1,383	41%
Others	946	1,971	48%	925	2,046	45%
Total researchers	2,945	10,430	28%	3,953	13,319	30%

Note: * Researches presented in FTE.
Source: (MINECON, 2015b).

The evidence analysed so far helps to explain why firms do not consider universities as relevant collaboration partners. This is because of the type of research firms carry out, the limited importance firms give to R&D activities, and the lack of the financial and human capacities needed to collaborate with these organisations.

6.5 Barriers to university-firm collaboration

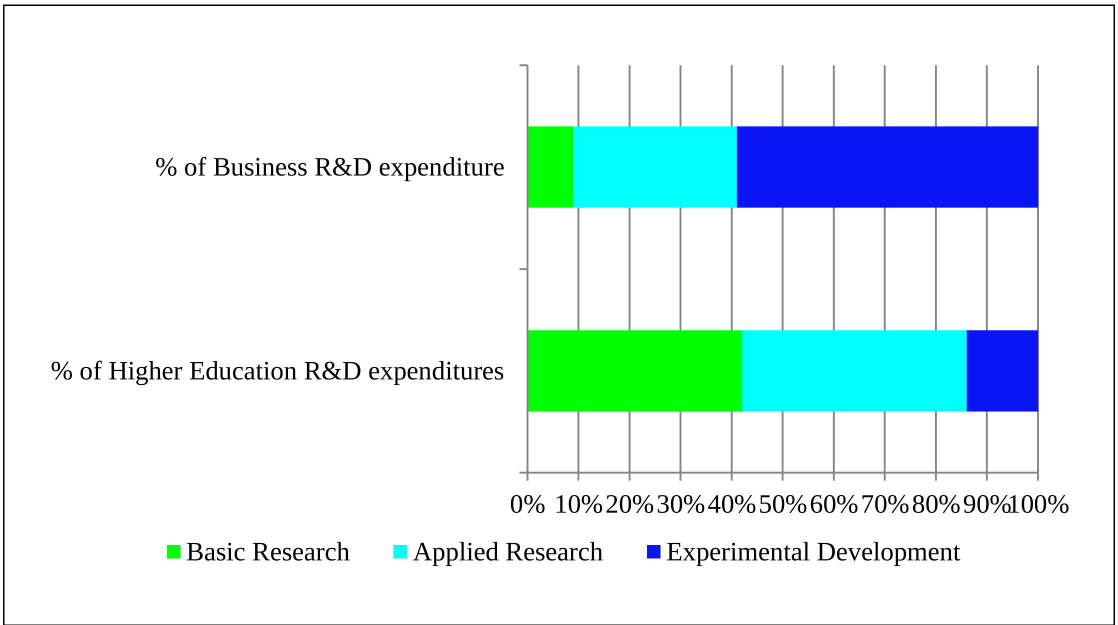
So far I have examined the macroeconomic factors influencing Chilean firms' innovation strategies. I have also examined the type of innovations Chilean firms carry out in response to their needs and capacities, and the limited role played by R&D and universities in this regard. However, there are additional factors that also have to be considered when analysing innovation in firms because they are part of the environment in which firms interact and in which they decide their innovation strategies.

This section discusses the firm-level factors that appear to influence firms' incentives to collaborate with universities. In particular, three factors appear to negatively influence the incentives for firms to select universities as innovation partners: (i) lack of understanding of the problems affecting firms by universities; (ii) differences between innovation timeframes; and (iii) coordination costs and information sharing.

6.5.1 Lack of understanding firms' innovations demands

Among firms, there is a generalized perception that universities do not understand their research needs. Indeed many of the interviewees felt that academia was not interested in, or did not know, the real problems affecting the firms. There is discordance between the types of R&D carried out by firms and universities. The latest indicators from the National R&D Survey show that universities largely conducted basic research in the year 2013 (42%) while firms only devoted 9% of their expenditure to this type of research. In contrast, firms focused 59%% of their R&D activities on experimental development (see Figure 29).[64] This fundamentally different approach to research may partly explain why firms believe universities do not understand their needs.

Figure 29: Percentage of Higher Education and Business R&D expenditures according to type of research (2013)



Source: (MINECON, 2014d).

When consulted about this issue, a senior manager of a private research fund aimed at fostering applied research between universities and firms and an industry representative explain:

[64] The Glossary of Statistical Terms of the OECD (OECD, 2005a) defines *basic research* as experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. *Applied research* is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. *Experimental development* is systematic work, drawing on existing knowledge gained from research and/or practical experience that is, directed to producing new materials, products or devices; to installing new processes, systems and services; or to improving substantially those already produced or installed.

> Since academia is not involved in industry, it does not know where the industry hurts ... academia lives in its world ... certainly no firm gets engaged in a FONDEF project from their strategic needs and says ‘hey the industry of the future is this way, let’s get an academic’, the academic lives in his world ... the truth is that there are only a few [academics] that realize it, that are able to look beyond... they know [their research] will be useful to someone, but they do not know how, they do not get involved ... However, in the past five years there has been a dramatic change in the view of academics towards projects (N° 49, senior executive private R&D fund).

> Many times the university researchers do what they want and not what firms want (N° 46, industry representative)

However, when universities *do* understand the research problems that firms have, this eases the firms' attitude towards engaging with them as research partners. The director of one industrial association, which exports approximately 20% of their production, largely to other Latin American countries, explains the close links between the industry the interviewee represents and the universities, especially those in the petrochemical cluster in the Bio-Bio region:

> In this industry in particular, there is a close linkage. I believe this is largely explained by the petrochemical cluster. Having Petroquim S.A. in Concepcion, CIPA and UDT [R&D centres, UDEC] and, at the same time, being very connected with the firms producing containers and packaging it gives them plus. This linkage means that the problems they [the academics] identify are not very far from the reality (N° 47, industry representative)

It appears too that it is easier to transfer knowledge when universities understand the problems of industry, as this statement from a senior manager of a private research fund, recalling the introduction to the market of a locally developed virus detection kit developed by academics at the peak of the ISA virus crisis that affected the salmon industry (late 2000s), confirms:

> We do have some projects that have been transferred [to the firms] . . . for instance, two projects, one created virus ISA testing kits and another one also useful to the salmon industry. We received their [the

> academics] projects and the virus ISA happened and their projects got in [into the market] immediately... This was very easy to transfer because there was a real necessity, and that is the point. Because when other projects arrive [to the fund] ... they arrive because the researcher believes there is a problem and he proposes to solve this problem with this solution he is proposing to do, that he identified, not that the industry necessary has this problem ... that is how it works in the country (N° 49, senior executive private R&D fund)

The importance of understanding firms' needs was also underscored by an academic leading an important research centre belonging to the UDEC:

> We have clients with whom we have worked continuously for 15 years, such as Arauco, Petro and Conama [regional firms and government agencies], project after project in a continuous relationship. With other firms, smaller ones [relationship] is more sporadic, but the relationship with clients is fundamental, it is very important. We have to try to understand their requirements (N°14, Academic UDEC).

6.5.2 Innovation timeframes

Another factor that appears to negatively affect the interest of firms in working with universities is their long-term approach to research and problem solving. As one interviewee put it, 'there are issues that are related to opportunity: normally firms would tell me "I need a solution today and universities take forever"' (N° 44, senior civil service). Conversely, as discussed in Chapter 5, academics view industry's short-term orientation as the most important barrier to collaboration (Tartari, Salter, & D'Este, 2012).

This does not mean that firms do not have long-term innovation strategies that could involve universities. But, given the importance to firms of process innovation and experimental development in R&D activities (see Figure 29), it appears that, in general, firms are focused on activities that do not necessarily allow long-term projects:

> Two years is enough for a project for a firm... In the academy they would say ‘two years is nothing’, but COPEC [Chilean conglomerate focused on natural resources] would say ‘how is that nothing?’ According to the way firms work, which is normal, things need to be very fast. They have to be for yesterday and not for tomorrow (N° 49, senior executive private R&D fund).
>
> Firms need a relatively fast solution let's say six months to a year and the university takes two to three years, then obviously that is not useful for the firm (N° 43, mining sector representative).

Yet, when universities and research centres are able to understand the firms’ timeframes for research, they may become more attractive to firms:

> I distinguish the immediate problems from the long-term research, those immediate problems you have to go to the company and within the same week give a result and we do not consider that research but consultancy. At this moment I have two projects with Escondida [mining company]; one is about filtering and the other one about transport (N° 17, senior academic UDEC).
>
> CIPA manages very well the issue of timing, they manage very short timeframes and they understand that when the problem is now it is now (N° 47, industry representative).

When explaining about an experience of trying to create a link between a very important university and industry, one interviewee made a distinction between the university’s approach to research timeframes and that of and more applied research centres:

> I graduated from this university, so it was natural for me to go to them but they were thinking about very long terms and they were not really interested in creating linkages. It is not a business for them but it is a business for the UDT and CIPA. For them it is a business to have linkages with industry and to solve problems with industry in the short term (N° 47, industry representative).

In consequence, the different approaches to incremental innovation—not only in terms of type of research but also as a source of income—that exist between universities in Chile, may partly explain why some institutions are actually attractive for firms to collaborate with.

6.5.3 Coordination costs and information sharing

Universities and firms have different communication cultures, as well as different incentive sets, influencing collaboration (Metcalfe and Ramlogan, 2008). This creates a coordination problem, which requires public intervention. As discussed earlier in this chapter as well as in Chapters 4 and 5, since the 1990s the government has followed a policy oriented to fostering innovation, including promoting R&D linkages with universities. Although several programmes have been created, it appears that there could be improvements in their diffusion. For instance, although cost appears to be the most important obstacle to innovation (see Table 34) and the second reason explaining the lack of R&D activity in firms (see Figure 27), six years after the R&D tax credit was created, only 17% of the firms claimed to know about the incentive (MINECON, 2013b). This rate is similar between innovative and not innovative firm (MINECON, 2013b), perhaps reflecting inadequate diffusion and promotion of R&D instruments among firms. However, it is important to acknowledge the potential bias and opportunistic behaviour of respondents to this type of question.

At the same time, it appears that only a limited number of firms are really capable and/or interested in collaborating with universities on R&D projects. It is therefore important that policy not only promotes R&D collaboration but also contributes to increasing the capacity of firms so that they both value, and are able to carry out, this type of activity in the future. However, the Government's efforts have not always captured the real demands of Chilean firms and have had limited success in promoting the value of R&D as part of the innovation strategies of firms:

> If we have to label that [when academics come for support to apply for projects] it would be business social responsibility. What cost is it for us to sign the letter to the professor? But I would not demand anything from him. Today the collaboration is to be nice to them [academics] (N° 48, senior executive, mining company).
>
> We are interested in the issue of innovation. Personally, I believe in a profound educational reform, I believe everything starts from this. The supporting role of the Government is fundamental. The only thing is that I do not know is whether we are generating public policies customized to the demand of Chilean firms. This is what I get worried about... there is no acknowledgement that the productivity issue is at debit...and I believe that in general, these systems of innovation in a first stage generate largely projects that are not the type that the Government would expect to happen. [This is the] the typical discussion with the executives from InnovaChile (CORFO) is about the innovativeness of projects. That is fine but they [firms] need to improve their performance (N° 50, construction sector representative)
>
> ... if you are convinced that you want to innovate and that the innovation will create value therefore you will look at it as an investment and you will do it anyway without considering where the money comes from ... but you have to be one hundred per cent convinced that the innovation will generate value, innovate for the sake of innovate I believe is not innovation (N° 46, industry representative)

6.6 Tax credit as a policy to foster demand for firms to collaborate with universities on R&D

In order to incentivize firms to increase their R&D expenditure and strengthen their links with universities, in 2008 the government implemented a tax credit that would reduce the cost of R&D funded by firms and conducted in universities. This instrument was aimed at reducing the market failures related to innovation, in particular the lack of appropiability of innovation efforts.[65] This section discusses the tax credit, its changes and their possible implications for university-firm linkages.

The tax credit was approved by Law 20.241 of 19 January 2008 (*Incentivo Tributario a la Inversión Privada en Investigación y Desarrollo*). The main objective of this instrument was to reduce the difference between private expenditure on R&D as a percentage of the total of R&D carried out in the country and the average of the OECD countries. The law also aimed to strengthen the links between the research centres and firms, creating incentives for the creation of more value added in Chile (MINECON, 2013a: 3);

The law allowed firms to:

i. Deduct 35% of their total expenditure on R&D from the total of income tax (*Impuesto de Primera Categoría*)
ii. Consider as expenditure required to produce income, 65% of the total of expenditure on R&D

In practice, the tax credit would reduce the total cost of R&D contracts by 48% (CORFO, 2012). The law stipulated that the R&D projects should be conducted by a registered research centre, and that the contracts should be certified in advance by CORFO. Since the research centres largely belong, or are closely related, to universities it is possible to argue that this instrument created a direct incentive for

[65] The incentives that universities and academics have to collaborate with firms are discussed in Chapter 5.

firms to interact with universities by reducing the R&D costs and reducing the coordination costs. The latter being the case because belonging to the list of registered centres managed by CORFO can be interpreted as a signal of the quality of the research centres. This quality proof could have been especially important for independent research centres as well specialized centres that may not be associated with highly recognised universities.

The law established a maximum amount for research contracts of USD 398,000 dollars (3,000 *Unidad Tributarias Mensuales, UTM*) and a minimum of USD 8,000 dollars (100 UTM). [66] The value of the contract was limited to a maximum of 15% of the total sales of the firm (BCN, 2008).

Unfortunately, the tax credit did not achieve its expected output in terms of number of applications. By 2011 CORFO had only certified 73 contracts (See Figure 30), 27 of which were hired to research centres directly dependent on universities (37%). As a manager from CORFO explains:

> The first version of the law established this incentive so that firms would invest in R&D. Effectively, the first objective was that firms would invest in R&D. The second objective was to help strengthen the link between research centres, universities, or creators of knowledge in general. But in practice the modality that allowed firms to apply for the benefit only if they hired the research out to a research centre registered in the registry that we managed, in practice I would say that it was not adequate for the Chilean reality (N° 44, senior civil service).

The Government claimed that the reduced impact of the tax credit was explained by the lack of more flexible possibilities for making use of the tax credit and the relatively low maximum of the incentive (MINECON, 2013a). Additionally, links with universities at that time were not as high as might have been expected.

[66] Dollar prices of June 2008.

Although 71% of the research centres registered in CORFO are directly associated with universities (i.e.80 out of 112), only 27% of the firms that have used the tax credit have hired the services to universities. Indeed, 73% of the contracts have been carried out in association with centres not directly related to universities (MINECON, 2013a).

The results of the tax credit, however, were not as expected in terms of the volume of projects approved as eligible for the tax reductions. According to the MINECON (2013a) the volume of application unveiled several deficiencies in the design of the instrument. To solve this, in March 2012, Law 21.240 was modified by changes defined in Law 20.570. [67] The changed increased the benefits and flexibility of the system of incentives by allowing firms to also deduct the costs of internal R&D activities from their tax calculations (MINECON, 2013a: 4). As a CORFO manager explains:

> ... the law did not fulfil the expectations in terms of volume of firms interested in applying for tax credit through hiring R&D from research centres ... the law was modified to allow firms to claim tax credit not only for hiring third parties to carry out R&D but also for their internal R&D expenditure (N° 44, senior civil service)

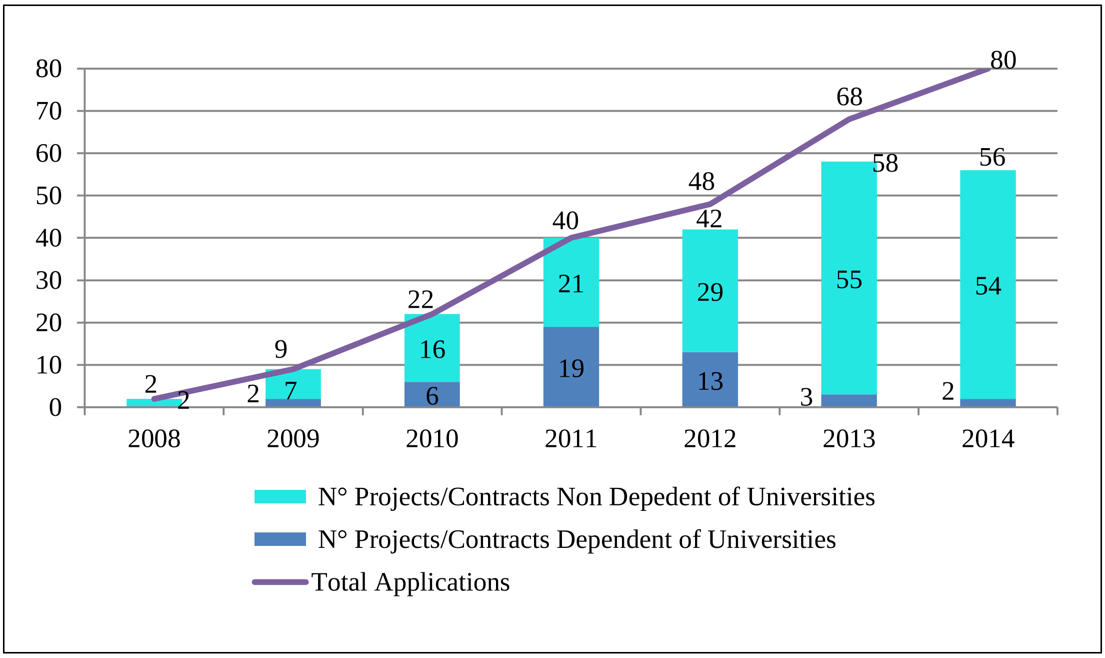
Figure 30 shows the trends in the number of applications and projects/contracts. CORFO differentiates between projects conducted inside the firms (projects) and the R&D activities contracted to R&D centres (contracts). The number of applications can consider more than one project/contract. From this figure is possible to observe that the number of projects has steeply increased since the implementation of the changes to the tax credit. The increase is particularly marked

[67] Law 20.570 approved in March 2002 and implemented in September of the same year (MINECON, 2013a).

in the value of the projects (see Figure 31). In 2013 the value of the projects/contracts approved reached three times the amount of resources certified in 2012. The increase in both the number and value of projects/contracts indicates that the changes introduced to the tax credit appear to have produced positive incentives for firms to carry out internal R&D activities. This seems to be in line with the Chilean firms' preference for conducting their innovation activities in house. As the same civil servant continues:

> Firms would tell me: 'I prefer to do it [R&D] with my own capacities, because I am the one who has the knowledge, my experts and I, our daily work on the topics of the firms.' There you can see the reality of the Chilean firm (N° 44, senior civil service).

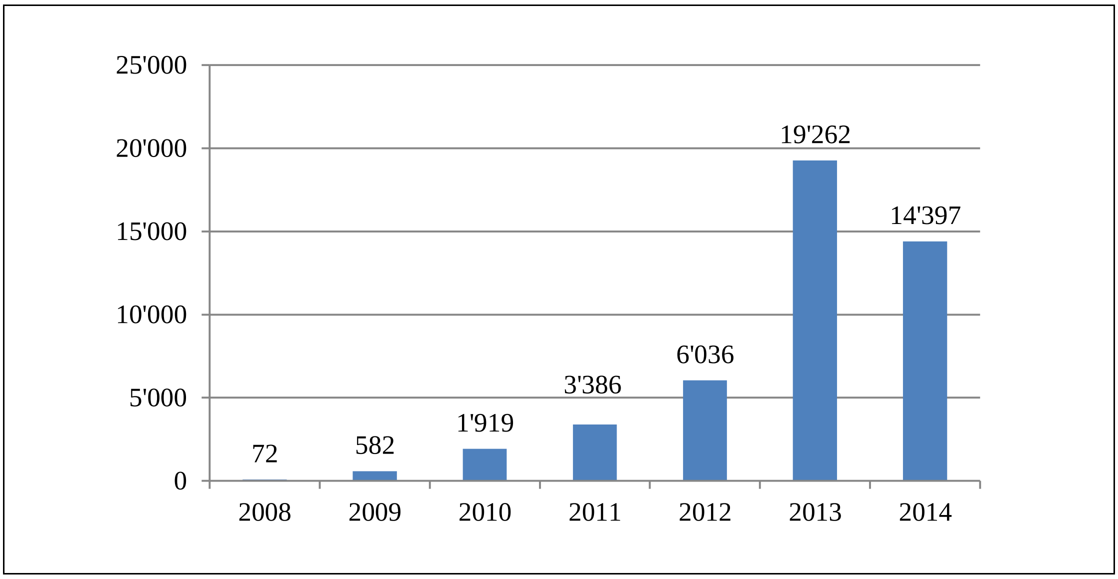
Figure 30: Number of R&D projects, contracts and applications certified by CORFO, by year and by type of organisation



Source: CORFO (2014).

However, this increase in the value of certified projects/contracts could also be interpreted differently. It may in fact reflect the normal level of firms' R&D and not necessarily represent an increase in activity. If this is the case, the changes in the law would have transferred the cost of R&D projects from the firms to the government and not necessarily increased firms' 'real' private internal investment on R&D. If so, then the tax credit should be revised because benefitting firms would have the intellectual property rights to knowledge created with public funds. A third interpretation is that the tax credit is funding non-R&D innovation, as firms need absorptive capabilities in order to carry out internal R&D projects and it is unlikely that they have created these in such a short time. Therefore, the increase may be explained by the inclusion of innovation activities that do not necessarily involve R&D. This is yet to be confirmed by long-term evaluations of the tax credit instrument.

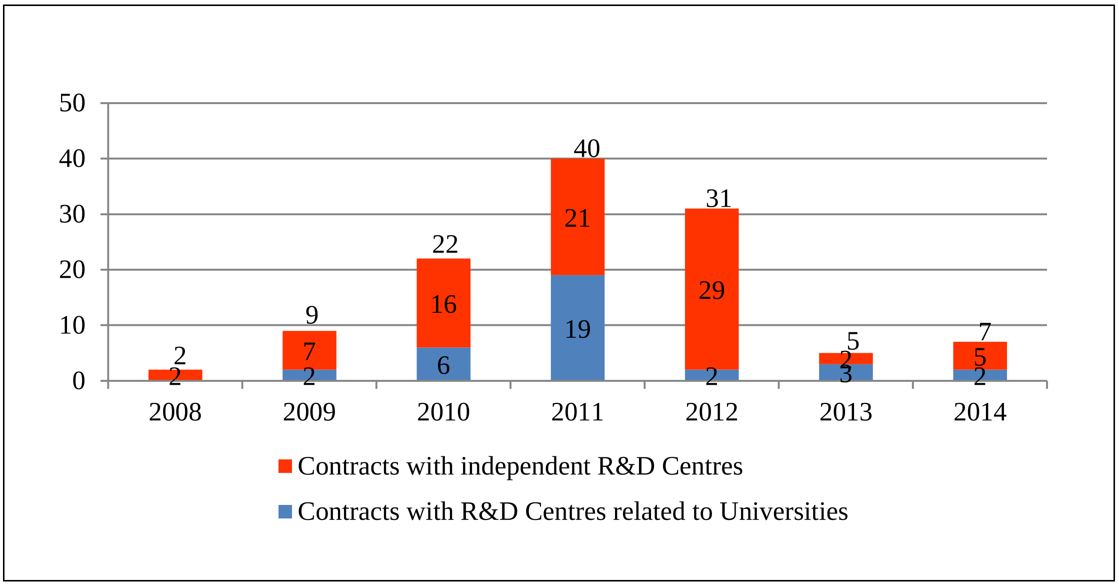
Figure 31: Value of certified projects/contracts by year, millions of Chilean pesos



Note: Amounts in current prices of each year.
Source: (CORFO, 2014).

The second effect that the changes to the law appear to have produced is that, although the number of contracts (R&D projects hired to research centres) slowly but steadily increased following the establishment of the tax credit in 2008 to reach a peak of 40 in 2011, the number of applications was severely reduced following the changes to the law in late-2012. In 2013 and 2014 the number of certified contracts was five and seven respectively (see Figure 32).This underscores the preference of firms for internal R&D projects.

Figure 32: Number of R&D contracts certified by CORFO: by year and type of contract



Source: (CORFO, 2014).

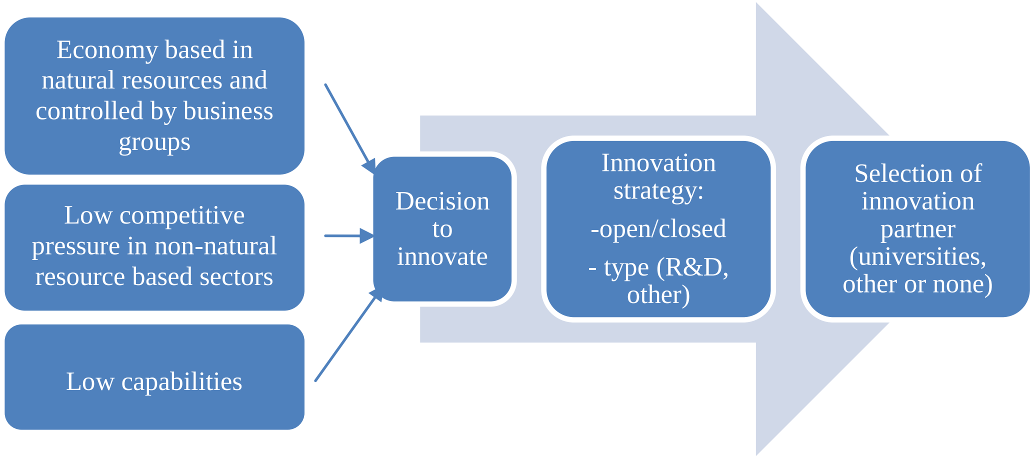
In summary, more than six years have passed since the tax credit was implemented. The fact that this direct and horizontal incentive to increase firms' innovation and university-firm linkages did not achieve the expected results in terms of volume, led the government to introduce changes in the law. These changes appeared to respond to the R&D demand from firms and to reduce the market failure related to innovation. They also reflected, however, the secondary relevance that research centres and universities represent as research partners for Chilean firms and highlight the preference of firms to conduct R&D internally:

> A law or a grant does not solve the fundamental problems that the country has, which are related to the fact that these worlds [academia and industry], in general, do not talk to each other. They will not talk because there is a law of because you have a programme. This means a deeper work needs to be done (N° 44, senior civil service)

6.7 Conclusion

In this chapter I have examined the factors influencing firms' innovation and collaboration on R&D activities with universities. Through the analysis I have shown that the productive structure of the country, characterized by its specialization in natural resources can partly explain the low innovation effort of firms and the unimportance of universities as research partners. In addition, I have shown that there are other characteristics—the lack of competitive pressure, the strong influence of business groups and the lack of capabilities to conduct R&D—of the macro environment in which Chilean firms work that reduce the incentives to innovate and, hence, reduce the potential for universities to collaborate. These macro factors generate an environment in which firms feel that R&D is not needed to survive in the market.

In addition, there are firm-level challenges to collaboration with universities. These include the low absorptive capacity of firms and institutional barriers to university-firm linkages. Both macro and firm-level pressures appear to influence the innovation strategy of firms and, in the case of Chile, help explain the limited role of universities as innovation partners. The model below summarizes the observed general pressures influencing how Chilean firms decide their innovation strategies.



In practical terms, Chilean firms carry out innovation activities as part of their business strategy. However, their innovations strategies are based on the perceived needs of the markets, as well as on the firm's innovative capacities and, in general, do not include R&D activities. As this chapter as shown, firms largely conduct incremental innovation based on acquiring and adapting available technology. This leaves a limited space for R&D activities, including collaboration with universities. This reflects both the lack of value that firms place on R&D and their lack of capabilities for carrying out this type of activity. Furthermore, these factors negatively complement each other. This does not mean, however, that collaboration between firms and universities is non-existent. Universities provide laboratory testing and consultancy services to firms and are highly regarded by firms for the quality of both their facilities and their researchers. But university-firm interactions are largely limited to the short-term solution of specific needs.

The fact that Chilean firms do not have significant incentives to collaborate with universities is in line with Katz (2004) claim that the national innovation systems in developed countries are different from the ones in Latin American countries. According to Katz, the latter were not born with the mission of exploring the world's technological frontier, but created with the purpose of adapting to the local environment production processes and product designs originating in more developed countries. At the same time, the lack of absorptive capacities in firms is a negative complement that limits their interest in, and opportunities for carrying out, R&D activities and collaboration with universities.

Chapter 7: Impact of collaboration on firms' innovation performance

7.1 Introduction

Having explored the incentives for both universities and firms to collaborate on innovation in the Chilean context, I turn now to evaluate whether that collaboration influences the innovation performance of firms.

In particular, this chapter assesses whether collaborating with universities has a positive effect on the likelihood of introducing innovations and on the share of innovative sales. As outlined in Chapter 3, the analysis is conducted using a novel panel of innovative firms in Chile for the 2005–2010 period, applying Tobit, probit and random effect methods as the estimation strategy. However, before presenting the results from the analysis, I will discuss the recent literature about collaboration for innovation and introduce the hypotheses to be tested, the models to be used in the estimations and the estimation strategy.

7.2 Literature review and theoretical framework

This section aims to complement the discussion presented in the literature review (Chapter 2) by focusing on the impact of collaboration with universities on firms' innovation output and performance. As we saw in that chapter, firms are increasingly drawing on open innovation as part of their innovation strategies (Chesbrough, 2003), in part, to overcome the fact that no organisation has sufficient human talent or the capacity to cover all the scientific disciplines that can contribute to product development and innovation (Markman et al., 2008). The use of external relations not only compensates for missing capabilities and helps expand the competencies of firms (Kogut and Zander, 1992), but also concentrates the use of their complementary assets in the division of labour (Powell and Grodal, 2005) while facilitating the attainment of complementary assets related to innovative labour (Mowery et al., 1996). Moreover, external collaboration should increase their innovation output and increase their comparative advantage (Broström, 2012). External collaboration makes firms more innovative in comparison with non-collaborating firms (Fitjar and Rodriguez-Pose, 2013) and increases their success in product innovation (Un et al., 2010). Further reasons for collaboration can be identified in learning and network strengthening (Broström, 2012).

In addition to the direct benefits that firms can attain through external collaboration, the potential indirect benefits may also prove attractive for these organisations. For instance, collaborative agreements can provide mechanisms for uncovering new ideas, convert inventions into products faster, fend off competition, compensate for technology lock outs, and adapt to swift market changes (Markman et al., 2009:644). Collaboration on R&D also helps firms fill the gaps in their knowledge and, as a result, increases their innovation activities (Lockett and Wright, 2005).

Universities play a smaller role as sources of knowledge than the business sector itself and other intermediate sources, such as suppliers and customers (Cosh and Hughes, 2010; Hughes, 2011). However, firms may decide to partner with universities because it allows them to participate in the generation of new knowledge (Perkmann and West, 2014) and in frontier development, especially in science-based sectors (Perkmann, 2015). Collaboration with universities is also attractive for firms because costs can be scaled across a number of participants without necessarily reducing the value created (Perkmann and West, 2014).

Collaboration with universities also seems to be primarily a way for firms to generate capabilities for innovation since it allows firms to increase their ability to translate market opportunities into technical or organisational problems (Broström, 2012: 326) increases the range of knowledge available to them (Kaufmann and Todtling, 2001), and allows them to strengthen their explorative and exploitative capabilities by providing access to new ideas, which improves the development of explorative learning capabilities and offers assistance in the development of innovation conducive to the introduction of new products and processes (Bishop et al. (2011).

7.2.1 Impact of university-firm collaboration

Several factors help explain the impact of collaboration on firms. These include the particular characteristics of the firm and their collaboration partners, the objectives of the collaboration, and the transaction and coordination costs of the agreements (Belderbos et al., 2004b; Crespi et al., 2008; Okamuro, 2007). Recent literature has also found evidence that collaboration has a positive impact on the innovation performance of firms only when is conducted persistently (Belderbos et al., 2015).

The impact on firms of collaborating with universities can be classified under at least two headings (Barge-Gil and Modrego, 2011): (i) the technical impact, i.e. the effects of university-firm on new goods, services, products, etc.; and (ii) the economic impact, i.e., its effect on sales, exports, profits, productivity, among others (Barge-Gil and Modrego, 2011).

Empirical evidence has demonstrated the positive technical impact of university-firm collaboration on the innovation output of firms. For instance, research has found that R&D collaboration with universities has a positive impact on product innovation (Srholec, 2014; Un et al., 2010). Cooperation with universities has been shown to have a positive influence on the economic success of firms through the development of radical or new-to-the-market innovations (Aschhoff and Schmidt, 2008; Cassiman et al., 2010; Köhler et al., 2012; Tödtling et al., 2009), which improve the growth performance of firms (Belderbos et al., 2004b).

Collaboration with universities also produces a positive impact on process innovation (Un and Asakawa, 2015). In particular recent research has found that R&D collaboration positively affects process innovation in low-tech industries (Maietta, 2015). This correlation means that even though process innovation tends to be internal and tacit to the firm, it can still benefit from external R&D collaborations. There may be complementarities also in the type of innovation produced. However, research has found conflicting results in this regard. While some research has found the existence of complementarities in performance between product, process and organisational innovation (Ballot et al., 2015), others have found that that cooperating with public research organisations such as universities increases product innovation, but has no effect on process innovation

(Robin and Schubert, 2013). According to Ballot et al. (2015), however, these complementarities depend on the national context as well as on firm size and capabilities.

The empirical evidence has also not found agreement on the economic impact of collaboration with universities. Collaboration with research organisations has been found to significantly improve product sales (Faems et al., 2005; Lööf and Heshmati, 2002). However, collaboration with research organisations has been found to negatively affect new products sales (Caloghirou et al., 2004; Frenz and Ietto-Gillies, 2009; Ledwith and Coughlan, 2005) and collaboration with other types of partners to have an insignificant effect on sales (Ledwith and Coughlan, 2005).

The economic impact of innovation of collaborating with universities can also be influenced by sectoral differences (Lööf and Broström, 2008). According to Lööf and Broström (2008), university collaboration has a positive influence on the innovative performance of large manufacturing firms. In contrast, there appears to be an insignificant association between university collaboration and the average service firm’s innovation performance (Lööf and Broström, 2008).

The lack of agreement in terms of effects of university-firm collaboration may be explained by the misalignment between the research capacities of universities and the absorptive capacities of firms. Recent research has found that the impact of firms' collaboration with universities is influenced by the country of origin of the universities (local or foreign) and by the country' level of development (Fu and Li, 2016). This underscores the importance of exploring the effects of university-firms linkages in the context of developing countries.

7.2.2 Empirical studies on university-firm collaboration in developing countries

Although many studies of university-firm linkages in developed countries have agreed that collaboration with universities is useful for the development of market innovations (e.g. Aschhoff and Schmidt, 2008; Cassiman et al., 2010; van Beers and Zand, 2014) and the innovation performance of firms (e.g. Belderbos et al., 2004b; Faems et al., 2005), a number of recent studies, drawing on evidence from developing countries, have yielded conflicting results (Fu and Li, 2016; Tsai, 2009). Hall and Mairesse's (2006), suggest that the different circumstances surrounding innovation in developing countries in comparison to Western Europe may partly explain the results. These authors argue that in developing countries, the difficulties associated with the intrinsic characteristics of innovation are more severe than in the developed countries as developing countries usually suffer stronger information asymmetries, coordination problems, and have less developed financial markets. At the same time, they not only have limited technical capabilities but also often lack skilled human capital.

Recent research has found that the main source of successful process and product innovation in developing country settings is the acquisition of technologies, either alone or in combination with internal development (Goedhuys and Veugelers, 2012). Also, R&D collaboration initiatives in emergent industries are less likely to occur with academic support or public funds than collaborative projects with mature industries. One of the reasons explaining this is the lack of developed knowledge networks in emergent markets and the absence of coordinated public funding, an absence which harms emergent markets more often than mature ones (Bodas Freitas et al., 2013).

Research using data from developing countries has shown that collaboration with national universities contributes to the diffusion of available technology in local firms (Fu and Li, 2016). Empirical analysis using data from Chinese companies has shown that collaboration with universities from other developing countries appears to be fruitful in enhancing the creation of ground-breaking innovations in indigenous Chinese firms while collaboration with domestic firms has been beneficial for the diffusion of advanced technologies in China. Conversely, the contribution of universities from developed regions is beneficial to foreign-invested firms (Fu and Li, 2016).

7.2.3 Summary and hypothesis

The study of the effects of university-firm interactions in developing country settings is becoming increasingly relevant for the design and evaluation of public policies. Recent empirical studies have shown that the level of development and innovation systems in developing countries appear to influence the impact of the university-firm linkages and its characteristics (Fu and Li, 2016; Goedhuys and Veugelers, 2012; Kafouros et al., 2015).

Based on the evidence from developed countries it would be reasonable to expect that firms engaged in collaboration with universities will demonstrate clear positive effects on their innovation performance. This is based on the assumption that collaborating with universities allows firms to obtain knowledge not available in the market—i.e. new knowledge created from university research—which will strengthen firm's absorptive capabilities. These linkages should allow firms, as mentioned earlier, to obtain direct and indirect comparative advantages. However, these effects should reflect the differences in innovation capacity between developed and developing countries.

As discussed in the previous chapter, Chile’s economic structure and the fact innovation in Chilean firms is mostly aimed at adapting available technologies rather than creating new technologies (MINECON, 2012a), have produced limited incentives for firms to collaborate with universities. In fact, in terms of expenditure on formal collaborative agreements in Chile, universities are the smallest source of knowledge for firms. Consequently, collaboration with universities for the introduction of technological (product or process) innovations may be less relevant than collaboration with other types of partners. However, universities in this country have higher skills than those available in firms (not necessarily as skilled to introduce new to the world innovations but higher than those required to introduce new-to-the-firm innovations), and high-skilled labour may be needed when firms are interested, and have the capacity, to adapt internationally available technologies that are not yet in available in local markets. In developing countries, universities may be the only source for this type of labour. Consequently, the first hypothesis to be tested is as follows:

Hypothesis 1: Collaboration with universities increases the likelihood of firms introducing new-to-the-market innovations; but it may not influence the likelihood of introducing new-to-the-firm innovations.

Considering the potential benefits for firms of collaborating with universities, one might expect that firms that do invest in innovative collaborative projects with universities are those working on the development of more radical innovations (because universities are supposed to have comparative advantages in this type of research). Collaborating with universities should, thus, have a positive effect on the innovative efficiency of firms by increasing the sale of innovative products or reducing their costs through process innovations. Therefore, the second hypothesis this chapter will assess is as follows:

Hypothesis 2: Collaboration with universities increases the innovation performance of firms.

7.3 Model

The goal of the empirical analysis presented here is to assess the impact of university-firm collaboration on the innovation performance of firms. To examine these effects the models examine the innovation output of firms resulting from their collaboration with universities while controlling for a vector of firm and industry-specific characteristics. The long-term effects of collaboration with universities are considered by including the first lag of collaboration with universities as a variable in the model. Although one lag may not be enough to capture the long-term effects of university-firm collaboration, the limited availability of data only allows for the inclusion of this variable in the estimations. Complementary estimations are also carried out to assess the effects of collaboration with other types of partner—suppliers, clients, competitors, consultants, and other firms from the same conglomerate—on the innovation output of firms. Therefore, to estimate the likelihood of introducing product and process innovation I estimate the following specification:

$$tech\_inn_{(i,t)}=\alpha_i+\alpha_1 universities_{(i,t)}+\alpha_2 R\&D_{(i,t)}+\sum_{j=1}^{j} Control\ Var_{(i,t)}+\mu_{(i)}+\varepsilon_{(i,t)},$$

$$i=1,\ldots,N \quad t=1,\ldots,T \quad (1)$$

$$tech\_inn_{(i,t)}\begin{cases}1_{(i,t)}, & \text{if firm } i \text{ introduced technological innovation in time } t\\ 0, & \text{if firms } i \text{ did not introduce technological innovation in time } t\end{cases}$$

Where $tech\_inn_{(i,t)}$ is a dummy variable that takes the value to 1 if the firm i at time t introduced technological innovations and zero otherwise, $R\&D_{(i,t)}$ is the R&D effort of firm *i* in time *t*, $universities_{(i,t)}$ is a dummy variable that identifies that the firm *i* collaborated with universities in time *t*, $Control\ Var_{(i,t)}$ represents the vectors of variables that control for the specific characteristics of firms and industries. Finally, $\mu_{(i)}$ represents the unobservable and time invariant individual effects, and $\varepsilon_{(i,t)}$ is the error term ($\varepsilon_{(i,t)} \sim N(0,\sigma^2)$).

To estimate the impact of collaboration with universities on the innovation output of firms I estimate the following specification:

$$I_{(i,t)}=\alpha_i+\alpha_1 universities_{(i,t)}+\alpha_2 R\&D_{(i,t)}+\sum_{j=1}^{j} Control\ Var_{(i,t)}+\mu_{(i)}+\varepsilon_{(i,t)},\ i=1,\ldots,N\ t=1,\ldots,T \quad (1)$$

$$I_{(i,t)}=\begin{cases}I^*_{(i,t)}, & I^*_{i,t}>0\\ 0, & I^*_{i,t}\le 0\end{cases} \quad (2)$$

Where $I_{(\mathrm{i,t})}$ is the innovation output of firm i at time t, $R\&D_{(\mathrm{i,t})}$ is the R&D effort of firm i in time $t, universities_{(\mathrm{i,t})}$ is a dummy variable that identifies that firm i collaborated with universities in time t, $Control\,Var_{(\mathrm{i,t})}$ represents the vectors of variables that control by the specific characteristics of firms and industries. Finally, $\mu_{(\mathrm{i})}$ represents the unobservable and time invariant individual effects, and $\varepsilon_{(\mathrm{i,t})}$ is the error term ($\varepsilon_{(\mathrm{i,t})} \sim \mathrm{N}(0, \sigma^2)$).

7.3.1 Measurement

Dependent variable

Following previous empirical studies of university-firm collaboration (Belderbos et al., 2004b; Faems et al., 2005; Lööf and Broström, 2008; Tsai and Hsieh, 2009), I measure the dependent variable of the model measuring the impact of collaboration with universities on the innovation performance of firms as the share of innovative sales in the total turnover of firms (*lgitsales*). The share of turnover produced from innovative sales can be seen as an indicator of the effectiveness of the innovation strategy of firms in terms of creating new products as well as in terms of the further development of already available technologies and products (Faems et al., 2005). This means firms are considered innovative if they introduced product or process innovations. An alternative measure of innovation output used in the literature is the number of patents (e.g. Baba et al., 2009; Eom and Lee, 2010; Lööf and Broström, 2008). Despite the fact that the number of patents is the direct outcome of the innovative process, especially if the inventions are expected to have a commercial impact, this indicator nevertheless possesses two major disadvantages: firstly, not all inventions are patentable and, secondly, firms may sometimes choose alternative methods for protecting their inventions (Archibugi and Planta, 1996).

Although the EIT considers two sources of innovative turnover: sale of products and services new-to-the-market and sale of products and services innovations new-to-the-firm (INE, 2009b), this panel does not differentiate these. This is because the categorization of innovative sales by type of novelty of the innovations was only introduced in the sixth version of the survey (INE, 2007; 2009a). The share of innovative sales ranges between 0 and 1, therefore, in order to make it lie within the set of real numbers I use the logit transformation of the share of innovative sales in the estimations (Hall and Mairesse, 2006; Mairesse and Mohnen, 2010; Raymond et al., 2010; Raymond et al., 2007). There are cases of firms that only introduced process innovation during the period and consequently, reported no innovative sales during the period. There are also firms that report 100% of their sales to be from the sale of innovative products. To take account of these extreme values, I replaced the zeros by some ε_1 between 0 and the lowest positive value of the corresponding variable, and the ones by some ε_2 between the largest value (smaller than 1) of the variable and 1 (Raymond et al., 2009). Additionally, since firms decide if they introduce innovations, there may be a sample selection bias. To account for this, generalized Tobit methods are appropriate for the estimation process (Wooldridge, 2001).[68]

Measurement of university-firm collaboration

[68] Tobit models refer to regression models in which the range of the dependent variable is constrained in some way (Amemiya, 1984).

The specifications include a dummy variable (*col_univ*) that takes the value 1 if firms collaborated with universities and zero otherwise.[69] In order to capture the dynamic effects of collaboration with universities in the innovation success of firms, the model measuring the impact of collaboration with universities on the innovation performance of firms considers the first lag of collaboration with universities (*lcol_univ*).

Control variables

The control variables considered in the models are intended to measure the direct factors influencing the innovation output of firms. Empirical evidence has largely found that the main direct inputs for the innovation process are the internal and external efforts of firms on R&D (Frenz and Ietto-Gillies, 2008). Variables measuring firms' efforts on R&D have been used as proxies to capture the current absorptive capacity of firms (Aschhoff and Schmidt, 2008; Cohen and Levinthal, 1990; Negassi, 2004). Therefore, I have included the share of R&D expenses over the total of sales of firms. The logarithm transformation of this variable is included for observations that report R&D expenses higher than zero (*logr_d*). Also, in order to take into account of the fact that there are firms that do not invest in R&D, I have followed Raymond et al. (2010) and included a dummy variable that takes value 1 when firms do not report R&D expenditure and zero otherwise (*dr_d*). In addition, the absorptive capacity of firms has been identified as relevant for the innovation

[69] This type of collaboration also includes firms that collaborated with public research centres. This facilitates comparison with the literature. There are 77 observations from innovative firms that reported collaboration with public research centres but did not collaborate with universities in the period considered in the panel. This represents 0.7% of the observations of the subsample of innovative firms and 0.8% of total observations of the panel.

performance of firms since it contributes to the better assimilation and exploitation of external knowledge (Cohen and Levinthal, 1990) and consequently influences the innovation output of firms. Since the absorptive capacity of the firm depends on the absorptive capacity of its individuals (Cohen and Levinthal, 1990), ideally I would have included in the model the intensity of high skilled personnel in the firm—measured by the share of graduates with PhD, masters, or professional degrees in relation to the total employees of the firm (Aschhoff and Schmidt, 2008). However, although the EIT includes data on R&D personnel, the data is not available for the third wave of the panel (seventh EIT) and I was not, therefore, able to include it in this dataset. However, the absorptive capability of firms is also path dependent and the existence of an R&D department can be used as a proxy for the accumulated absorptive capacity. Therefore, in order to measure past trends in innovation, the model considers a dummy variable that takes the value 1 if the firm has an R&D department or unit and 0 otherwise (*R&D department*).

In line with the available literature about collaboration and the innovation performance of firms (Aschhoff and Schmidt, 2008; Belderbos et al., 2004b; Faems et al., 2005; Frenz and Ietto-Gillies, 2008; e.g. Miotti and Sachwald, 2003), the logarithm of employment is included in the models as a variable to control for the size of firms (*size_emp*). In the case of Chile, R&D expenditure is concentrated in large firms (MINECON, 2012b), and thus we might expect that large firms are more likely to have a higher innovation output.

Additionally, three variables are included in the models to control for the specific characteristics of firms: (i) the logarithm of the age of firms; (ii) a vector of sector dummy variables to control for heterogeneity across sectors; and (iii) dummy variables to control for heterogeneity across years (*age*). According to Wooldridge (2005), including dummy variables for groups helps to control for a certain amount of the heterogeneity that might be correlated with the time constant elements of the explanatory variables.

The literature has shown that specific types of R&D cooperation directly influence the innovation success of firms (Aschhoff and Schmidt, 2008; Cassiman et al., 2010:57). In order to include this in the specifications, the models include dummy variables for collaboration with suppliers, clients, competitors, consultants, and other firms from the same conglomerate. In order to measure the effect of collaboration on the innovation in firms, a dummy (*col_any*) equal to 1 when a firm collaborated with any type of organisation or equal to 0 in the absence of collaboration is included. Furthermore, to take into account the potential correlation between collaboration with universities and with other partners, I have included a dummy equal to 1 for firms declaring collaboration activities with any of the already mentioned non-university collaboration partners (*col_other_org*).

Since the model assessing the impact of collaboration on the innovation performance of firms will be estimated using generalized Tobit estimation (see estimation strategy below), I included the dummy variables *foreign*, *group*, *export* and *public_funds* as explanatory variables to the random Probit estimations. The significant variables are then considered in the selection equation of the generalized Tobit estimation. These variables are also the ones included in the model estimating the effect of collaboration with universities on the likelihood of introducing new-to-the-firm and new-to-the-market innovations. The inclusion of the variable *foreign* is based on the belief that firms that are subsidiaries of multinational have higher absorptive capacities and are consequently more likely to introduce product and process innovation.[70] It is also reasonable to expect foreign multinational companies to be more competitive given that they trade in international markets and, since these firms share the same culture and, often, share technical and managerial capacities, it could be argued that this variable may also reflect the capabilities of firms.

The reasoning behind including a dummy variable *group*, which equals 1 for firms belonging to domestic business groups and 0 otherwise, is that one would expect that firms that are part of domestic business groups have higher capabilities that allow them to introduce product and process innovations. The third dummy included in the random probit estimations is *export.* It takes the value 1 when firms declare they are exporters and 0 otherwise. This variable aims to capture exposure to international markets as exporting firms are potentially more likely to introduce innovations since they face higher competition (Álvarez et al., 2012). The dummy *public_funds* takes the value 1 when firms received public funding for innovation and 0 otherwise, with the expectation that this variable presents a positive and significant effect on the likelihood of introducing innovations because the cost of innovation was one of the main obstacles to innovation cited by Chilean firms (MINECON, 2012a) and public grants would help reduce this cost. Table 36 presents the definition of the variables that are included in the model:

[70] Categorizing whether firms belong to multinationals from developed or developing countries would help obtain a clearer proxy of their level of competitiveness. Unfortunately, this information is unavailable.

Table 36: Definition of variables

Variable	Definition
Dependent Variable Tobit Generalized estimation	
Lgitsales	Logit transformation of the share of innovative sales (sales of innovative products/total sales)
Dependent Variable Likelihood estimation	
new-to-the-firm	Dummy variable that takes the value of 1 if the firm introduced new-to-the-firm innovations and 0 otherwise
new-to-the-market	Dummy variable that takes the value of 1 if the firm introduced new-to-the-market innovations and 0 otherwise
Measurement of University-firm collaboration	
col_univ	Collaboration with universities. Dummy variable that takes the value of 1 if the firm declared that it collaborated with universities or research centres, and 0 otherwise
lcol_univ	Collaboration with universities (Lagged)
Control Variables	
logr_d	Log (R&D Expenses/Total Sales)
dr_d	Dummy variable that takes the value of 1 if firm did not have R&D expenses
R&D department	Dummy variable that takes the value of 1 if firm has R&D unit, and 0 otherwise
size_emp	Log employment
ln_age	Log (age of firm)
col_suppl	Collaboration with suppliers. Dummy variable that takes the value of 1 if the firm declared that collaborated with suppliers, and 0 otherwise
col_cli	Collaboration with clients. Dummy variable that takes the value of 1 if the firm declared that it collaborated with clients, and 0 otherwise
col_comp	Collaboration with competitors: Dummy variable that takes the value of 1 if the firm declared that it collaborated with competitors, and 0 otherwise
col_con	Collaboration with consultants. Dummy variable that takes the value of 1 if the firm declared that it collaborated with consultants, and 0 otherwise
col_other	Collaboration with other firms from the same conglomerated. Dummy variable that takes the value of 1 if the firm

	declared that it collaborated with other firms from the same conglomerate, and 0 otherwise
col_other_org	Collaboration with other organisations. Dummy variable that takes the value of 1 if the firm collaborated with any of the following partners: suppliers, clients, competitors and other firms from the same conglomerate, and 0 otherwise
lcol_other_org	Collaboration with other organisations (lagged)
col_any	Collaboration, Dummy variable that takes the value of 1 if the firm collaborated with any of the following partners: universities, suppliers, clients, competitors, and other firms from the same conglomerate and 0 otherwise
lcol_any	col_any (lagged)
	Additional variables innovation Likelihood (and selection equation estimations)
Foreign	Dummy variable that takes the value of 1 if the property of the firm is foreign or mixed foreign (national and foreign capital) and 0 otherwise
Group	Dummy variable that takes the value of 1 if the firm belongs to a national business group and 0 otherwise
Export	Dummy variable that takes the value of 1 if firm declared they are exporters and 0 otherwise
public_funds	Dummy variable that takes the value of 1 if firm declared they received public funds for innovation and 0 otherwise

7.4 Estimation strategy

Two main factors influence the estimation strategy: the characteristics of the dataset and the objective of the research. In terms of the characteristics of the dataset, information about the level of innovative sales is only available for those firms that introduced product and/or process innovations. Additionally, the dependent variable (share of innovative sales over the total of sales of the firm) only takes values between zero and 100, which indicates a censored regression that requires the use of Tobit estimation methods (Wooldridge, 2001). From the total of innovative firms, 29% report shares of innovative sales of less than 5%. This means that almost a third of the observations from innovative firms show values close to zero.

Consequently, estimating the parameters using ordinary least square (OLS) methods will produce inconsistent estimators; this is because the censored data is not representative of the population (Cameron and Trivedi, 2010; Grosse Kathoefer and Leker, 2010). In addition, the dummy variable that identifies innovative firms is endogenous. There are two decisions that firms make: First whether to innovate or not, and second, the level of innovative sales they hope to achieve. This produces selection effects on the decision to innovate. In the presence of selection effects, Tobit generalized methods provide the best estimation strategy (Wooldridge, 2001). It is important to mention that a caveat of the Tobit method is that its estimators are only consistent with the assumption that the latent dependent variable follows a homoskedastic normal distribution (Wooldridge, 2001).

I estimate the likelihood of introducing technological innovations through random probit methods. This allows me to explore the variables influencing a firm’s to introduce new-to-the-market and new-to-the-firm innovations. This, in turn, will help uncover whether the potential benefits of collaboration are available to all firms or are limited to innovative firms. In addition, I use the variables showing significant coefficients as explanatory variables in the selection equation of the generalized Tobit estimations.

In relation to the type of data and its influence on the estimation strategy, the availability of panel data allows us to control for the unobserved time-constant heterogeneity between firms that can influence their innovation output. The presence of unobserved heterogeneity produces endogeneity, which means that the there is a correlation between the explanatory variable and the error term that makes the coefficients inconsistent (Baum, 2006). The unobserved individual effects can be correlated with the error or they can be randomly distributed. Random effects models assume that the individual specific constant term is randomly distributed across cross-sectional units (Greene, 2008). Fixed effects models allow the unobserved individual effects to be correlated with the included variables of the model (Greene, 2008). This implies that differences across groups can be measured by differences in the constant terms (Greene, 2008).

There are several advantages to using random effects (RE) rather than fixed effects (FE) as an estimation strategy. First, by using RE, the mean and variance of the unobserved effects can be estimated instead of calculating the unobserved effects for each firm as when using FE (which would severely influence the degrees of freedom within the estimation) (Maddala, 1987). Second, FE does not measure the effects of time invariant variables as the RE method does. Since there is evidence in the literature that the innovation output of firms varies according to the sector (Frenz and Ietto-Gillies, 2009; e.g. Lööf and Broström, 2008), which is a time invariant variable, the RE method is more appropriate. Consequently, the model is estimated using generalized Tobit methods and random effects when controlling for the unobserved heterogeneity of firms.

In practice, I use Heckman sample selection methods allowing for random effects. To measure the inter-temporal effects of collaboration in the innovation output of firms, the estimation strategy also estimates the model using lagged values of the variable collaboration with universities. For robustness purposes, the specification of the model assessing the impact of collaboration with universities on innovative firms is estimated using the two following subsamples: firms with two consecutives observations in the panel, and firms from the manufacturing sector.

7.5 Data

As we saw in Chapter 3, the analysis is based on a novel panel dataset of innovative firms in Chile based on three waves of the EIT covering the innovation efforts of firms during the 2005–2010 period (fifth, sixth, and seventh surveys). The survey provides information about the innovative activities of only those firms that declared that they introduced innovations (product, process, or managerial innovation). In the dataset, however, I only consider as innovative firms, those carrying out technological innovations, i.e. innovations in product and/or process.[71] The restriction on the availability of information leads to sample selection bias. This limitation makes Tobit generalized methods an appropriate estimation strategy but it also needs to be considered when elaborating conclusions from the analysis.

Table 37 presents the distribution of innovative firms in the panel by sector and year. The data shows that the sectors most represented in the panel are: manufacturing (33%); real state and business activities (12%); and transport, storage and communications (9%).

[71] The distribution of innovative and non-innovative firms in the panel is presented in Chapter 3.

Table 37: Innovative firms by sector and year

Sector	2007	2009	2011	Total
A: Agriculture, Hunting and Forestry	77	68	46	191
B: Fishing	24	6	24	54
C: Mining and Quarrying	9	14	13	36
D: Manufacturing	426	330	266	1,022
E: Electricity, gas and water supply	27	28	36	91
F: Construction	89	92	72	253
G:Wholesale and retail; other	11	99	114	224
H: Hotels and restaurants	0	39	52	91
I: Transport, storage and communications	57	144	89	290
J: Financial intermediation	44	38	52	134
K: Real estate, renting and business activities	133	155	95	383
N: Health and social work	72	61	66	199
O: Other community, social and personal activities	33	30	35	98
Total	**1,002**	**1,104**	**960**	**3,066**

7.6 Descriptive statistics

The observations in the dataset show that, on average, innovative sales account for 19% firms' total sales and that firms report that on average 0.86% of their sales are invested in R&D activities, both internal and external. This very low participation is partly explained by the fact that 72% of the observations declared that they did not invest in R&D. For those that did invest, the share of sales spent on R&D was 3%. In terms of the type of property, 47% of the observations indicate firms belonging to a group while 12.36% report that their capital is foreign or mixed.[72] In addition, 27% of the observations are from exporting innovative firms.

[72] There is information about affiliation to a group for 83% of the observations of the innovative firms.

Table 38 shows the descriptive statistics of the variables.[73] It is possible to observe from this table that there is data missing in the R&D related variables. This is the result of a change in the survey strategy of the seventh version of the EIT.[74] Also, the data from the table shows that if the lagged values of the collaboration-related variables are included in the estimations, then the number of observations is significantly reduced to 835.

Table 38: Descriptive statistics innovative firms

Variable	N° observations	Mean	Std. Dev	Min	Max
Share of innovative sales (logit transformation)	3,066	-3.9064	6.59987	-11.513	16.6355
New-to-the-firm	3,066	0.87182	0.33434	0	1
New-to-the-market	3,066	0.36921	0.42267	0	1
Log(R&D/sales)	2,649	-1.4832	2.58315	-11.531	0
Non expenditures on R&D (dummy)	2,649	0.71574	0.45115	0	1
Co with any organisation	3,066	0.36138	0.48048	0	1
Co with any organisation (lagged)	835	0.28623	0.45227	0	1
Co with universities	3,066	0.15851	0.36528	0	1
Co with universities (lagged)	835	0.13892	0.34607	0	1
Co with other firms	3,066	0.20189	0.40148	0	1
Co with other firms (lagged)	835	0.27545	0.44701	0	1
Co with suppliers	3,066	0.2619	0.43974	0	1
Co with clients	3,066	0.18982	0.39223	0	1
Co with competitors	3,066	0.1122	0.31566	0	1
Co with consultants	3,066	0.15688	0.36375	0	1
Co with non-universities	3,066	0.3441	0.47515	0	1
R&D department (dummy)	3,066	0.19341	0.39504	0	1
Log (Firm size)	3,066	4.39842	1.78725	-0.6931	9.32376
Log (Firm age)	2,513	2.8431	0.80157	0	4.69135
Foreign firm dummy	3,066	0.12361	0.32919	0	1
Export firm dummy	3,066	0.27136	0.44474	0	1
Group firm dummy	2,517	0.47239	0.49934	0	1
Public funds dummy	3,066	0.09687	0.29583	0	1
Total innovative firms	3,066				

[73] Please refer to the Appendices (Table 47) for the correlation matrix of the variables.
[74] Please refer to Chapter 3 for a description of the EIT and the dataset.

Table 39 presents the collaboration patterns of the dataset according to partner and industrial sector. The data is categorized according to the following collaboration partners: universities, other firms from the same conglomerate, suppliers, clients, competitors, consultants, and collaboration with non-university partners. The category non-university partners, includes collaboration with other firms from the same conglomerate, suppliers, consultant, clients, and competitors. The table also shows the number of observations that declared any collaboration with any type of organisation, which totals 1,108 for the period 2005–2010.

The dataset reveals that innovative firms' main collaborators are, in order of relevance: suppliers, other firms from the same conglomerate, and clients. The reason why suppliers rank so highly, might be down to the relative importance in the dataset of the observations from the manufacturing sector, of which 30% declared that they collaborated with suppliers. In contrast, collaboration with competitors appears to be the least frequent source of collaboration for firms.

The sectors that show the highest rates of collaboration are as follow: mining and quarrying, with 50% of the observations conducting some kind of collaboration during the period of analysis; agriculture (44%); and health and social work (42%). The sector least inclined to collaboration appears to be Hotels and restaurants, with a collaboration rate of 19%. The low importance of collaboration in this sector does not surprise since this may be a sector less prone to introduce technological innovations. However, the fact that belonging to this sector innovated in products and/or process during the period; and that firms collaborated with other organisations with innovation purposes are surprising results. One possible explanation may suggest that the collaboration activities were aimed at training personnel. In this sector, suppliers appear to be the most important partners.

Collaboration with universities (together with collaboration with consultants) is rated fourth in terms of importance to firms in general. However, universities have a relatively significant role as collaboration partners for firms from the mining and quarrying and agriculture sectors, while they are reported to be the main collaboration partner only for firms in the fishing sector. Universities appear as fourth out of five relevant collaboration partners for firms from the manufacturing sector and, overall, are second only to competitors as the least frequently used partners.

Table 39: Innovative firms by collaboration partner and industrial sector

Sector	Universities N°	Universities %	Other firms N°	Other firms %	Suppliers N°	Suppliers %	Clients N°	Clients %	Competitors N°	Competitors %	Consultants N°	Consultants %	Col with non-universities N°	Col with non-universities %	Total Collaboration N°	Total Collaboration %	Total Innovative Firms
A: Agriculture, hunting and forestry	45	24%	46	24%	62	32%	46	24%	34	18%	43	23%	79	41%	84	44%	191
B: Fishing	14	26%	9	17%	8	15%	8	15%	8	15%	9	17%	16	30%	18	33%	54
C: Mining and quarrying	10	28%	13	36%	14	39%	5	14%	4	11%	8	22%	18	50%	18	50%	36
D: Manufacturing	192	19%	231	23%	307	30%	216	21%	105	10%	202	20%	385	38%	396	39%	1,022
E: Electricity, gas and water supply	16	18%	25	27%	21	23%	6	7%	8	9%	21	23%	34	37%	35	38%	91
F: Construction	28	11%	39	15%	47	19%	35	14%	22	9%	26	10%	63	25%	67	26%	253
G:Wholesale and retail; other	23	10%	31	14%	44	20%	35	16%	16	7%	22	10%	60	27%	66	29%	224
H: Hotels and restaurants	3	3%	4	4%	10	11%	5	5%	6	7%	4	4%	16	18%	17	19%	91
I: Transport, storage and communications	28	10%	46	16%	59	20%	51	18%	24	8%	30	10%	82	28%	88	30%	290
J: Financial intermediation	15	11%	33	25%	34	25%	29	22%	24	18%	25	19%	49	37%	49	37%	134
K: Real estate, renting and business activities	58	15%	81	21%	109	28%	91	24%	50	13%	47	12%	140	37%	149	39%	383
N: Health and social work	42	21%	43	22%	60	30%	32	16%	32	16%	33	17%	75	38%	83	42%	199
O: Other community, social and personal activities	12	12%	18	18%	28	29%	23	23%	11	11%	11	11%	38	39%	38	39%	98
Total	486	16%	619	20%	803	26%	582	19%	344	11%	481	16%	1,055	34%	1108	36%	3,066

7.7 Results

This section presents the main results from the estimations. These are presented in two subsections. The first part shows the results from examining the factors influencing the likelihood of introducing technological innovations, which helps explain the impact of collaboration with universities for non-innovative firms. The second part presents the results of estimating the impact of university-firm collaboration on the innovation performance of firms.

Impact of university-firm collaboration on the likelihood of introducing technological innovations

Table 40 shows the results from estimating the likelihood of introducing new-to-the-firm technological innovations. In order to correct the potential endogeneity between the R&D efforts of firms and the innovation output of firms, I estimated the models using instrumental variables. I used a vector of variables as instruments for the dummy indicating firms that have declared R&D expenditures. The variables included as instruments were the following: the lag of the potentially endogenous variable, the other explicative variables of the model, and the control variables of the model. The results from these estimations show the presence of endogeneity (L coefficient significant at 10% of confidence). Hence, these results are preferred in comparison to the RE estimations.[75]

[75] For robustness purposes the results from the RE estimations are presented in the Appendices.

The results from Table 40 show that collaboration in general increases the likelihood of firms introducing new-to-the-firm innovations (model 1). Although collaboration with universities appears to have a positive and significant impact on the likelihood of introducing this type of innovations (model 2), when controlling for collaboration with other organisations (which include consultants, suppliers, clients, other firms from the group, and competitors) (model 3), then it loses its significance. In contrast, non-university collaboration appears to have a positive and significant coefficient (model 4). The significant coefficient for the variable measuring collaboration with non-university organisations is not surprising given that Chilean firms innovate by adapting available technologies and collaborating with universities may not be relevant for these activities. The role of universities as research partners appears not be relevant to the introduction of technologies that are already available in the market. Universities may not be as interested in participating in this type of collaboration anyway since it involves limited novelty. Hence, collaboration partners other than universities may be the most appropriate for these projects. The coefficients representing the R&D effort of firms show the expected direction of impact and are significant. These results show that R&D investment influences the likelihood of introducing new-to-the-firm technological innovations. Having an R&D department, however, is not relevant to the introduction of new-to-the-firm innovations. This result is not surprising given that this type of innovation may require a different type of support from firms and no R&D efforts.

The results from the four models estimated show that being an exporter has a positive impact, although weakly significant effect, on the likelihood of introducing new-to-the-firm innovations. Also positive, but highly significant, is the impact of receiving public funds for innovation. These results underscore the lack of funding as a relevant factor hindering innovation in firms (see Chapter 6) and are in line with the findings from Eom and Lee (2010) in their study of university-firm collaboration in South Korea, in which they argue that their results, which differ those from European countries, reflect the importance of public policy in fostering collaboration with public research centres in latecomer economies.

Table 40: Likelihood of introducing new-to-the-firm technological innovations, probit estimates using instrumental variables

	(1)	(2)	(3)	(4)
Co with any organisation	1.696***			
	(0.267)			
Co with universities		0.919***	-0.155	-0.236
		(0.178)	(0.209)	(0.171)
Co with non-universities				1.814***
				(0.323)
Co with suppliers			1.305***	
			(0.333)	
Co with other firms			0.204	
			(0.170)	
Co with clients			0.667***	
			(0.226)	
Co with consultants			0.0869	
			(0.205)	
Co with competitors			0.485**	
			(0.237)	
Log(R&D/Sales)	0.0155	0.0205	0.0446	0.0329
	(0.0513)	(0.0481)	(0.0581)	(0.0517)
Non R&D expenditure (dummy)	-1.202***	-1.431***	-1.541***	-1.364***
	(0.389)	(0.396)	(0.538)	(0.422)
Log(Firm size)	0.114***	0.131***	0.129***	0.121***
	(0.0218)	(0.0233)	(0.0335)	(0.0246)
Log(firm age)	-0.00985	-0.00133	-0.00835	-0.00925
	(0.0299)	(0.0298)	(0.0326)	(0.0308)
R&D department (dummy)	0.0418	0.203	0.0805	0.0840
	(0.166)	(0.149)	(0.179)	(0.168)
Export firm dummy	0.112*	0.147**	0.142*	0.121*

	(0.0644)	(0.0650)	(0.0751)	(0.0672)
Public funds dummy	0.648***	0.806***	0.878***	0.716***
	(0.169)	(0.171)	(0.249)	(0.184)
Firm part of a group dummy	0.0778	0.124**	0.0907	0.0840
	(0.0511)	(0.0522)	(0.0578)	(0.0530)
Foreign firm dummy	-0.188**	-0.145*	-0.182*	-0.200**
	(0.0845)	(0.0807)	(0.0947)	(0.0885)
L	0.644*	0.594*	0.814*	0.698*
	(0.344)	(0.345)	(0.491)	(0.370)
Sector dummies	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes
Constant	yes	yes	yes	yes
N Observations	8,329	8,329	8,329	8,329
Log Likelihood	-3,724	-3,960	-3,784	-3,734

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

The results are not conclusive with regard to the impact of being part of a national group, although they largely show that this variable does not have a significant effect on the likelihood of introducing new-to-the-firm innovations. The effects of being a foreign firm, however, show interesting results, as all the models report a negative but significant coefficient. This means that firms from the sample that have mixed or foreign capital are less likely to introduce new-to-the-firm innovations.

Table 41: Likelihood of introducing new-to-the-market technological innovations (random effects probit estimates)

	(1)	(2)	(3)	(4)
Co with any organisation	1.038***			
	(0.0843)			
Co with universities		0.913***	0.467***	0.378***
		(0.119)	(0.149)	(0.131)
Co with suppliers			0.416***	
			(0.137)	
Co with other firms			0.260*	
			(0.138)	
Co with clients			0.388***	
			(0.135)	

Co with competitors			0.174	
			(0.150)	
Co with consultants			-0.202	
			(0.155)	
Co with non-universities				0.867***
				(0.0944)
Log(R&D/sales)	0.140***	0.138***	0.146***	0.144***
	(0.0380)	(0.0381)	(0.0391)	(0.0387)
Non R&D expenditures dummy	-1.743***	-1.852***	-1.777***	-1.750***
	(0.245)	(0.246)	(0.248)	(0.248)
Log (Firm size)	0.0898***	0.0971***	0.0920***	0.0896***
	(0.0162)	(0.0160)	(0.0159)	(0.0162)
Log (Firm age)	0.0343	0.0376	0.0337	0.0322
	(0.0379)	(0.0376)	(0.0374)	(0.0378)
R&D department dummy	0.416***	0.458***	0.416***	0.427***
	(0.143)	(0.141)	(0.142)	(0.144)
Export firm dummy	0.164**	0.172**	0.170**	0.157**
	(0.0722)	(0.0727)	(0.0717)	(0.0726)
Public funds dummy	0.508***	0.539***	0.538***	0.481***
	(0.139)	(0.140)	(0.139)	(0.142)
Firm part of group dummy	0.0844	0.118**	0.0806	0.0841
	(0.0612)	(0.0600)	(0.0605)	(0.0611)
Foreign firm dummy	0.115	0.151*	0.139	0.120
	(0.0901)	(0.0887)	(0.0887)	(0.0897)
Sector Dummies	yes	yes	yes	yes
Year Dummies	yes	yes	yes	yes
Constant	yes	yes	yes	yes
N Observations	8,329	8,329	8,329	8,329
Log Likelihood	-1,786	-1,848	-1,808	-1,793
Rho	0.265	0.27	0.252	0.265

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

Table 41 show the results from estimating the likelihood of introducing new-to-the-market innovations using random effects probit estimations.[76] The results show that variables related to the firms' R&D efforts present positive and significant coefficients in the four models estimated. Collaboration with any type of

[76] The models were also estimated using instrumental variables to correct for the potential endogeneity of the dummy variable indicating whether firms have declared R&D expenditures. The results of the estimations reported absence of endogeneity (see Table 50), therefore the results from the RE probit estimations are preferred.

organisation (model 1), as expected, shows a positive and significant coefficient. However, contrary to the results presented in Table 40, Table 41 reveals a positive impact from collaboration with universities on the likelihood of introducing new-to-the-market innovations even after controlling for collaboration with non-university organisations (model 4). These results may appear counterintuitive since empirical evidence from developed countries has shown that collaboration with universities is more effective in the introduction of radical innovations associated with new to the world innovations (Belderbos et al., 2004a). However, there is no data available about new to the world innovations in Chile, although the number would probably be very low given the innovation output of the country. This may signal that universities are a useful collaboration partner for Chilean firms that introduce innovations to their respective markets (leaders rather than followers) and appears to confirm the first hypothesis tested in this chapter. As Table 40 shows, collaborating with non-university organisations results in a positive and statistically significant coefficient, which is consistent with the results from interviews with academics, where they acknowledge that there are some firms that have some degree of innovation with which they collaborate:

> ... I have been lucky to work in an area in which companies are relatively large and although they are not innovative they have some degree of innovation. This has allowed me to materialize some of my proposed ideas mainly through Fondef, InnovaChile and some other funds such as from United Nations projects, and directly, which is the main source of technological development, direct funding from companies. (N°18, Academic UDEC)

The results show that having a R&D department has a positive impact on the likelihood of introducing new-to-the-market innovation, suggesting that this type of innovation requires a higher level of absorptive capacity in firms. However, the dummy variables around whether firms are exporters, belong to a group, use foreign capital, or have used public funds for innovation, show similar effects on the introduction of new-to-the-market and new-to-the-firm innovations.

Impact of university-firm collaboration on the innovation efficiency of firms

Table 42 shows the results from assessing the impact of collaborating with universities on the innovative performance of firms. The results show that the coefficient indicating the presence of sample selection (L) is significant. This means that the results from the generalized Tobit model are preferable to the results obtained by using random effects methods.[77] In order to control for the potential endogeneity between collaboration with universities and the level of innovative sales of firms, I estimated the models using instrumental variables. The lagged values of the collaboration with university variables and the rest of the explicative and control variables were used as a vector of instruments. The results, however, show that it is not possible to reject that the models are exogenous and consequently, the results from estimating the models using generalized Tobit methods are preferable.[78]

Table 42: Universities and innovation efficiency of firms: Generalised Tobit model estimates

	(1)	(2)	(3)	(4)
Co with any organisation	0.932***			
	(0.280)			
Co with universities		1.403***	0.944**	0.883**
		(0.406)	(0.439)	(0.450)

[77] For robustness purposes the models were also estimated using random effects methods (Appendices, Table 51).
[78] For reference, the results from estimating the models using instrumental variables are presented in the Appendices (Table 52).

Co with non-universities				0.225
				(0.307)
Co with suppliers			0.0650	
			(0.384)	
Co with clients			0.852**	
			(0.411)	
Co with competitors			-0.0327	
			(0.428)	
Co with consultants			0.384	
			(0.443)	
Non R&D expenditures dummy	-10.86***	-10.76***	-4.061***	-4.532***
	(1.264)	(1.277)	(0.860)	(1.283)
Log(R&D/sales)	0.618***	0.612***	0.322**	0.401**
	(0.176)	(0.178)	(0.137)	(0.156)
R&D department dummy	1.446**	1.432**	0.591	0.531
	(0.612)	(0.612)	(0.443)	(0.523)
Log (Firm age)	-0.188	-0.194	-0.295*	-0.180
	(0.209)	(0.209)	(0.174)	(0.185)
Log (Firm size)	0.416***	0.409***	-0.0887	-0.206*
	(0.111)	(0.111)	(0.0838)	(0.117)
L	7.315***	7.305***	7.396***	0.0695
	(0.402)	(0.403)	(0.375)	(5.082)
Sector dummies	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes
Constant	yes	yes	yes	yes
N Observations	8,330	8,330	8,900	8,330
Log Likelihood	-10,604	-10,604	-11,616	-10,623

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

The results in Table 42 show that collaboration in general (model 1), and in particular with universities (model 2) positively and significantly influence the innovation efficiency of firms. These effects, however, are reduced after controlling for collaboration with another type of partners (model 3).[79] These results confirm the hypothesis that collaboration with universities positively impacts the innovation efficiency of firms. This means that for firms that *are* innovative, collaborating with

[79] Obtaining the marginal effects of the Tobit estimations would provide information about the magnitude of the impact of collaboration with universities on the share of innovative sales of firms. However, this exercise is out of the scope of this thesis.

universities has a positive effect on the share of innovative sales. These positive effects are in line with the empirical literature from developed countries (e.g. Cassiman et al., 2010; Faems et al., 2005; Lööf and Broström, 2008). Collaboration with non-universities organisations, however, appears not to have a significant effect on the innovation efficiency of firms (model 4).

As expected, the variables related to the R&D efforts of firms show significant coefficients in the four models estimated. However, the results are not conclusive in relation to the impact of having an R&D department on the share of innovative sales of firms. The results show positive and significant coefficients for the dummy indicating whether firms have an R&D department only in models 1 and 2, and not in models 3 and 4. These results may suggest that the accumulated absorptive capacity of firms is really more important when assessing the likelihood to innovate (Table 41) rather than on the efficiency effects on innovative firms.

With regard to the control variables, and in line with empirical research using the EIT survey (Álvarez et al., 2012; Benavente, 2006; Crespi and Zuniga, 2012), the results show that the age of firms does not appear to influence innovation efficiency. The coefficients for the size of firms, however, indicate that this variable strongly influences the share of innovative sales. This may reflect the fact that larger firms have the resources (either human or financial) to engage in fruitful collaboration with universities.

For robustness purposes the models were also estimated using the subsample of firms with two or more consecutive observations and the subsample of manufacturing firms.[80] The results of the estimations using the subsample of firms with continuous

[80] See Appendices (Table 53 and Table 54).

observations are strongly consistent with the results reported in Table 42. By contrast, the results from analysing the subsample of manufacturing firms show that collaboration with universities is not significant after controlling for collaboration with clients, which appears to have a positive and significant impact on innovation efficiency.[81]

In order to assess the long-term effects of collaboration the first lag of this variable was also included in the estimations. Table 43 shows the results from these estimations and reveals positive and significant coefficients from past collaboration efforts on current innovation efficiency (model 1). This is to be expected given that there may be a gap between when collaboration took place and when its effects are reflected on the level of innovative sales.

However, the results from estimating model 2 and model 3 show that past collaboration with universities does not present a positive and significant effect on firms' innovative sales. The variable current collaboration efforts, however, keeps its positive and significant coefficient. Taken together, this may signal the presence of endogeneity between these variables and the share of innovative sales. However, the estimations using instrumental variables reported the absence of endogeneity.[82] Unfortunately, the characteristics of the dataset do not allow testing alternative, and perhaps better, variables as instruments.

[81] These apparently conflicting findings in comparison with the results depicted in Table 42 could reflect the heterogeneity among sectors in terms of the importance of university as collaboration partners and their research strategies. Also, they could imply that more time is needed to observe the effects of collaboration with universities in this sector taking into consideration that collaboration with universities could be a costly process requiring longer time horizons in developing economies (Crespi and Zuniga, 2012).

[82] See Appendices, Table 52.

Further, model 3 shows results that conflict with those from Table 42 when examining the effects of collaboration with non-university organisations. When controlling for collaboration with these organisations, collaboration with universities is no longer significant and also there is a change in the direction of the effect. A similar situation occurs when examining the coefficients related to the R&D efforts of firms, which appear to not be significant in any of these specifications. These conflicting results may be related to the fact that the sample is significantly reduced when using the lags of the collaboration with universities. There are only 563 observations, representing 496 firms, informing positive collaboration with universities during the period of analysis and 52% of these were reported for 2007. This means they are not considered when including lags.

Table 43: Universities and innovation efficiency of firms: Generalized Tobit model estimates (long term effects)

	(1)	(2)	(3)
Co with any organisation	1.078**		
	(0.534)		
Co with any organisation (lagged)	1.630***		
	(0.557)		
Co with universities		1.660**	1.400*
		(0.724)	(0.790)
Co with universities (lagged)		0.752	-0.525
		(0.697)	(0.763)
Co with non-universities			0.463
			(0.596)
Co with non-universities (lagged)			1.756***
			(0.619)
Non R&D expenditures dummy	-1.538	-1.841	-2.039
	(1.954)	(1.998)	(1.996)
Log(R&D/sales)	0.0696	0.0718	0.163

	(0.316)	(0.327)	(0.321)
R&D department dummy	6.851***	6.776***	6.445***
	(1.442)	(1.409)	(1.352)
Log (Firm age)	-0.174	-0.168	-0.142
	(0.330)	(0.332)	(0.348)
Log (Firm size)	-0.113	-0.0727	0.383**
	(0.134)	(0.136)	(0.180)
L	6.735***	6.650***	6.838***
	(0.631)	(0.628)	(0.629)
Sector Dummies	yes	yes	yes
Year Dummies	yes	yes	yes
Constant	yes	yes	yes
N Observations	8,899	8,899	8,887
Log Likelihood	-6,549	-6,552	-6,450

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

7.8 Discussion and concluding remarks

After controlling for unobserved heterogeneity, sample selection and potential endogeneity, there are three key findings from the analysis. First, external collaboration strategies contribute, on average, to increasing the share of innovative sales and have a positive impact on the likelihood of introducing new-to-the-firms *and* new-to-the-market innovations. Second, the influence of collaboration with universities on the likelihood of introducing innovations differs according to the type of innovation; university collaboration is not significant for the introduction of new-to-the-firm innovations but has a positive and significant impact in the introduction of new-to-the-market innovations. Third, the results from the estimations using generalized Tobit methods show that firms that collaborate with universities have, on average, a higher share of innovative sales compared to those that do not collaborate with universities. This means that collaboration with universities makes innovative firms more efficient.

However, it is important to keep in mind that collaboration, as defined for this analysis, includes not just R&D collaboration but any formal agreement on innovative activities. Therefore, interactions with universities may be more specialized—leading, as we have seen, to new-to-the-market innovations—than interactions with other sources of knowledge. Considering that Chilean firms focus their innovation strategy on the acquisition of readymade technology and that most of the innovations introduced in Chile are new-to-the-firm (see Chapter 6), the results from the empirical analysis suggest that collaborating with universities is only beneficial for a limited number of firms— i.e. those that have the capacity to introduce innovation and want to introduce new-to-the-market innovations and those that are already working to introduce technological innovations—since collaborating with universities does not result in the introduction of the type of innovations that most Chilean firms need.

Taken together, the results suggest that companies need to have a minimum level of innovation capacity to take advantage of the potential benefits of collaborating with universities. These findings agree with the argument that collaboration with universities may benefit firms not only in terms of technical but also in regard to economic impact since collaborating with universities increases the share of innovative sales of firms.

The findings also underscore the importance of understanding the characteristics of Chilean firms and the type of innovations, if any, that they introduce when designing public policy aimed at strengthening university-firm collaboration. Identifying the determinants, impact, and conditions under which university-firm collaboration is useful for firms would help ensure that public policy creates the right incentives for innovation.

In this regard, the work of Grazzi and Pietrobelli (2016), through its exploration of innovation and productivity in Latin American firms, suggest that in order to achieve efficiency improvements within it is necessary to move beyond one-size-fits-all firm growth policies to detailed microeconomic policies that take into account the heterogeneity of firms (Grazzi and Pietrobelli, 2016). These authors found that policies need to address the factors associated with firm-level innovation, technology, management and organisational improvements, and human capital development.

From the evidence provided in this chapter, I suggest that the determinants of innovation should also be taken into account when designing collaborative innovation policies since only innovative firms will benefit from working with universities. Therefore identifying the type of firms most likely to benefit from linkages with universities would improve the effectiveness of the policies. The results also suggest that collaboration with non-university partners is more effective for firms trying to innovate. Since most of firms do not innovate and the productivity gap between innovative and non-innovative for firms in Latin America is 50% (Crespi et al., 2016) then policies aimed at making more firms innovative should be the central part of the policy. The role of non-university innovation partners should then also be promoted.

Overall, the findings show that to design effective policies, meaning policies that help firms to introduce innovations and upgrade, it is important to identify the best type of partner. Collaboration with non-universities appears to be the more effective for technological upgrading of firms with fewer capabilities.

Another interesting feature of the findings is that they highlight the importance of public funds for promoting innovation. The results from the estimations systematically report that public funding has a positive impact on both the likelihood of introducing innovations and the innovation performance of firms. These results are consistent with the findings reported in Chapter 6 which identified a lack of financial as an obstacle to innovation and suggested that Chilean innovation policy played an important role in this regard. However, understanding which firms are most likely to benefit from public funds for university-firm collaboration may help to ensure the efficient use of public resources.

The results also stress the importance of building absorptive capacity in order to be able to reap the benefits of collaboration with universities. The coordination failure problem produced by the heterogeneity of the actors of the NIS in terms of absorptive capabilities can limit the potential benefits of university-firm collaboration, since this problem can be stronger in developing countries. In fact as we saw in Chapter 6, in Chile, PhDs are concentrated in the universities and there is only very limited number of high-skilled labour working in firms. Therefore, innovation policy should design a set of incentives that leads the individuals and organisations concerned to reveal and trade information or to collaborate in knowledge production (Metcalfe and Ramlogan, 2008:443) .

The results of this analysis come with two considerable caveats. First, the characteristics of the data only allow the inclusion of one lag of the explanatory variable, which limits the capacity to measure long-term effects. Second, because of the characteristics of the panel, the results of the estimations are only valid for the firms in this panel. However, it is important to keep in mind that, as in other studies based on this survey, the results are sensitive to the different subsamples (Álvarez et al., 2012). These may reflect several types of heterogeneity: across sectors, type of collaboration, and timeframe needed to capture the results. Therefore, these results highlight the importance of purposely collecting panel data that properly capture these heterogeneities (Álvarez et al., 2012).

Chapter 8: Conclusion

8.1 Introduction

This thesis has used a supply–demand lens to explore the dynamics of university-firm linkages in Chile. Chile presents an interesting case as a developing country that has experienced remarkable economic growth in recent decades and has also engaged in efforts to develop its innovation system, including fostering university-firm linkages. Despite these efforts, however, Chile's level of innovation remains the lowest among OECD countries (OECD, 2013). By considering the multilayer forces influencing these linkages, I have hoped to add to our understanding of the reasons for this poor performance and, in turn, suggest ways for ensuring that future innovation policy is more successful in strengthening university-firm linkages and improving innovation.

At the beginning, I set out to answer three key research questions: What factors influence innovation linkages between academics, universities, and firms? What factors explain the incentives for firms to engage in linkages with universities? And, is university-firm collaboration beneficial for the innovation performance of firms? Through the use of qualitative and quantitative methods, I have shown the existence of multilayer factors working on both sides of the linkages, which counteract to create an overall negative impact on university-firm linkages. Firms and academics in Chile have very little incentives to engage in collaboration for the purposes of innovation and this explains the weak ties between universities and firms in the country, which have been acknowledged by all stakeholders in Chile (OECD, 2007: 200). The novelty of this thesis lies in its exploration of *what* these incentives are, *where* they come from and *how* they influence the behaviour of the actors in the NIS. It shows that public policy has not only been ineffective in promoting university-firm linkages, but that its public programmes have created multi-layer incentives that counteract their desired effect of fostering effective university-firm collaboration and technology transfer. The incentives are incorporated into the decision-making processes of firms, universities, and academics, perpetuating the status quo in terms of collaboration and, most importantly, in terms of the promotion of technological change.

This thesis has contributed to the long standing debate about the role of universities in knowledge and technology transfer in developing countries. The findings have shown the existence of high aspirations on the part of the government, which appear not to reflect the capacity of firms and universities. These aspirations may reflect a limited understanding of the real capacity and potential university-linkages and appear to be guided by the belief that selected success cases in developed countries could be easily replicable in developing countries.

This debate is particularly stronger in developing countries because of the level of development in their innovation systems and their structural weakness related to lack of capacities to create and absorb knowledge, particularly advanced knowledge (Arocena et al., 2015). Moreover, according to Arocena et al. (2015), most developing countries are not in a transition towards knowledge-based and innovation-driven economies, as on some other places of the world. This suggests the need maintain a degree of scepticism about the potential of universities as tools for the technological upgrading of firms.

According to an evaluation of the Chilean tertiary education system carried out by the OECD and The World Bank (2009b), the Chilean Government reported that the functions of the higher education system (HES) in the 21st century included training, research, and supporting reflective culture and public debate. In this evaluation the Chilean Government explicitly reported that HES should also supply information and advanced knowledge for a country's government and economic growth, by analysis, research and experimentation in different disciplines and collaboration with firms, public organisations, and the community. The government is therefore clear that universities should also collaborate with firms. However, what type of linkages should be fostered? Should all universities have the same role?

The results suggest that the rational response of universities to the incentives provided by the public policy reflects their interest in obtaining resources, which are then leveraged by the universities for research and organisational capacity building. Investment in these activities creates a funding virtuous circle for the departments studied because of the competitive nature of research grant allocation. However, it is important to recognize that the three departments studied are the exception and not the rule in Chilean universities. It would be natural, then, to expect that the gap between high and low capacity universities widens with time. This suggests that issues such as the capacity of universities and the type of collaboration activities need to be taken into account when examining the expected contribution of universities to the innovation of firms.

The results suggest, indeed, that is important to take into account the heterogeneity of capacities of universities in developing countries not only in comparison with universities from developed regions but also between Chilean universities. In this country not all universities are equally equipped to participate in linkages with firms and to design their strategies to respond to new trends in the needs of markets and society. It is important to consider that the history and development of universities becomes critical to define the potential according to what universities can do and not according to what they say they can do (Contreras and Katz, 2011).

Additionally, I hope to have contributed to the literature in four ways. First, by adding to the empirical research on university-firm linkages in developing countries—particularly from Latin America. As mentioned in the Literature review chapter, the available literature is largely based on the study of developed country experiences. However, developing countries have innovation systems that are not similar to developed countries (Lundvall et al., 2011), and therefore their study requires us to acknowledge the features of these developing countries, in particular, in relation to the development of the national innovation system. Second, by incorporating management and innovation theories into the study of university-firm collaboration, this thesis enriches the empirical evidence that employs innovation studies in the context of developing countries. So far, the study of these linkages in Chile has been based on studies measuring and assessing the impact of innovation on the productivity of firms (Alvarez et al., 2011; Benavente and Contreras, 2011; Crespi and Zuniga, 2012) and on the analysis of market failures which the policy makers have cited as justification for the need to establish an innovation policy. However, while the existence of market failures does indeed argue for the need for public intervention, it does not explain *how* to intervene and *how* the public policy mix shapes the dynamics of the innovation system.

My third contribution is analytical. By analysing the dynamics of university-firm linkages using a supply–demand lens, I contribute to the recent, but as yet still relatively limited empirical literature employing this approach (see, for instance, De Fuentes and Dutrénit, 2012; Dutrenit et al., 2011; Hughes and Kitson, 2012). In addition, by considering the multi-level factors (produced by public policy and by the macro environment) that shape the incentives of university-firm linkages in Chile, I hope to shed light on how these factors influence academics, universities and firms incentives to work on collaboration and to transfer technology.

My fourth contribution is empirical. By using a panel database assembled specially for the thesis, I have conducted what to my knowledge is the first empirical attempt to assess the impact of collaboration with universities on the innovation performance of firms in Chile.

In the following, I summarize my findings, discuss how they relate to current scholarship and explore the policy implications of the research before highlighting the methodological lessons to be taken from the thesis, acknowledging its shortcomings and pointing to possible areas for future research.

8.2 On the factors influencing the supply side of university-firm linkages

The literature dealing with the supply side of the university-firm linkages shows that reputation, access to resources, and research interests among other things, affect the interaction of academics with firms. At the organisational level, factors including technology transfer capacity and experience appear to influence these linkages. The underlying logic for collaboration is *opportunity*.

When examining the factors influencing the supply side of university-firm linkages (Chapter 5), I focused on two areas that appear to have a direct impact on university-firm linkages. First, I examined the incentives at work at both the organisational level (i.e. at the level of universities) and at the individual level (at the level of individual academics) to transfer technologies and promote linkages with firms. Second, I analysed the organisational development path of the technology transfer units at universities. Through this analysis, I contended that public policy, especially the type and focus of research grants, create inconsistent incentives on why and how academics and universities interact with firms and on how universities create organisational technology transfer capacity.

The policies of the 1990s and 2000s to promote university-firm collaboration and technology transfer created new opportunities in terms of the type of activities available to and employed by researchers and universities. Similar effects were created by recent initiatives aimed at strengthening the organisational capacity of universities. Before the establishment of these public programmes, the main sources of research funding were internal university funds and individual public grants. Most of these funds were small grants aimed at the individual researcher. The creation of matching grants and resources to facilitate technology transfer allowed academics and universities to access to large and long-term sources of funding that allowed them to invest in capital goods for research, establish laboratories, and fund students, among other things. In addition, the chance to apply for funds to protect their inventions and the establishment of additional funds aimed at technology transfer, spurred the interest of academics and universities in these types of activities, which underscores the importance of incentives in shaping the behaviour of academic and institutions (Lach and Schankerman, 2008). These results test the conclusion of Lach and Schankerman (2008) that it is the possession of a higher share of intellectual property rights that encourages academics to increase their patent and technology transfer activities. Indeed, these authors fail to take into account the income that academics perceive may be attained through their inventions, which this research has found, in fact, to be very little. Academics often believe that much more work needs to be done to commercialize their inventions and therefore have very limited expectations of the income from future royalties. Having a larger percentage of an expected zero revenue would not offer much incentive to patent or transfer technologies, but accessing a grant for those exact purposes would appear to increase this incentive.

At the same time, the block grants given to universities and R&D grants given to academics, which favour basic research, create an unintentional imbalance between basic research activities aimed at collaboration and technology transfer to firms within the universities. This is because the performance evaluations of both universities and academics are largely focused on R&D performance and capacity. The importance of public resources for funding research has led universities to align their performance evaluation criteria of academics and to develop organisational structure that will help them to secure public funding. In this regard, my findings are also in line those from Salter et al. (2010) in their evaluation of the attitude of UK academics to entrepreneurship and collaboration with industry. These authors found that university-firm linkages are perceived as useful for gaining research funding, but given little or no value by department and universities in their hiring and promotion policies (Salter et al., 2010).

Furthermore, being given basic research grants has a strong reputational effect in the Chilean academic system and has very real effects on career promotion. My work found that in the selection of Chilean universities studied, a basic research grant is regarded as a symbol of high quality research. This complements the findings of Dutrenit et al. (2010) in their study of Mexican university-firm linkages, which suggest that researchers prize the benefits of improved knowledge over financial reward, as they value interaction for its intellectual rather than economic benefits. Similar findings have also been found by the work of Dutrenit and Arza (2015) in their study of a sample of Latin American countries. However, these results are mirrored in work on universities in developed countries (D'Este and Patel, 2007). For example, Haeussler and Colyvas (2011) found that the level of reputational importance placed on scientific compared to commercial achievements in life science departments in the UK and Germany is significant in shaping the involvement of academics in start-ups, consultancy, and patenting.

Organisational development

The increasing availability of funds and the promotion of technology transfer and collaborative R&D projects between universities and firms have led universities to develop organisational capacities in these different areas. However, the main reason for this organisational development has been to secure the newly available funds rather than to facilitate technology transfer activities in any meaningful way. Taken together these findings underline the importance of taking into consideration not only the technological capabilities of firms as part of the framing and fashioning of policy design but also the impact of incentives and the levels of academic capabilities (Schiller and Lee, 2015). Furthermore, the strong influence of public policy, especially in contexts where public funds are the main source of research funding, shows that the role of the state is central to understanding the dynamics of university-firm linkages in developing countries such as Chile.

These results reveal the rational response of universities and academics to the incentives created by the structure of research funding in the country. This strategy, however, may not be one intended by policy makers, who believe universities should have a role in the economic development of the country through linkages with firms. In the case of Chile the government has explicitly stated that the universities should contribute to economic development through linkages with universities (OECD and The World Bank, 2009b). The responses of academics and universities to incentives, however, may not maximise the social returns of the programmes, and therefore suggests that the design of the programmes should be improved (Crespi et al., 2014). Efforts in this line do not need to be exclusively focused on the supply-side of knowledge production but should also consider aligning the incentives between the supply and demand for knowledge and technology, as well as promoting the diffusion of knowledge through the economy. This includes initiatives that increase the demand of innovation in firms, which may include university-based innovation in firms with the necessary capacities to incorporate this knowledge into their productive processes. In addition, it may be necessary for policy makers to assess the systemic capacities of the Chilean innovation system as well as the institutional capabilities—including coordination and monitoring and evaluation capacities. This would allow them to identify where capacities should be honed and improved in order to increase the effectiveness of the innovation policy.

8.3 On the factors influencing the demand side of university-firm linkages

One of the general findings of the literature review was that the desire of firms to collaborate is influenced by their industrial sector and their age and size (see, for instance, Schiller and Lee, 2015). The underlying theoretical logic for collaboration is *necessity.*

In this research, I have revealed the existence and interdependence of multi-level factors (micro, industrial, and macro) that explain the reduced level university-firms linkages for innovation in Chile. In particular, three main factors underlie the dynamics of the innovation strategies of firms and the role of universities as innovation partners: (i) the productive structure of the country, which reduces the incentives to innovate; (ii) the reliance of firms on the adoption of technologies developed abroad; and (iii) the lack of absorptive capacities that would allow firms to benefit from R&D collaboration with universities. These results highlight that micro strategies and learning are not only correlated and dependent upon a conflicting macroeconomic environment and policy regime, but can be annulled by them (Dutrénit et al., 2013: 5).

Productive structure of the country

The type of capitalism present in Chile, as well as the country's economic comparative advantages have led to a productive system in which innovation involving R&D is not key to the survival of firms. In particular, the focus on natural resources and the dominance of business groups have created an environment lacking in competition in which firms have limited incentives to engage in collaborative activities involving innovation and more importantly R&D. In this, the findings agree with those of Eisenhardt and Schoonhoven (1996), who have shown that firms build alliances when they are competing in emerging or highly competitive industries or when they are attempting pioneering technical strategies. In Chile, the lack of competitive pressure in the industries that dominate the economy means that innovation linkages with universities are not as important as in other markets.

This would seem to complement Maloney and Rodriguez-Clare (2007) belief that Chile's specialization in natural resources is not the only reason explanation for Chile's low investment in R&D. This is particularly clear from the review of evidence about the factors related to the type of capitalism and the role of public policy in explaining the innovation strategies of firms.

Technology imports as innovation in Chilean firms

The findings also point to the interconnectedness between the productive structure of the country and the firm level factors influencing university-firm collaboration. The literature has largely studied and recognised the importance of firm size and sector on the likelihood to innovate, and on the propensity to create linkages with universities (for instance, Cassiman et al., 2010; Cohen et al., 2002). This thesis, however, has identified two characteristics of innovation in Chilean firms that may help explain why only 5% of Chilean firms collaborated with universities on innovative activities according to the latest results from the national innovation survey (MINECON, 2014a) and why university-firm linkages, in general, are rather less valued than other sources of knowledge for innovation (Hughes, 2011: 437). First, Chilean firms focus their innovation activities on the acquisition of available technologies and, second, the majority of firms do not collaborate on innovation with other organisations, including—and especially— universities. Studies from other Latin American countries have shown that firms from the region are yet to show real interest in developing new technologies and are mostly happy to acquire technologies developed abroad when they need to and that few companies have developed university-firms linkages or created their own R&D facilities (Katz, 2008: 93).

By focusing the innovation of firms on acquisition and adaptation of technologies developed abroad countries can upgrade their technologies and increase their productivity, but the strategy may limit its capacity to conduct the new activities, which, according to Katz (2006), are essentially associated with development and the long-term transformation of society (Katz, 2006: 59). The refusal to conduct activities oriented at increasing indigenous capacity may, in fact, limit the benefits from international technology diffusion, which according to the work of Fu et al. (2011), can only be delivered with parallel indigenous innovation efforts and the presence of modern institutional and governance structures and conducive innovation systems. Yet, focusing innovation on the acquisition of technologies developed abroad does not mean that there is no space for collaboration with universities. In Chile, as in other developing countries (see, for instance, Kruss et al. (2015a) on Nigeria), academics often play a role in supporting the adaptation of technologies to suit local conditions. But this collaboration is largely limited to specific activities and in general does not involve R&D.

In addition to the perceived 'lack of need' in Chilean firms to engage in R&D activities and low collaboration with other organisations, including universities, there are several other barriers hindering these linkages, namely: the limited understanding among university personnel of the needs of firms; different innovation time-frames between universities and firms; and the heavy costs of coordination sharing and information. The barriers identified are not particular to Chile and may reflect broader cultural differences between universities and firms. Other barriers to university-firms linkages have been also identified by recent scholarship (for a review, see Gilman and Serbanica (2015)). For instance, in analysing UK university-firms interactions, Hughes (2011) reports that firms regard their lack of resources to manage these relationships as the primary limitations on developing interactions, while cultural differences appear to be significant only for large firms. Cultural differences are also reported in my findings however I did not find evidence of internal management capacity as a factor hindering collaboration with universities. This difference may be explained by the methodological differences between my own work and that of Hughes. Alternatively, the difference may be due to the fact that the management issue may be a constraint that becomes relevant only after firms have become more experienced in university-firm linkages, which may be the case in developed countries. Still, it is nevertheless possible that while the non-use of collaboration strategies by Chilean firms may be an appropriate response to the fact that they prefer to adapt foreign technology rather than create new technology, it could also reflect a lack of management capacities.

Lack of absorptive capacities

The third issue identified as reducing the incentives of firms to engage in innovative activities with universities is their lack of absorptive capacity. The lack of skilled human capital, reflected, in general, in the low scores of the Chilean education system in international comparisons, and more generally, in the limited number of researchers working in firms, appears to hinder the absorptive capacity of firms (Cohen and Levinthal, 1990). This, in turn, limits the potential benefits that countries and organisations can reap from the international transfer of technology (Fu et al., 2011). These findings are in line with those in the Molina-Domene and Pietrobelli (2012) comparative study of manufacturing firms in Argentina, Brazil and Chile. They found that size is relevant for firms in building technological capabilities—because large firms can spread cost related from capability acquisition better— and that this fact may help explain the concentration of R&D activities in large firms in Chile. But my findings underscore the fact that firms must have a certain level of absorptive capacity, internal capacities, and managerial processes, before entering into cooperation with universities (Gilman and Serbanica, 2015).

There are both similarities and differences between my results and those found in other studies from developing regions. As in the Mexican case presented by (Dutrenit et al., 2010) and in Dutrenit and Arza's (2015) literature review of university-industry linkages in Latin America, I too found that firms engage in short-term problem solving with universities. However, while firms in Mexico were found to connect to domestic universities and research centres in order to obtain insights for their long-term innovative strategies, I only found evidence of this type of initiative in Chile undertaken and facilitated by the state.

Overall, my results are similar to those of Brimble and Doner (2007) in their study of university-industry links in Thailand, which point to the relationship between low level innovation in firms and reduced university-firm linkages and highlight the relevance of incentives in universities in explaining the frail linkages in the country. These similarities underscore the value of developing country settings as the focus and framework for research on innovation.

8.4 On the impact of university-firm linkages on the innovation performance of Chilean firms

In the quantitative section of this research, I explored the effects of collaboration with universities on the likelihood of the introduction innovations of firms and on their innovative efficiency. The results showed that universities do not exercise a significant effect on the likelihood of introducing new-to-the-firm innovation but do show a positive effect on the likelihood of introducing new-to-the-market innovations. Collaboration with universities also appears to have a positive and significant effect on the share of innovative sales of firms, suggesting that it affects the effectiveness of their innovations.

These results are in line with those from Belderbos et al. (2004b), which found that cooperation with universities is instrumental in creating and bringing to market radical innovations, which create sales of new-to-the-market products and thus improve the share of innovative sales. I found that, in terms of economic benefits, collaboration with universities is only beneficial for firms which are already innovative in character and objectives. This concurs with the findings from Kafouros et al. (2015) on a sample of Chinese R&D intensive firms. These similarities might be explained by the reduced and skewed group of firms (in terms of size) that actually collaborate with universities in Chile.

My findings point to the link between absorptive capabilities and the capacity to reap the benefits of collaboration with universities. In order to benefit from collaboration with universities, firms have to posses and dominate a set of absorptive capacities—as argued by the findings of Schiller and Lee (2015) on linkages between public research organisations, which include universities and firms in Asian countries. Their findings show that firms that carry out R&D activities tend to collaborate more with public research organisations. This however, might indicate a limitation on university-firm linkages as a new vehicle for catch-up (Schiller and Lee, 2015), because internal R&D is not typically carried out by a broad range of firms.

My research calls for the recognition of the heterogeneous character of Chilean firms when examining university-linkages and the potential contribution of this type of collaboration to innovation in firms. This heterogeneity needs to be considered in addition to the major heterogeneity in the rationales and goals of R&D cooperation identified by recent scholarship (Belderbos et al., 2004b: 1488). Policy design and implementation must reflect the specific nature of each country, industry or region, together with an assessment of the co-evolution of technological, institutional and economic forces (Katz, 2001b: 125).

The results show furthermore that university-firm linkages are a complex phenomenon involving a broad range of factors from the intrinsic characteristics of firms to the macro environment in which firms and universities operate.

Consideration of both sides of university-firm linkages underlines the complexity (as well as the richness) of the realities of these types of interaction.

In addition, the importance of natural resources in the productive structure of Chile underscores the need to consider the particular role of science and technology in these industries and the potential of inter-organizational linkages. The literature on innovation and development has largely seen natural resources as a curse for development (Marin et al., 2015). It has also considered that industries intensive in natural resources have limited potential to innovate and drive long-term growth (Marin et al., 2015). The reasoning behind the negative view of natural resources in the literature has associated these industries with: deterioration of terms of trade between natural resources industries and manufactures in the long run (Prebisch, 1950; Singer, 1950); instability of export prices that leads to limited investment; rent seeking behaviour, *Dutch disease*; and limited linkages (Marin et al., 2015).

According to Marin et al. (2015), this negative view of natural resources industries has led policy makers to choose strategies aimed at shifting the specialization patterns towards other sectors. In the case of Latin America, it has been argued that the important presence of multinationals in these sectors in the region could help explain the lack of R&D in these sectors since multinational activities are more focused on exploiting comparative advantages and that they also innovate at the headquarters level (Navarro et al. 2010). However, Maloney and Rodriguez-Clare (2007) argue that Chile's specialization in natural resources is not the only reasonable explanation for Chile's low investment in R&D. These authors argue that factors related to the lack of human resources and labour market rigidities, among other factors, also contribute to the innovation shortfall in this country.

However, new opportunities to develop specialised capabilities, companies and networks have emerged due to technological advances in areas such as biotechnology and nanotechnology. These have multiplied the possibilities for differentiation and innovation in natural resources (Marin et al., 2015). At the same time, the fast development of information and communication technologies (ICTs) has facilitated innovation in all sectors, including natural resources. Industries such as mining have seen in recent years the consolidation of a process of *technological rejuvenation* that produced high rates of innovation, productivity, growth, and organisational change, and which has also led to the emergence of knowledge-intensive mining services suppliers (Urzua, 2011).

Increasing pressure innovate has also been driven by factors including: environmental concerns from the demand side; changes in regulation; and from the incorporation of environmental concerns in the supply side in the form of increased risks and costs (Marin et al., 2015). In the case of mining, demand side pressures include: demand for tailor-made solutions, linkages that promote learning within local the value chain, and vertical disintegration and outsourcing trends (Marin et al., 2016).

The recent evolution of the natural resources industries has led to the emergence of literature aimed at understanding the linkages between learning processes and natural resources that can encourage economic diversification and structural change (e. g. Álvarez and Labra, 2013; Andersen et al., 2015; Bastida, 2014; Marin et al., 2015; Marin and Stubrin, 2015; Molina et al., 2016). Research in this area suggests that development strategies can also promote more innovative knowledge in natural resources intensive sectors (Marin et al., 2015), A report prepared by the Global Research Network (Globelics)[83] (Andersen et al., 2015) claims that establish competence as well as building backward and forward linkages with other activities are key for the economic transformation of countries if they wish to build upon their natural resource base industries. However, the report argues that these linkages will only be produced if local suppliers have the required capacities. This underlines the importance of investing in specific knowledge relevant for natural resource intensive industries. According to Marin and Stubrin (2015), the extent of linkages heavily depends on the capabilities of local firms (including non scientific ones) and the general economic and political context, which underlines the importance of regulation in the promotion of innovation. However, in assessing the opportunities and challenges offered by natural resources industries, it is important to take into account the differences between natural resources industries (Álvarez and Labra, 2013) and the heterogeneity of firms.

An example of a sector that has created significant linkages is the mining industry in Chile. This sector has recently experienced a significant transformation. According to Marin et al. (2015), this sector has gone from a predominantly enclave model in the past to a highly de-integrated model that has enabled the emergence of a new sector of specialised intensive local and foreign mining suppliers. These are not pure knowledge intensive providers; they incorporate high-tech specialised services, capital goods and equipment and consumable inputs such as chemicals. This transformation has opened up opportunities for new actors to become global providers of high tech services to the industry (Marin et al., 2015)

[83] Globelics is a well known international network of innovation studies researchers (www.globelics.org).

8.5 Policy implications and the role of the State

We have seen that, in Chile, university-firm linkages are affected by a series of incentives operating in contradictory ways to create negative aggregated effects. These incentives are endemic to the particular macro environment of the country but are also produced by the public policy directly and indirectly influencing these linkages. The analysis has shown the existence of policy instruments that may hinder the development of the innovation system and highlighted the fact that incentives have broad, indirect and complex effects beyond those for which they may have been created. These results suggest two areas in which the role of the state and public policy are relevant when studying university-firm collaboration in Chile.

First, the results underscore the role of the state as a coordinating agent in the innovation system. Developing countries tend to design their policies based on what they see has worked in developed countries. In this way, policies become trends. Chile's focus, in its innovation policy, on university-firm linkages stems from a desire to reduce innovation market failures. However, the systemic factors influencing the actors of the innovation system as well as their interactions have not been taken into account in the policy design. The lack of a systemic view of the functioning of the innovation system has led the state to establish an innovation policy that considers a series of public programmes that creates incentives that are inconsistent with the promotion of university-firm linkages.

Policy makers thus need to consider the factors influencing these interactions when designing innovation strategies aimed at fostering collaboration and technology transfer between these actors. As argued by Lanahan and Feldman (2015) it is necessary to consider the employment of policy instruments as part of a policy mix implemented by different jurisdictions and operating in different contexts; each cannot be examined in isolation. Failure to consider all elements may not only reduce the potential development outputs of the policy but may create undesired incentives in the innovation strategies of universities and firms.

Moreover, the findings from this thesis underline the importance of recognizing the heterogeneity of firms in the design of public policies. The results have shown that collaboration with universities is only beneficial for innovative firms and may reveal capability gaps in non-innovative firms that make collaboration with universities in innovative activities fruitless. Other types of partners may be more effective if the goal is to make more firms innovative. This underlines the importance of identifying the alignment of the objectives of policies with the selection of the programmes and initiatives. Policy makers need to be clear about what they want to achieve with the programmes and policy instruments so that they can elaborate the appropriate policy strategies. For instance, if they want to increase the number of innovative firms, then R&D collaboration with universities will not achieve the expected outcomes. In this case, collaboration with other partners may be more effective. For instance, estimations carried out by Crespi et al. (2014), using data from Chilean programmes oriented to support business innovation and university-firm linkages, shows the impacts of these policy tools would have been twice as large if the support would have focused only on highly competitive sectors (Crespi et al., 2014).

The importance of acknowledging the heterogeneity of firms is recognized in a recent edited book by Grazzi and Pietrobelli (2016) that explores innovation and productivity in Latin American firms. Findings from their analysis suggest that in order to achieve efficiency improvements within firms, it is necessary to move beyond one-size-fits-all firm growth policies to detailed microeconomic policies that take into account the heterogeneity of firms (Grazzi and Pietrobelli, 2016).

From my analysis, the main issue that needs to be taken into account when promoting collaborative innovation is that universities may not be the most suitable partner for all types of firms. My results show that only innovative firms will benefit from interaction with universities. This suggests that the government has also overestimated the potential role of universities, since this type of linkage is not a useful strategy for all firms. Policy makers therefore need to identify the characteristics of innovative firms and focus the promotion of university linkages only in those firms. Other types of partners, such as suppliers, clients, and even competitors, are more important for firms and also increase the likelihood of introducing new-to-the-firm innovations, which is the most typical type of innovation introduced by Chilean firms.

Second, the significant effects of public policy on shaping the incentives for collaboration on innovation activities in both universities and firms suggests that in developing countries—or at least in Latin American countries with a similar productive structure as Chile—university-linkages cannot be understood without taking into consideration the role of public policy and of the state as a provider of funding for innovation, operating within an economic structure that, at least in the Latin American context, creates an unconstructive environment for those linkages.

In summary, the findings of this thesis have shown that, university-firm linkages are influenced by three key factors: (i) the particular policies elaborated to promote these linkages; (ii) the other public policies that also affect universities and academics; and

(iii) the broad macroeconomic environment in which the interactions take place. Policymakers need to acknowledge that these factors produce different and sometimes inconsistent incentives in the behaviour of the actors in the system and factor these interactions and their impacts into policy design. More importantly, they need to recognise that policies that do not shift simultaneously the incentives of firms and academics in a substantial way will have only the most limited effectiveness and application.

In line with Fagerberg (2015), my findings support the argument that the innovation system dynamics of a country, as well as a particular 'problem', cannot be revealed by studying a single component in the system, but require the analysis of the technological dynamics of the national innovation system as a whole. This author indeed proceeds to argue that the evaluation of single innovation policy instruments 'may be of little value if interactions between different policies, as well as system-wide effects and feedbacks, are not taken properly into account' (Fagerberg, 2015: 15).

As my results have also shed light on the heterogeneity of firms and universities and on the possibility that collaboration with universities may not be beneficial *per se*, policymakers need to create instruments suitable for the variety of firms existing in the country and not simply assume that all firms will benefit from direct collaboration with universities. Firms may benefit, moreover, not only from R&D collaboration activities but also collaboration on other types of innovative activities; public policy should therefore encourage, and be designed to encourage, R&D collaboration but not at the expense of other types of collaboration. We may note, however, that this does not mean that R&D is irrelevant. On the contrary, as already discussed, R&D collaboration allows firms to expand their product range while at the same time increase their capacities and is generally beneficial for innovative firms.

This study also calls for caution when assessing the sensibility of agents to policy design. As discussed in Chapters 5, 6 and 7, there appears to be a strong sensibility to changes in policy and to the availability of new resources. For instance, recent trends regarding the tax credit appear to reveal the importance of the public sector in shaping the type of innovation produced in the country. Other recent changes allowing firms to access a tax credit regardless of the type of innovation have undoubtedly produced short-term results that indicate that the level of innovation in firms will rise. However, the changes have also reduced the number of university-firm linkages associated with the tax credit; the number of contracts to promote R&D activities fell sharply as soon as the changes were included. Although it is possible to argue that the design of the instrument was already flawed, it seems likely that the changes may have increased the incentives for firms to conduct less advanced innovations, involving less R&D.

8.6 Methodological lessons

This study exploited a combination of quantitative and qualitative data sources, which ranged from surveys and descriptive quantitative data to interviews and archival analysis. It was carried out using a mixed methods approach, combining such qualitative and quantitative methods as Tobit, probit, archive analysis, and semi-structured surveys. By selecting this research approach I believe I was able to obtain a more comprehensive understanding of the factors influencing university-firm linkages in Chile. Since case studies do not allow for statistical generalization (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Gibbert et al., 2008), the findings from this thesis cannot be directly extended to the population of developing countries. However, the insights from this analysis may raise awareness of similar issues in similar settings, particularly those Latin American countries with a macroeconomic environment and types of capitalism similar to those seen in Chile. The collection of the data and its analysis has led me, however, to recognise two significant methodological lessons: the potential bias produced by single methods in research (either quantitative or qualitative) and the importance of ensuring longitudinal comparability when using quantitative data.

Potential biased conclusions from using single data methods

The research strategy for this research considered both qualitative and quantitative methods and was chosen as the best feasible approach to answer the research questions of this thesis. However, a large part of the work has involved trying to make sense of the different, and sometimes even contradictory, insights produced by the qualitative and quantitative components of this research. In particular, separate findings produced by the quantitative and qualitative methods, often led me to conclusions that appeared contradictory but that actually signalled the nuances of university-firm linkages in a developing country context. Furthermore, given that the quality and scope of quantitative data in developing countries is sometimes limited, I believe that relying only on quantitative studies would have provided unreliable results as a consequence of a series of problems ranging from weaknesses in the fundamental design of the survey to a lack of knowledge, particularly of innovation issues, of the respondents to the surveys. In this regard, the findings from this thesis emphasize the benefits of using mixed methods in the study of university-firm linkages, since these allow researchers to leverage the complementarities of the data while reducing their limitations.

Ensuring longitudinal comparability of quantitative data

As discussed in the methodology chapter (Chapter 3), the quantitative component of this thesis draws on data from the Survey of Technological Innovation of Chile. The fact that the survey has been conducted since 1994 and that, by the time I was undertaking the fieldwork for this thesis, the Ministry of Economy was analysing the results from the 7th survey created a unique opportunity to use the newly available data. However, two challenges became evident when analysing the data in detail in order to assess its coverage and comparability across cross-sections. The first one was, to some extent, expected and related, firstly, to the changes made in the questionnaire to the topics covered and, secondly, to the variable range of detail employed in the questions. In general the changes were minor and, although they did reduce the scope of analysis, did not produce radical changes in the quality of data. But the changes introduced in the 7th version of the survey, which collected data about the innovation efforts of firms during 2009–2010, produced a break in the quality of the survey that strongly limited its potential use, not least because in this version of the survey the questionnaire did not include questions relating to the R&D efforts of firms, either in financial or human resources terms.

The second change to the survey that also produced unintended consequences was the introduction of representative sampling of Chilean firms. This change took place in the 6th version of the EIT (2007-2008) and meant that, unlike in earlier versions, it was no longer mandatory to include firms from the directory of firms carrying out R&D in the country. Although this change may increase the quality of data in terms of statistical representativeness, it reduces the likelihood of capturing the efforts of the firms that are most likely to be conducting R&D and innovation efforts. Consequently, this raises a particular dilemma for a developing country like Chile; should it aim at statistical perfection or at capturing most of the national efforts? I would argue that since Chile is still building its innovation capacity, emphasis should be placed on capturing the majority of the efforts. In a country where innovation, especially R&D, is not an ordinary activity conducted by a large number of firms, this would allow policy makers to keep closer track of the development of the innovation system.

8.7 Research limitations and areas for further research

Although this thesis has allowed me to obtain a general picture of university-firm linkages in Chile, it has not considered in-depth the sectoral differences within developing countries regarding university-firm linkages. Exploring which sectors in other developing country economies collaborate with universities on innovative activities would contribute considerably to our knowledge of what sectors have a strong impact on economic performance of countries. The literature has already underscored the fact that university-firm linkages are influenced by the sector of the firm and by the field of research.[84] In developing countries, however, the type of productive structure of the sector, as well as the capacities of the university

[84] See for instance Bozeman and Gaughan (2007) on the influence of industrial sector, and Thursby and Thursby (2002) on the effects of field of research on university-firm linkages.

departments, are limited and clearly this must influence the dynamics of university-firm linkages. Furthermore, the development of new research fields, like biotechnology, related to natural resources, means that links of firms to universities are no longer confined to the 'original' fields associated with the sector, such as engineering and metallurgy, and these new linkages may well produce some rewarding new insights.

On a broader level, the scholarship on university-firm linkages could benefit from similar research in other developing countries, especially those with similar productive structures to Chile, such as other Latin American countries. This would help with *analytical generalization* (Eisenhardt, 1989). [85]

Along with the particularly important gains that both a comparative and sectoral case study would yield, I believe that scholarship would benefit from further research in three other areas: the characterisation of firms that benefit from linkages with universities and the role of universities in the upgrading process; the role of business groups in regional innovation; and the interactions between trade and innovation potential.

This thesis has shown that collaboration with universities plays a very limited role in terms of the importance of innovation partners for firms. The results have also shown that collaboration with universities is only beneficial for innovative firms. These findings reveal areas that need additional research in the context of university-firm linkages in Chile. In particular, more research is needed at identifying the type of activities that universities carry out as research partners in the context of developing

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[85] This is a process different from statistical in that it refers to the generalization from empirical observations to theory, rather than a population (Gibbert et al., 2008).

countries. How much of the role of universities as partners is aimed at translating the knowledge they create as opposed as at adapting available knowledge through consultancies or similar activities? Are these organisations replacing lack of skilled suppliers/consultants in developing countries? If so, should this role be enhanced? More research on these questions would contribute to the debate about the role of universities in the promotion of technological upgrading in developing countries.

In addition, more research aimed at identifying the characteristics of the firms that benefit working with universities would also provide useful information for the design of policies that foster innovation and technological upgrading. Research could also be advanced on the role of other innovation partners for firms such as suppliers and the impact of these types of linkages on the performance of firms. Knowledge about the impact of other collaboration strategies can contribute to a more effective design of innovation policy.

Furthermore, in Chapter 5, I considered the significant role of business groups as part of the development and dynamics of the productive sector. The relevance of business groups in Latin America has also been advanced by the work of Schneider as part of the type capitalism observable in Latin America (see, for instance, Schneider, 2009; 2013a). But the economic importance of business groups in terms of their market share, the range of sectors in which they participate, the focus of their power concentration, and the quality of their internationalization strategies have led me to believe that their innovation patterns, especially the types of innovation employed by them, should be further examined. This would help develop a better understanding of how globalized firms from developing countries contribute to innovation, develop national capacities and promote technological upgrading. Research in this area would contribute to the literature on multi-national corporations and technology transfer in the context of South-South interactions.

Finally, I believe that more research is needed into the links between the innovation potential of firms and trade patterns. During the fieldwork and analysis stages of this thesis, I noticed that the innovation strategies of firms responded to the markets which they served. Respondents in some sectors would point out that they do not need radical innovations to serve their markets because these lag behind Chile in terms of development. This means that is not only important *what* you produce but also *who* your clients are. Scholarship has found that firms innovate more if they trade in competitive markets. I believe, however, that there may be a general technological innovation ceiling in sectors of the economy that serve comparatively less-developed markets in the sense that firms serving these markets experience limited pressure to engage in innovative activities that require more research-oriented efforts. Considering that firms in developing regions may not be competitive enough to serve developed countries with high value added products may reveal that, in practice, their markets are restricted. It may therefore be useful to explore to what extent the markets served by developing countries influence and even limit the innovation strategies of firms.

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Appendices

Figure 33: Map of Chile

Source: Downloaded from Maps.com (1999) on 14 March 2016.

Table 44: List of Interviews

Identification Number	Institution	Date
1	UCHILE	22.12.2010
2	UCHILE	01.12.2010
3	UCHILE	24.11.2010
4	UCHILE	15.11.2010
5	UCHILE	24.11.2010
6	UCHILE	22.11.2010
7	UCHILE	15.11.2010
8	UCHILE	02.12.2010
9	UCHILE	03.12.2010
10	UCHILE	17.12.2010
11	UCHILE	24.11.2010
12	Government	30.11.2010
13	Government	02.11.2010
14	UDEC	06.12.2010
15	UDEC	06.12.2010
16	UDEC	16.12.2010
17	UDEC	15.12.2010
18	UDEC	07.12.2010
19	UDEC	09.12.2010
20	UDEC	13.12.2010
21	UDEC	13.12.2010
22	UDEC	07.12.2010
23	UDEC	13.12.2010
24	UDEC	14.12.2010
25	UDEC	16.12.2010
26	UDEC	15.12.2010
27	PUC	10.01.2011
28	PUC	11.01.2011
29	PUC	10.01.2011
30	PUC	11.01.2011
31	PUC	25.01.2011
32	PUC	25.01.2011
33	PUC	25.01.2011
34	Government	30.11.2010
35	Government	30.11.2010
36	Government	30.11.2010
37	PUC	26.01.2011
38	UDEC	19.11.2012
39	Former civil servant	02.09.2012

40	Former civil servant	21.11.2012
41	Industry representative	10.06.2014
42	Former civil servant and private TTO	24.06.2014
43	Industry representative	19.06.2014
44	Government	23.06.2014
45	Industry representative	25.06.2014
46	Industry representative	11.06.2014
47	Industry representative	25.06.2014
48	Expert from firm	25.06.2014
49	Private R&D fund manager	18.06.2014
50	Industry representative	01.01.2013
51	Expert from firm	07.01.2013

Table 45: List of people interviewed during the exploratory phase of the project (December–January, 2009–2010)

Identification Code	Institution	Occupation
A	Universidad de Chile	Researcher
B	Universidad de Chile	Researcher
C	Universidad de Chile	Manager TTO Office UCHILE
D	InnovaChile	Former Director
E	Government	Director
F	University Incubator	Head of Strategy and Development
G	Government	Unit Director
H	Private research centre	Executive Director
I	Private firm/Manufacturing sector	Finance Director
J	Private research centre	Director of Business Development

Table 46: Global Competitiveness Index 2014–2015, innovation indicators for selected countries

	Chile		Brazil		Mexico		Turkey		New Zealand		Finland	
Variables	**Index**	**Ranking**	**Index**	**Ranking**	**Index**	**Ranking**	**Index**	**Ranking**	**Index**	**Ranking**	**Index**	**Ranking**
Capacity for innovation	3.7	76	**4.1**	**44**	3.7	72	3.7	77	**5.1**	**15**	**5.6**	**5**
Quality of scientific research institutions	4.0	51	**4.0**	**50**	3.9	58	3.9	64	5.3	19	**5.7**	**10**
Company spending on R&D	3.1	**3**77	**0.5**	**43**	3.1	71	2.9	89	3.8	29	**6.0**	**1**
University-industry collaboration in R&D	4.2	39	3.8	54	**4.0**	**44**	3.7	61	4.9	17	**4.1**	**22**
Gov't procurement of advanced tech products	3.8	40	3.4	77	3.4	76	**4.2**	**17**	3.4	71	4.1	22
Availability of scientists and engineers	**4.6**	**29**	3.3	114	3.9	78	4.2	42	4.4	40	**6.2**	**1**
PCT patents, applications/million pop.	6.7	43	**3.2**	**50**	1.8	58	**6.8**	**42**	73.9	22	**286.7**	**4**

Note: 'Index' scores on a 1–7 scale, with 7 being the best possible outcome; 'Ranking' reports the country's position among the 144 economies covered by the GCI 2014–2015. Chile, Brazil, Mexico and Turkey are considered economies in transition between being 'efficiency driven' (stage 2) and 'innovation driven' (stage 3), while Finland and New Zealand are considered 'innovation driven' economies. The number in bold identify comparative advantages among economies of the same group identified in the report.
Source: Own elaboration based on WEF (2014).

Table 47: Correlation Matrix

Table 47 presents the correlation between the variables under analysis. From this table it is possible to observe the high correlation between the different types of collaboration partners. Also, collaboration with universities appears to correlate closely with its lagged values. This may be an indication of persistence in the collaboration process. It may also be explained by the required time to obtain results in R&D projects, which can take several years and which can cover more than one innovation survey. Another detail worthy of observation is the important correlation between collaboration with universities and collaboration with other types of partners. This may indicate that both types of collaboration (with universities and with other types of partners) may in fact be complementary.

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Lgitsales	1																				
2	Log (R&D/sales)	-0.1	1																			
3	Non R&D expenditures dummy	-0.16	0.93	1																		
4	Co with any organisation	0.08	-0.42	-0.45	1																	
5	Co with any organisation (lagged)	0.14	-0.28	-0.28	0.25	1																
6	Co with universities	0.1	-0.37	-0.39	0.64	0.17	1															
7	Co with universities (lagged)	0.08	-0.29	-0.29	0.23	0.61	0.23	1														
8	Co with other firms	0.07	-0.38	-0.4	0.72	0.19	0.53	0.21	1													
9	Co with suppliers	0.08	-0.39	-0.42	0.83	0.2	0.53	0.21	0.65	1												
10	Co with clients	0.11	-0.35	-0.39	0.69	0.15	0.48	0.21	0.59	0.64	1											
11	Co with competitors	0.04	-0.22	-0.25	0.53	0.11	0.38	0.08	0.45	0.51	0.49	1										
12	Co with consultants	0.05	-0.36	-0.38	0.63	0.18	0.61	0.23	0.55	0.61	0.51	0.42	1									
13	Co with non-organisations	0.07	-0.42	-0.45	0.97	0.24	0.58	0.23	0.74	0.85	0.71	0.55	0.65	1								
14	Co with non-organisations (lagged)	0.14	-0.29	-0.28	0.24	0.98	0.17	0.56	0.2	0.2	0.15	0.11	0.18	0.24	1							
15	R&D department dummy	0.11	-0.66	-0.71	0.34	0.19	0.3	0.2	0.29	0.31	0.29	0.16	0.29	0.33	0.19	1						
16	Log (Firm size)	-0.09	-0.23	-0.19	0.2	0.21	0.18	0.17	0.18	0.19	0.12	0.11	0.19	0.2	0.21	0.22	1					
17	Log (Firm age)	-0.04	-0.12	-0.11	0.09	0.09	0.09	0.07	0.07	0.09	0.06	0.05	0.1	0.09	0.1	0.13	0.24	1				
18	Foreign firm dummy	0.01	-0.08	-0.07	0.08	0.08	0.06	0.07	0.1	0.07	0.04	0.04	0.07	0.09	0.09	0.09	0.18	-0.01	1			

19	Export firm dummy	0.00	-0.23	-0.22	0.16	0.14	0.16	0.13	0.13	0.14	0.11	0.07	0.15	0.16	0.15	0.23	0.26	0.13	0.23	1		
20	Group firm dummy	-0.01	-0.16	-0.15	0.17	0.18	0.14	0.15	0.2	0.16	0.11	0.07	0.15	0.17	0.17	0.14	0.3	0.00	0.25	0.16	1	
21	Public funds dummy	0.01	-0.17	-0.2	0.21	0.08	0.25	0.1	0.16	0.16	0.15	0.11	0.23	0.2	0.08	0.18	0.11	0.05	0.01	0.09	0.03	1

Table 48: Likelihood of introducing new-to-the-firm technological innovations (random effects probit estimates)

	(1)	(2)	(3)	(4)
Co with any organisation	1.440***			
	(0.0717)			
Co with universities		0.798***	-0.119	-0.191
		(0.112)	(0.159)	(0.135)
Co with non-universities				1.500***
				(0.0827)
Co with suppliers			1.010***	
			(0.108)	
Co with other firms			0.170	
			(0.130)	
Co with clients			0.519***	
			(0.129)	
Co with competitors			0.381**	
			(0.153)	
Co with clients			0.0722	
			(0.160)	
Log(R&D/sales)	0.0126	0.0175	0.0348	0.0265
	(0.0435)	(0.0415)	(0.0446)	(0.0424)
Non R&D expenditure dummy	-0.972***	-1.203***	-1.147***	-1.074***
	(0.261)	(0.248)	(0.266)	(0.258)
Log(Firm size)	0.0970***	0.113***	0.100***	0.0999***
	(0.0113)	(0.0115)	(0.0114)	(0.0114)
Log(Firm age)	-0.00896	-0.00184	-0.00740	-0.00823
	(0.0253)	(0.0258)	(0.0254)	(0.0255)
R&D department dummy	0.0789	0.212*	0.117	0.117
	(0.137)	(0.127)	(0.138)	(0.137)
Export dummy	0.0946*	0.127**	0.111**	0.0993*
	(0.0529)	(0.0533)	(0.0530)	(0.0531)
Public funds dummy	0.549***	0.695***	0.684***	0.591***
	(0.121)	(0.115)	(0.114)	(0.119)
Group dummy	0.0687	0.110**	0.0740*	0.0724*
	(0.0424)	(0.0427)	(0.0422)	(0.0424)
Foreign dummy	-0.160**	-0.127*	-0.145**	-0.167**
	(0.0681)	(0.0675)	(0.0673)	(0.0683)
Sector dummies	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes
Constant	yes	yes	yes	yes
N Observations	8,329	8,329	8,329	8,329
Log Likelihood	-3,572	-3,809	-3,633	-3,583
Rho	.154	.204	.164	.162

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

Table 49: First stage selection equation new-to-the-firm technological innovation using instrumental variables

	(1)	(2)	(3)	(4)
Dependent variable:				
Non R&D performer				
Independent variables				
Log (R&D/sales) lagged	-0.196**	-0.190*	-0.199**	-0.199*
	(0.0996)	(0.0989)	(0.101)	(0.102)
Non R&D performer (lagged)	2.363***	2.334***	2.387***	2.421***
	(0.636)	(0.618)	(0.645)	(0.650)
Log (Firm size)	-0.195**	-0.195**	-0.197**	-0.200**
	(0.0839)	(0.0810)	(0.0850)	(0.0869)
Log (Firm age)	0.211	0.210	0.214	0.220
	(0.209)	(0.206)	(0.211)	(0.214)
R&D department dummy	-5.099***	-5.026***	-5.134***	-5.223***
	(0.716)	(0.644)	(0.749)	(0.730)
Export firm dummy	-0.527	-0.524	-0.526	-0.545
	(0.329)	(0.324)	(0.331)	(0.338)
Public funds dummy	-1.019*	-1.022**	-1.023*	-1.074**
	(0.525)	(0.505)	(0.529)	(0.536)
Group firm dummy	-0.696**	-0.684**	-0.700**	-0.703**
	(0.292)	(0.287)	(0.296)	(0.299)
Foreign firm dummy	0.228	0.247	0.229	0.246
	(0.375)	(0.374)	(0.377)	(0.384)
Sector dummy	yes	yes	yes	Yes
Constant	yes	yes	yes	Yes
N Observations	8,329	8,329	8,329	8,329
Log Likelihood	-3,734	-3,960	-3,724	-3,784

Table 50: Likelihood of introducing new-to-the-market technological innovations, probit estimates using instrumental variables

	(1)	(2)	(3)	(4)
Co with any organisation	1.102***			
	(0.145)			
Co with universities		0.490***	0.946***	0.392**
		(0.165)	(0.147)	(0.143)
Co with non-universities				0.918***
				(0.137)
Co with suppliers		0.448***		
		(0.154)		
Co with other firms		0.268*		
		(0.148)		
Co with clients		0.418**		
		(0.152)		
Co with consultants		-0.216		
		(0.166)		
Co with competitors		0.186		
		(0.162)		
Log(R&D/sales)	0.148***	0.155***	0.144***	0.152***

	(0.0441)	(0.0457)	(0.0425)	(0.0446)
Non R&D expenditures dummy	-1.905***	-1.942***	-1.973***	-1.900***
	(0.360)	(0.370)	(0.341)	(0.357)
Log (Firm size)	0.0952***	0.0977***	0.101***	0.0945***
	(0.0199)	(0.0200)	(0.0189)	(0.0195)
Log (Firm age)	0.0371	0.0364	0.0394	0.0346
	(0.0406)	(0.0400)	(0.0395)	(0.0401)
R&D department dummy	0.394**	0.393**	0.442***	0.406**
	(0.152)	(0.151)	(0.147)	(0.152)
Export firm dummy	0.175**	0.182**	0.181**	0.166**
	(0.0786)	(0.0786)	(0.0774)	(0.0783)
Public funds dummy	0.540***	0.574***	0.565***	0.510***
	(0.159)	(0.162)	(0.155)	(0.159)
Group firm dummy	0.0863	0.0826	0.120*	0.0856
	(0.0657)	(0.0651)	(0.0635)	(0.0653)
Foreign firm dummy	0.125	0.150	0.160*	0.129
	(0.0960)	(0.0951)	(0.0932)	(0.0951)
L	0.369	0.374	0.309	0.352
	(0.348)	(0.366)	(0.346)	(0.348)
Sector dummy	yes	yes	yes	yes
Constant	yes	yes	yes	yes
N Observations	8,329	8,329	8,329	8,329
Log Likelihood	-1,939	-1,961	-2,002	-1,947

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

Table 51: Universities and innovation efficiency of firms: Random effects Tobit estimates

	(1)	(2)	(3)	(4)
Co with any organisation	1.146** (0.440)			
Co with universities		1.679** (0.603)	1.232* (0.707)	1.440** (0.657)
Co with suppliers			-0.112 (0.609)	
Co with clients			1.219* (0.647)	
Co with competitors			0.209 (0.721)	
Co with consultants			-0.0714 (0.746)	
Co with non-universities				0.443 (0.486)
Log(R&D/sales)	0.447** (0.213)	0.437** (0.213)	0.430** (0.213)	0.440** (0.213)
Non R&D expenditures dummy	-5.457*** (1.366)	- 5.367*** (1.367)	- 5.226*** (1.368)	- 5.341*** (1.367)
R & D department dummy	0.748 (0.771)	0.714 (0.772)	0.670 (0.772)	0.696 (0.772)
Log (Firm age)	-0.239	-0.246	-0.245	-0.247

	(0.272)	(0.272)	(0.272)	(0.272)
Log (Firm size)	-0.331**	-0.343**	-0.337**	-0.350**
	(0.128)	(0.129)	(0.130)	(0.129)
Sector Dummies	yes	yes	yes	yes
Year Dummies	yes	yes	yes	yes
Constant	yes	yes	yes	yes
N Observations	2096	2096	2096	2096
Log Likelihood	-5627	-5627	-5624	-5626

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

Table 52: Universities and innovation efficiency of firms: Random effects Tobit estimates using instrumental variables

	(1)	(2)
Co with universities	1.320*	1.081
	(0.719)	(0.753)
Co with non-universities		0.440
		(0.454)
Non R&D expenditures dummy	-5.432***	-5.408***
	(1.258)	(1.259)
Log(R&D/sales)	0.439**	0.443**
	(0.205)	(0.205)
R&D department dummy	0.750	0.732
	(0.704)	(0.705)
Log(Firm age)	-0.244	-0.245
	(0.273)	(0.273)
Log(Firm size)	-0.330**	-0.338**
	(0.138)	(0.138)
L	1.319	1.253
	(2.586)	(2.555)
Sector Dummies	yes	yes
Year Dummies	yes	yes
Constant	yes	yes
N Observations	2,096	2,096
Log Likelihood	-5,803	-5,802

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

Table 53: Universities and innovation efficiency of firms: Generalized Tobit estimations (Industry subsample)

The results from estimating the effects of collaboration with universities on the subsample of innovative manufacturing firms show that collaboration, in general (model 1), and with universities in particular (model 2), appears to have a positive and significant impact on the innovation performance of firms. However, after controlling for collaboration with other organisations (model 3), the effects of collaboration with universities and with other organisations keep their expected signs but their coefficients are not significant. Further, model 5 shows that collaboration with universities is not significant after controlling for collaboration with clients, which appears to have a positive and significant impact on the innovation efficiency of firms.

	(1)	(2)	(3)	(4)	(5)
Co with any organisation	1.024** (0.451)				
Co with universities		1.040** (0.528)	0.607 (0.564)	0.878 (0.574)	0.642 (0.525)
Co with non-universities			0.751 (0.494)		
Co with other firms				0.0142 (0.666)	
Co with suppliers				-0.132 (0.674)	
Co with clients				1.292** (0.624)	1.114** (0.510)
Co with competitors				0.0866 (0.670)	
Co with consultants				-0.506 (0.630)	
Non R&D expenditures dummy	-5.811*** (1.465)	-5.908*** (1.476)	-5.813*** (1.475)	-5.673*** (1.510)	-5.640*** (1.499)
Log(R&D/Sales)	0.502** (0.216)	0.504** (0.218)	0.506** (0.217)	0.488** (0.216)	0.489** (0.218)
R&D department dummy	5.128*** (1.101)	4.948*** (1.110)	5.071*** (1.098)	5.104*** (1.112)	5.125*** (1.105)
Log(Firm age)	-0.309	-0.297	-0.305	-0.295	-0.294

	(0.298)	(0.298)	(0.298)	(0.296)	(0.296)
L	6.814***	6.757***	6.815***	6.840***	6.844***
	(0.596)	(0.604)	(0.596)	(0.601)	(0.599)
Log(Firm size)	0.492**	0.474*	0.475**	0.508**	0.497**
	(0.239)	(0.247)	(0.242)	(0.244)	(0.241)
Year dummy	yes	yes	yes	yes	Yes
Constant	yes	yes	yes	yes	Yes
N Observations	2,605	2,605	2,605	2,605	2,605
Log Likelihood	-3,555	-3,556	-3,555	-3,554	-3,554

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$

Table 54: Universities and innovation efficiency of firms: Generalized Tobit estimates (subsample continuing observations)

	(1)	(2)	(3)
Co with any organisation	0.837**		
	(0.342)		
Co with universities		1.054**	0.855*
		(0.470)	(0.500)
Co with non-universities			0.384
			(0.364)
Non R&D expenditures dummy	-4.400***	-4.422***	-4.382***
	(1.144)	(1.147)	(1.151)
Log(R&D/sales)	0.401**	0.400**	0.403**
	(0.174)	(0.176)	(0.175)
R&D department dummy	5.606***	5.562***	5.576***
	(0.806)	(0.804)	(0.803)
Log(Firm age)	-0.156	-0.155	-0.157
	(0.269)	(0.269)	(0.269)
Log(Firm size)	0.490***	0.486***	0.480***
	(0.134)	(0.134)	(0.134)
L	7.313***	7.300***	7.315***
	(0.438)	(0.440)	(0.439)
Constant	-12.03***	-11.78***	-11.94***
	(1.834)	(1.827)	(1.835)
N Observations	4,943	4,943	4,943
Log Likelihood	-6,813	-6,814	-6,813

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.005$