Social Networks, Collaborations and High-tech Cluster Formation in an Emerging Country: The Case of Biotechnology in Chile



Thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in International Development

by

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LIST OF ACRONYMS

ASEMBIO	Industrial Association of Biotechnology Companies of Chile (Asociación de Empresas de Biotecnología)
CORFO	Chilean Economic Development Agency (Corporación de Fomento Productivo)
CONICYT	National Commission for Science and Technology of Chile (Comisión Nacional de Ciencia y Tecnología)
CNIC	National Innovation Council of Chile (Consejo Nacional de Innovación para la Competitividad)
DBF	Dedicated biotechnology firm
ECLAC	Economic Commission for Latin America and the Caribbean
FIA	Foundation for Agrarian Innovation (Fundación para la Innovación Agraria)
INIA	National Institute of Agricultural Research (Instituto Nacional para la Innovación Agriaria)
PCA	Principal component analysis
PROFO	Associative Development Projects (*Proyectos Asociativos de Fomento*)
OECD	Organisation for Economic Co-operation and Development
OLI	Ownership, location and internalisation
R&D	Research and development
SNA	Social Network Analysis

ABSTRACT

Geographic clusters of firms have been extensively studied in different bodies of literature, but little attention has been paid to the process of cluster formation and its determinants. While focusing on the effects of clusters on innovations and on the productivity of firms, the literature has neglected the agency of entrepreneurs in cluster emergence.

This thesis aims to contribute to the literature on clusters by studying the role of personal networks and firm networks in three aspects of the emergence of clusters: 1) the early stages of formation; 2) the creation of business relations between firms; and 3) the creation of knowledge among clustered firms.

The analysis was conducted using the biotechnology sector in four geographic regions of Chile as a case study. Data on firms was collected using in-depth interviews and a survey. The analysis of the data was carried out using content analysis, multilevel estimations and econometric analysis.

The results reveal three main findings. First, the personal and business relations of entrepreneurs can determine the location decisions of firms. Second, personal relations are positively associated with the emergence of formal business relations between firms. Third, the number of personal and business connections a firm has positively affects its production of knowledge, measured as patent applications and scientific journals.

These findings suggest that social networks within a cluster shape its emergence and development. The results also show that the different types of networks co-existing in a cluster – personal networks, business networks and research networks, among others – affect one another and determine the development of clusters.

The implications of this research may be helpful for policy-makers, professional associations and cluster managers. Activities to foster personal interaction between members of a cluster and other key actors – universities, incubators, venture capital firms, government agencies, etc. – may generate collaborations between firms that would not otherwise emerge.

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1 INTRODUCTION

1.1 INTRODUCTION

Cluster development programmes, which might be thought of as policies to promote the agglomeration of firms in a sector, have become fashionable in recent years in many middle-income countries as part of industrial policies focused on promoting economic growth (Giuliani and Pietrobelli, 2011; Pietrobelli and Rabellotti, 2004). However, there are a variety of successful and unsuccessful policies relating to clusters. In fact, the most successful clusters, such as Silicon Valley (Saxenian, 1994) and the biotech cluster of Boston (Feldman, 2003), were created without the direct involvement of public policies. The variety of cases shows that it is still not clear what the key factors are behind the emergence of clusters, and what the role of public policies in this respect may be (Karlsson, 2008a).

In the development economics literature, industrial policies have been thought of as a key factor in sustained economic growth. As Lin (2009, p. 484) remarks, sustainable economic growth requires continuous technological and industrial upgrading. There is evidence to suggest that the positive relation between clusters and firm productivity may lead to an increase in countries' economic growth (Lundvall, 1992; Nelson, 1992; Nelson and Winter, 1982; Porter, 2000, 1998a; Romer, 1990). In less developed countries, the promotion of clusters might have important implications for economic growth (Porter, 1998a, p. 86). Therefore, in the last decade, many emerging economies have adopted industrial policies to promote the emergence and development of clusters (Giuliani and Pietrobelli, 2011;

Pietrobelli and Rabellotti, 2004). In Latin America, countries such as Argentina, Brazil, Chile, Colombia and Uruguay have established innovation policies with incentives to promote cluster formation (Giuliani and Pietrobelli, 2011). Countries in Asia and Africa are following the same path. Given the importance of cluster policies in countries aiming at increasing their economic growth and closing the technology gap with industrialised countries, there is an evident need to study cluster phenomena, in particular, cluster formation in emerging countries. However, there is less consensus in the literature about the drivers and processes of cluster formation (Karlsson, 2008a). There is still a need to understand the creation of clusters and whether there is a role for public policy in this process (Bell and Albu, 1999; Boschma, 2005; Braunerhjelm and Feldman, 2006; Casper, 2007a; Karlsson, 2008a; Perez-Aleman, 2005; Porter, 1998a; Ter Wal and Boschma, 2009).

However, empirical evidence on cluster emergence has mainly focused on industrialised countries. The literature on clusters in emerging economies has focused mainly on the effects of clusters for firms' innovation and growth (Giuliani and Bell, 2005; Giuliani and Pietrobelli, 2011; Pietrobelli and Rabellotti, 2004). Also, there has been little research done on high-tech clusters in emerging economies, and the work has focused on clusters associated with natural resources. Most of the economic growth experienced in emerging countries in Latin America over recent decades has been driven by an increase in commodity production. However, knowledge-based sectors have the potential to increase the value added to exports and to diversify a country's production mix. Consequently, research on the formation of high-tech clusters in the context of emerging economies has theoretical and practical relevance.

The purpose of this thesis, which is exploratory in nature, is to provide evidence of the role of social relations in high-tech cluster formation in the context of an emerging economy. This thesis contributes to the literature on clusters, entrepreneurship and knowledge networks by employing different methodologies to understand the relative importance of social relations in cluster formation. During this study, I examine the way in which social networks shape cluster formation by tracing how personal and business ties shape the decisions of entrepreneurs to create and locate a firm, develop business relations within the cluster, and generate new knowledge. I study the emergence of the biotechnology sector in four regions of Chile, gathering primary data through in-depth interviews and surveys. The central question that I aim to answer is: Do relations between organisations positively affect the formation of a cluster?

This chapter will briefly present the conceptual framework, the research questions of this thesis, the significance of the study, the methodological approach, the definitions of the main terms used, and a thesis outline and overview.

1.2 CONCEPTUAL FRAMEWORK

A cluster will be considered, following the work of Porter (1998a), as 'a geographical concentration of interconnected companies and institutions in a particular field' (Porter, 1998a, p. 78). There are several streams of literature that have analysed cluster growth and lifecycle, and some of them have touched on the phenomenon of cluster emergence. However, there is not a developed theory of cluster emergence – a product of the high variability of cases (Karlsson, 2008b). In this section, I will summarise some of the different streams of literature that study clusters and cluster emergence.

The geographic agglomerations perspective

Companies in a cluster co-locate in a geographical area and may or may not have business relations or interactions in other aspects. Geographic proximity is seen as central for firms if they are to benefit from clusters in productivity, knowledge transfer and innovation. The early literature on local knowledge spillovers stresses geographical and local factors as being central to knowledge transfers among firms. The benefits of the spatial concentration of firms include lower transaction costs, a higher concentration of suppliers and clients, and closeness to universities and research centres, and have been called 'agglomeration economies'. These benefits of agglomeration have been considered the drivers of cluster formation (Karlsson, 2008b).

The latest research on economic geography and regional economics goes beyond this analysis, highlighting the role of firms' interactions and local institutions in cluster formation. The co-location of companies does not necessarily imply an increase in firm productivity (Boschma, 2005). Lately, it has been recognised that not only is geographical proximity positively associated with an increase in the innovations and productivity of clustered firms, but that other proximities – personal, social, cognitive, organisational and institutional – have an impact on clustered firms. There are, furthermore, interactions, substitutions and complementarities between these proximities (Boschma, 2005). However, there is still not enough research on the relations between these proximities (Balland et al., 2013); this study provides new empirical evidence on this area.

The relations between firms in clusters

Evolutionary economics theory and innovation systems literature emphasise the role of institutions, the environment and relations between firms and other relevant actors, such as public agencies, research centres and universities. The interactions between firms create different types of collaboration, generating multiple networks between the actors in a cluster. In fact, networks and connections between companies, formal or informal, are fundamental for knowledge spillovers and for the exploitation of the advantages of co-location (Giuliani, 2007; Giuliani and Bell, 2005). The importance of studying collaborations in clusters follows on from the nature of the relation between economic growth, innovation, knowledge and technical creation. Collaborations facilitate knowledge transfer and enhance firms' learning capabilities (Hagedoorn et al., 2000). In consequence, collaborations facilitate the transfer of knowledge between organisations.

The literature has studied, in particular, the knowledge networks that emerge from formal or informal collaborations between firms and workers in clusters, through which technical knowledge is transmitted or joint research and development (R&D) projects implemented (Boschma, 2005; Giuliani, 2007). However, less attention has been paid to other types of relations and networks in the process of cluster formation. There are multiple networks co-occurring in a cluster (Hilpert and Lawton Smith, 2012; Kadushin, 2012; Lawton Smith, 2008), and despite the theoretical notion that different networks and relations might affect one another, empirical evidence has failed to capture these interactions given the difficulty of obtaining quantitative data from different networks in a cluster (Kadushin, 2012). The work conducted in this thesis aims to contribute to this

discussion by collecting primary data on multiple networks within a cluster and by studying the effects between the personal network and the business network.

Entrepreneurship and social networks

Recently, few authors have included the role of entrepreneurship and social networks in the formation of clusters (Feldman et al., 2005; Pitelis, 2012). On the one hand, the literature on entrepreneurship focuses on the role of entrepreneurs in founding new companies, recognising the importance of networks of entrepreneurs, governmental policies and the local environment for the success and creation of start-ups. The study of entrepreneurs and the creation of new firms is important for the analysis of cluster emergence, since they might later form, and determine the dynamics of, a cluster (Pitelis, 2012).

On the other hand, the social network literature highlights the importance of social capital in creating links between actors in a network.[1] As Whittington et al. (2009) conclude from a study of life science industrial districts in the USA, social networks and social structures are the bases for understanding the co-location of firms.

A social network is a network between actors in which different types of relation are possible; therefore, in this thesis, when I refer to a 'social relation' I am considering any kind of relation – including personal, business, research and investment – between actors in the cluster. Similarly, when I refer to a 'social network' I am considering a network between firms, where the ties between the actors can identify any kind of relation.

[1] As Wassweman and Faust (1994, p. 20) state, a social network is formed by a group of actors and the relation or linkages between them. In this study, actors will be defined as firms, research centres, associations, consortia or universities.

In this thesis, I will focus on two types of relation between actors in a cluster: 'business relations' and 'personal relations'. Business relations will be understood as any formal business relation, including capital investments, client and supplier relations, research collaborations, and participation in industrial associations. These business relations create the *business network* between actors in a cluster. Personal relations encompass the relations between individuals in different organisations, including the career affiliations of company owners, managers or researchers, and family ties or connections established at school or university. Personal relations between individuals create the *personal networks* between organisations in a cluster.

The role of social networks between actors in a cluster can vary depending on the economic context in which the cluster is embedded. It might be the case that social networks are more important in the earlier stages of cluster development because of financial restrictions on entrepreneurs and the particular obstacles they face when co-creating a new sector or economic industry (Pietrobelli and Rabellotti, 2004; Pitelis, 2012). In addition to these obstacles, entrepreneurs in emerging economies face additional restrictions, such as financial market access, particularly to venture capital, and the knowledge gap between the local market and the technological frontier, among others (Casper, 2007b; Clarke et al., 2005; Feldman et al., 2005; Perez-Aleman, 2005; Presbitero and Rabellotti, 2016; Santibáñez, 2010a, 2010b; Solimano, 2014; Ter Wal and Boschma, 2009).

In the formative stages of a cluster, entrepreneurs play a major role in this respect, establishing the initial conditions for cluster emergence (Feldman et al., 2005; Feldman and Braunerhjelm, 2006; Pitelis, 2012). The social networks of entrepreneurs might facilitate or restrict the linkages that a start-up creates,

affecting the growth of the firm and the evolution of the cluster (Gulati, 1995a; Uzzi, 1997, 1996). Access to venture capital markets is crucial for the first stages of a company and for the emergence of a cluster, and the personal relations of entrepreneurs affect the access of start-ups to venture capital (Bauernschuster et al., 2010; Hsu, 2007; Wang, 2016). In less developed economies, social networks might be even more important for cluster formation since entrepreneurs face additional restrictions, such as difficulties accessing bank loans (Clarke et al., 2005; Presbitero and Rabellotti, 2016) or less developed financial markets with few venture capital firms and angel investors (Santibáñez, 2010a, 2010b; Solimano, 2014).

Recently, some studies have introduced entrepreneurial aspects into the analysis of clusters (Feldman et al., 2005; Menzel and Fornahl, 2009); others have included social networks in the analysis of natural resource-based clusters in the context of an emerging country (Felzensztein and Gimmon, 2009; Giuliani and Bell, 2005). Social networks and entrepreneurship theories are appropriate in analysing cluster formation because they can explain how and why the first firms in a cluster settle in an area and then how the linkages between firms are established. This study will contribute to the literature by including both a social network and entrepreneurial perspective in the analysis of cluster formation. It will also study a high-tech sector in an emerging economy context, widening the range of evidence on clusters in non-industrialised contexts.

The purpose of the thesis

From the overview of the relevant literature presented here, it is clear that no single stream of literature alone can explain the emergence of clusters. All these theories are complementary and are built up from the importance of endogenous factors

(social capital), exogenous factors (the economic advantages of co-location and shocks) and the dynamic process of a cluster (interactions between agents).

Therefore, this study will focus on the creation of relations between agents of a cluster in its early stages, with the aim of understanding the role of social networks in the initial phase of the formation of a knowledge-based cluster in the context of an emerging economy. The structure of a social network can influence the relations that a firm creates, affecting the formation of a cluster positively or negatively (Perez-Aleman, 2005; Uzzi, 1996; Whittington et al., 2009). However, it is not completely clear what role public policies and social structures play in the process of cluster formation. From the literature on clusters, it is possible to identify a large diversity in histories of cluster emergence (Braunerhjelm and Feldman, 2006; Karlsson, 2008a). There is still a need to examine how social interactions within clusters are structured and how these structures are created (Karlsson, 2008b; Ter Wal and Boschma, 2009). This thesis intends to contribute to the existing literature by tracing personal and business ties within a high-tech cluster in its initial stages, and by providing evidence on the role of such relations in the emergence of a new high-tech cluster in the context of an emerging economy.

1.3 RESEARCH QUESTIONS

As mentioned above, this study will analyse the role of personal and business networks in the formation of a knowledge-based cluster in an emerging country. In particular, I will study the formation of the biotechnology sector in four regions of Chile. The main research question in this thesis is: Do relations between organisations positively affect the formation of a cluster? For the particular case studied in this thesis, and given the examination of the relevant literature, the

research question can be refined to: Do personal and business relations between organisations positively affect the formation of the Chilean biotechnology cluster?

Some sub-questions that emerge from this main question are:

1. How important are personal and business relations for the creation and location of a firm within a cluster?
2. Are personal relations positively associated with the creation of business relations within a cluster?
3. Do the personal network and business network determine the knowledge creation of firms in a cluster?

These questions focus on three main areas of cluster formation: the emergence of agglomerations; the creation of networks within the cluster; and the development of capabilities that affect the potential growth of the cluster. Therefore, this thesis will study the effect of social relations – i.e. personal and business relations – between organisations and individuals on three aspects of the emergence of a cluster: a) the creation and location decisions of entrepreneurs; b) the creation of a network between organisations in a cluster; and c) the potential for growth of a cluster through the creation of knowledge by clustered firms. From these questions, specific hypotheses arise; these will be discussed in further details in Chapter 2.

1.4 METHODOLOGY AND DELIMITATIONS OF THE STUDY

This dissertation pursues a case study analysis of the biotechnology sector in four regions of Chile: Metropolitana, Valparaíso, Bío-Bío and Los Lagos. Chile is an interesting case: it experienced rapid economic growth during the 1990s but economic growth has slowed over the last two decades. In recent years, the Chilean government has established policies to promote innovation, cluster formation and

growth in order to increase the productivity and competitiveness of Chilean products. However, the design of these policies does not directly take into account the role of social networks in promoting cluster formation. Within this context, biotechnology is considered a sector that could enhance technological upgrading in other sectors, particularly in natural resource-based sectors, increasing the value added to emerging economies' production and export matrices. It is therefore important to study how knowledge-based clusters emerge in a non-industrialised country context.

A clarification about the biotechnology sector is necessary. According to the Organisation for Economic Co-operation and Development (OECD), 'A biotechnology firm can be defined as a firm that is engaged in biotechnology by using at least one biotechnology technique … to produce goods or services and/or to perform biotechnology R&D. Some of these firms may be large, with only a small share of total economic activity attributable to biotechnology' (OECD, 2009, p. 10). The OECD (2009) classifies biotechnology firms into three groups: 1) firms whose main activity is not biotechnology, but which use a biotechnology technique in their production process – biotechnology firms; 2) firms whose main activity involves the application of biotechnology to produce goods or services in this field – dedicated biotechnology firms (DBFs); and 3) firms that perform biotechnology R&D and whose main products and services depend on this research – biotechnology R&D firms. Most studies of biotechnology clusters and sectors use the term 'biotechnology firm' as if it referred to a DBF (Casper, 2007b; Owen-Smith and Powell, 2004), leading to a confusion. Also, according to the OECD definition, a biotechnology firm can be a client of a DBF, as with, for example, pharmaceuticals and DBFs in the biomedicine sub-sector.

Given the definitions of 'cluster' and 'biotechnology firm', I will take the biotechnology sector as including organisations such as DBFs, international distributors of supplies, universities and research centres, large client firms (pharmaceuticals, salmon farming firms, agriculture firms, etc.), venture capital and financing firms, and consultancy and law firms. However, the focus of attention will be on DBFs, since these firms are the core of the biotechnology sector, and in those firms the knowledge-creation process of the sector is concentrated. DBFs and their relations with other organisations, whether these are DBFs or not, are considered the focus of study for the clusters analysed in this research.

Most research on networks in clusters have used mainly secondary data and have focused on cluster growth in developed countries. Research on clusters in less developed economies has focused on natural resource-based sectors. In Chile, research has been conducted mostly in the salmon and wine industries (Felzensztein and Gimmon, 2009; Giuliani, 2007; Giuliani and Bell, 2005; Perez-Aleman, 2005). However, the formation of knowledge-based clusters, as in the biotechnology sector, in less developed economies has not been extensively analysed. This study is one of the first, to the best of my knowledge, to research the interactions between personal and business relations and the effect of these on the creation of a knowledge-based cluster in an emerging country using primary data on multiple networks.

Qualitative and quantitative research methods were adopted to provide descriptive, interpretive and empirical data. The approach used for the qualitative design was a semi-structured interview methodology, while the quantitative design gathered data from an original survey conducted in the sector in 2011 and 2013. This thesis also adopts mixed methods in the analysis of the data collected: content

analysis, descriptive statistics, multilevel modelling and other econometric techniques are applied to analyse the information collected.

The data is from a sample of biotechnology companies from four regions of Chile; more than 90% of firms in this sector are located in these regions.[2] The sector includes only 150 biotech firms in the country, and the response rate reached in this study was 54% of total biotech firms. Additionally, the total number of surveyed firms who offered complete information was only 66 – the product of the small number of firms in the sector. Therefore, even when the data collected is representative of the biotech sector in Chile, the absolute number of complete surveys gathered imposes restrictions on the econometric techniques carried out during the thesis.

Another restraint arising from the data is that biotech firms outside the Metropolitana region, where the capital is located, represent a small proportion of the firms in the country – the total count of firms in this category is less than 15. Therefore, statistical and econometric analysis to a regional level will not be possible.

Finally, another limitation of this study is the cross-sectional nature of the quantitative data collected. The process of cluster formation is dynamic, and longitudinal data would capture better the phenomenon under study. However, the triangulation of the results of the different methodologies applied in this study will add robustness to the conclusions obtained.

[2] Data collected in 2011 included only the biomedicine sector in just the Metropolitana region of Chile. In 2013, the research was extended to include firms in every biotechnology area in four regions of Chile – Metropolitana, Valparaíso, Bío-Bío and Los Lagos – which together include more than 90% of the biotechnology firms in the country.

1.5 SIGNIFICANCE OF THE STUDY

This study purpose and results will have implications for managers of biotech companies, university technology transfer offices and policy-makers. For managers and entrepreneurs of firms involved in biotechnology in emerging economies, this study presents new evidence on the interaction between personal and business relations and could be used to shape a wider understanding of the sector. In addition, social relations can shape the outcomes of collective actions, such as the creation of an industrial association and policies influencing a cluster (Pietrobelli and Rabellotti, 2004). Therefore, understanding the importance of different connections and the key agents in the emergence of a sector can be informative for firms at the individual and collective level.

For university technology transfer offices in emerging markets, the evidence presented here will inform them about the need to connect with other actors in the sector to increase the probability of success for potential spin-offs. Even though the science behind a potential new product developed at a university is important for a business idea, there are other aspects, such as personal relations and previous experiences, which shape the outcome of a potential new venture.

Finally, policy implications from this study could be beneficial not only for Chile, but also for other countries promoting cluster formation. Public programmes seeking to create a cluster need to consider the structure of social networks, since these structures provide framework conditions for the emergence of clusters, determining factors limiting or enhancing a cluster. This study will provide evidence concerning the importance of different connections between firms and other actors in the emergence and development of a cluster.

1.6 THESIS OUTLINE

The thesis has eight chapters. The main analytical chapters, Chapters 5, 6 and 7, are organised following a journal article structure; they therefore present specific aspects of the literature review and methodologies that apply specifically to each chapter. The objectives of this structure are twofold. First, it is expected that it will improve the interpretation of the results in each chapter. Second, this structure will facilitate the transformation of each chapter into a prospective journal article. This structure does imply the unavoidable repetition of some of the content of the thesis. To minimise repetition, the literature review and methodology chapters will introduce the content only briefly, since a specific review of the literature related to the topic and the methods used will be included in each analytical chapter.

After the introductory chapter, Chapter 2 briefly reviews the relevant literature, illustrating the main gaps in the literature on cluster formation. Chapter 3 describes the methodologies used in this study: it describes the data collection process, the selection criteria for the case study, the representativeness of the data collected, and the methodologies of analysis. Chapter 4 presents a description of the biotechnology sector in Chile, setting out the origins of the sector and the main trends, and providing descriptive statistics of the firms that participated in the survey conducted in this study. The chapter also analyses the main actors and the relations between them, and describes the networks observed and the knowledge flows within the cluster identified from the interviews and fieldwork conducted. This chapter provides evidence of the important role that leading firms, academic entrepreneurs and links between universities or research centres with biotechnology firms plays in the development of the sector.

Chapter 5 describes the process of the emergence of the cluster, analysing the results of in-depth interviews as well as quantitative data from the survey. It analyses the data in order to address the first research question. Some of the themes analysed are the location decisions of start-ups in the region, the difficulties faced by entrepreneurs when establishing a new firm and the current problems experienced by the sector's actors. Using content analysis of the comments and interviews, I was able to establish that social relations, in particular personal connections, are positively associated with the ability to access resources and identify opportunities for entrepreneurs during the initial stages of starting a company. Also, the data collected from the survey reveals that the traditional benefits of agglomerations are associated with the location decisions of the entrepreneurs.

Chapter 6 presents a non-parametric and econometric analysis of the quantitative data in order to estimate the importance of personal relations in the creation of business relations within the biotechnology sector in Chile. The chapter focuses on answering the second research question of this thesis. A multilevel logit model was estimated to measure the relevance of personal relations in the creation of business relations between two organisations, while controlling for features of both organisations and geographic distance. The results suggest that personal relations have a highly significant and positive effect on the likelihood of forming a business relation.

Chapter 7 studies the effect of connections in knowledge creation for the biotechnology sector, answering the third research question in the thesis. Most studies on external linkages in clusters do not consider the impact of international collaborations on the creation of knowledge by firms in emerging countries. In this

chapter, the different types of links and their effects on knowledge creation are analysed, contributing to the literature on cluster knowledge creation in emerging countries. The links considered involve national and international partners, and it is possible to distinguish between different orientations of the partners (focused on R&D or not) and the formality of the connection (business versus personal or formal versus informal), which is a central contribution of this chapter. Empirical analysis is carried out using non-parametric techniques and negative binomial regressions. The results suggest that connections with R&D partners, national and international, are positively associated with knowledge creation (measured by number of publications and patent applications). International business relations with R&D-oriented partners are positively related to, and more important than, other networks in the creation of scientific knowledge; however, it is not possible to observe the same results for patents: there is weak evidence that personal relations with national R&D-oriented institutions can positively impact the number of patent applications of firms.

Discussions of the results obtained in previous chapters and a conclusion are presented in Chapter 8. This chapter brings together all the information gathered, triangulating the results. It also presents the main conclusions of this study, as well as the potential policy implications of the thesis.

1.7 SUMMARY

This introductory chapter has set out the purpose and research questions that this thesis aims to address. The thesis seeks to contribute to the literature on cluster formation and development by analysing the role of personal and business

networks in the process of firm creation, inter-organisational collaboration, knowledge creation and, finally, cluster formation.

In particular, this thesis uses a novel dataset and qualitative and quantitative methods of analysis to better understand the relations between different types of actors and the emergence of a cluster. The results from this study will have implications for managers and university technology transfer offices given the importance of relations for the creation of firms. It will also be possible to extract from the thesis policy implications for emerging economies that are developing innovation policies to promote clusters and growth.

2 LITERATURE REVIEW

2.1 INTRODUCTION

Despite the large amount of literature on clusters, little is known about the emergence and early stages of a cluster. Given the high variability surrounding the factors present in the early stages of clusters in case study research, it has not been possible to develop a unified theory of cluster emergence (Karlsson, 2008b; Lawton Smith, 2008). Thus, research on clusters has focused on the growth, decline and renewal phases of clusters, and also on the effects of clusters on firms' productivity and innovation.

Different bodies of literature have focused on the study of clusters; approaches have included those taken from industrial economics, economic sociology, economic geography and evolutionary economics. However, there are at least two main issues that these bodies of literature have not systematically included in their analysis of clusters: the agency of the entrepreneurs; and the importance of social structures formed by personal and business relations in the support of clusters. Bringing together literature from different areas on clusters and including literature on entrepreneurship and multiple social networks can generate new insights into the study of cluster emergence.

This thesis aims to contribute to the existing literature by studying personal and business relations within a high-tech cluster in its initial stages. Thus, the purpose of this thesis is to provide evidence of the role of personal and business relations in the formation of a high-tech cluster in the context of an emerging country.

This chapter will present a short overview of the relevant literature for the subject of this thesis. As mentioned in the previous chapter, the analytical chapters are formatted as journal articles. Therefore, each chapter has a literature review section focused on the subject analysed in the chapter. In Section 2, I will briefly introduce the main bodies of literature on clusters. Later, in Section 3, I develop the main argument to be studied in this thesis. Finally, Section 4 summarises the chapter.

2.2 THEORY REVIEW

The existence of clusters has been studied since the seminal work by Marshall on industrial districts (Marshall, 1920). Mainstream approaches have concentrated on the analysis of the economic advantages and positive externalities of agglomerations and location decisions for firms. Subsequently, the literature included the importance of institutions and tacit common norms in managing common resources emerging from agglomeration (van Dijk and Rabellotti, 2005). Next to these ideas, the role of public policies and the interaction of public and private institutions were captured by the concept of systems of innovations that have been at the core of innovation policies during recent years.

Thus, previous literature on clusters has focused on a systemic view of cluster advantages, yet it has not explained in detail the emergence of clusters and the factors that influence this process. Recent literature on social networks and entrepreneurship has attempted to provide insights into this. Entrepreneurship theory explains how entrepreneurs decide to create a start-up and delivers new insights into how several start-ups can evolve to become a cluster. Social network theory, on the other hand, focuses on the creation of linkages and the dynamics

between firms, and how this process leads to the emergence of a cluster. These could be thought of as 'bottom-up' approaches to the study of cluster formation.

Throughout this thesis, the role and importance of social relations[3] for the emergence of start-ups and the creation of linkages between actors in a cluster will be analysed, combining social network and entrepreneurship literature with the more traditional approaches of the economics of innovation.

Cluster formation has been analysed in different streams of the literature, such as local factors and knowledge spillovers, economic geography and regional economics, evolutionary theory, innovation systems, entrepreneurship and social networks. The following sections discuss cluster formation from different perspectives and disciplines. Across the literature, the importance of social capital, collaborations, networks, institutions and the environment for cluster formation arises repeatedly.

2.2.1 Local actors and Agglomeration Economies

Under location theory, the optimal location of firms is based on the reduction of transport costs and close proximity to suppliers and clients. Some of the costs to consider when choosing a location are tax reductions, input costs and transport costs to and from clients and suppliers. Other considerations are employment and the presence of a skilled labour force. Carlton (1983) evaluates the location decisions of new firms in the USA between 1967 and 1971. He finds that energy costs have an important effect on location decisions, while taxes or state programmes to attract new firms do not seem to have a significant effect on such decisions. Also, the

[3] Social relations are understood in this thesis as any type of relation between actors in a cluster, including personal and business relations.

concentration of employment and skilled labour is important to these decisions, particularly for industries with a small average plant size and high-tech sectors.

Dunning (2001) provides a framework for plant location based on the comparative advantages of firms, the advantages of producing internally versus generating alliances, and the advantages of the region. This framework it is often referred to as the ownership, location and internalisation (OLI) model. This analysis, which is suitable for multinationals, large corporations or group of firms, and multi-plant companies, might not be suitable to explain the location decisions of entrepreneurs and small firms, yet this model has been considered in entrepreneurship and cluster literature (Pitelis, 2012).

The location of firms influences productivity and productivity growth, affecting the competitive advantage of regions (Audretsch, 2015; Porter, 2000). Following work by Porter (1998b), research has focused on the analysis of the competitive advantages of clusters. Within this framework, knowledge spillovers and labour mobility are seen as the main agglomeration forces (Feldman, 2003). A pool of highly skilled workers might also attract new entrepreneurs, firms and other such workers, since it may increase knowledge flows and spillovers (Lawton Smith and Waters, 2011). According to Porter (Porter, 2000), clusters reduce entry barriers to new firms because assets, inputs and staff are already available in the same region. However, as Boschma (Boschma, 2005) suggests, the co-location of companies will not necessarily produce increases in firms' productivity. Whittington et al. (Whittington et al., 2009) conclude, from a study of the industrial life science districts in the USA, that social networks and social structures are the bases for understanding the co-location of firms. As Almeida and Kogut (Almeida

and Kogut, 1999) conclude, 'the flow of knowledge is embedded in regional labour networks' (Almeida and Kogut, 1999).

Proximity might enhance knowledge diffusion, learning, innovation and interaction between organisations. Knowledge spillovers are found to be local and specialised. Innovation and knowledge creation are concentrated in regions where technology and knowledge-based industries are clustered (Audretsch, 2003; Audretsch and Feldman, 2004, 1996; Boschma, 2005). Bell and Albu (1999) analyse the dynamics of knowledge systems in industrial clusters in less developed countries. They propose an evolution of knowledge systems – from a closed and passive system in the diffusion, acquisition and generation of knowledge to a cooperative, active and open system. Yet they wonder if spatial proximity becomes less important with the evolution of the knowledge system within a cluster.

There is an on-going debate about the importance of location for knowledge transfer and collaboration, with the emergence of new communication technologies and the reduction of transport costs. According to Porter (2000), the geographic advantages of the close proximity of firms and institutions in a cluster are not diminished by globalisation and new communication technologies; thus, local proximity is an important feature of a cluster. However, in the empirical research of van Geenhuizen and Reyes-Gonzalez (2007), location in a cluster is not seen as having influenced innovation and growth for young, small, research-intensive firms in a biotechnology cluster in the Netherlands.

In summary, the geographic concentration of firms will not necessarily generate a cluster. As stated earlier in Chapter 1, a cluster involves interconnected firms and institutions in a particular location and field (Porter, 2000, 1998a). Thus, the importance of firm interaction is a key component of a cluster (Porter, 2000). On

a regional level, firms engage in collaborations with local research centres, universities, local labour markets, and clients and suppliers, creating regional innovations networks (Breschi, 2000; Malerba, 2005; Porter, 2000; Saxenian, 1994; Storper and Harrison, 1991). However, more than simple geographical proximity between these actors is required to generate collaboration between them (Boschma, 2005). Thus, other literature, such as social capital and social network theory, is needed to increase our understanding of how collaborations in a cluster emerge.

2.2.2 Economic Geography and Cluster Life Cycle

According to the model of a cluster's life cycle developed by Maggioni (2006), there are benefits and costs to agglomeration; only when the net benefits of agglomeration are positive will there will be enough incentives for new firms to locate in the same geographical area and form a cluster. However, cluster growth and formation depends on more than the resources available in the region and geographical proximity. Institutions and common norms – in particular, linkages between agents – are fundamental to cluster growth. The strength and effectiveness of these relations and their impact on regional economic development depends on social capital and the intangible assets available to firms (Breschi and Malerba, 2005). The environment is central in promoting agglomerations, learning by firms and knowledge transfer. Governments can play a major role in changing the business environment through policies to promote cluster formation. Science and technology policies, research capacity and institutional context are important for increasing firm agglomeration (Altenburg and Meyer-Stamer, 1999; Breschi, 2000; Breschi and Malerba, 2005; Malerba, 2005; Nelson and Winter, 1982; Pietrobelli and Rabellotti, 2004). Nevertheless, as Altenburg and Meyer-Stamer (1999) and Pietrobelli and

Rabellotti (2004) note in the Latin American case, there are different types of cluster with dissimilar origins and dynamics of evolution, requiring different policies to support growth. The emergence and growth of clusters is a path-dependent process (Altenburg and Meyer-Stamer, 1999; Gertler and Vinodrai, 2009), which implies that public policies need to consider the time of the intervention and the life cycle of the cluster in question (Pietrobelli and Rabellotti, 2004).

Closely related to this literature is the innovation system literature (Malerba, 2005; Nelson, 1992). The innovation system approach considers not only companies as part of the innovation process and cluster formation, but also the research institutions, universities, firms and public agencies which settle and shape the environment and institutions that promote clusters. The innovation system concept has led to differentiation by geography and economic sector, and the development of national, regional and 'sectoral' concepts of innovation systems (Breschi and Malerba, 2005). The system view brings a dynamic aspect to the innovation process and stresses the linkages between actors. The innovation process of firms might be slowed if different actors in an innovation system are not well connected. This again demonstrates the importance of network analysis in the process of cluster formation.

For example, Perez-Aleman (Perez-Aleman, 2005) studies the emergence of two clusters based on natural resources in Chile: the tomato processing and salmon industries. These industries have achieved international productivity levels. She concludes that there were three common factors in the formation of these clusters: an initial role played by governmental agencies in the exploration of the conditions and markets; the formation of industrial associations to increase collective cluster action and the quality of production and growth; and finally, the role of foreign

clients as a source of new ideas and technological requirements. Perez-Aleman highlights that 'a central element of the cluster formation process is the emergence of institutions that make LBM [learning-by-monitoring] possible', as well as 'relationships between the state and firms and among firms, which facilitate improvements in products, processes and capabilities' (Perez-Aleman, 2005).

This example shows the importance of interaction and collective action by the cluster's members. As Ostrom (2000) explains, the collective action of self-organised communities is possible if there is collaboration and social norms for monitoring and sanctioning divergences from the collective interest, which reduces the probability of members free riding. These social norms might be easier to establish in a group with similar characteristics, historical relations and interactions in other areas, since previous experiences may build trust.

The analysis of the evolution of clusters has led to the emergence of literature on cluster life cycles, and models of these. Menzel and Fornahl (2009) propose a model of cluster evolution with four stages: emerging, growing, sustaining and declining. They notice that a declining cluster could spark a stage of renewal, introducing new technologies through external linkages within the cluster. They also highlight that an important change in the cluster's movement from the emerging to the growing stage is collective action and institution-building. According to the authors, the emergence of a cluster will be based on the conditions of the region, such as political support, geographical advantage or a scientific base in the region.

For example, Gertler and Vinodrai (2009) analyse the emergence of biotechnology clusters in six cities in Canada. They show that in each city different factors influenced the emergence of the biotechnology cluster. The different

enabling factors are: an anchor or leading firm; important research centres or universities; public policies to promote the establishment of research centres; a pharmaceutical base; and financial venture capital markets. A common regional advantage was the local scientific and research base. Other important factors included the creation of industrial associations or collective initiatives to promote the cluster. The same factors for success are found in the case of the biotechnology cluster in Vienna, which had important backing from different public agencies and policies (Todtling and Trippl, 2009).

Nevertheless, the cluster life cycle literature does not directly address cluster formation. It is not clear how interactions between agents are created in the first stages of a cluster and how these linkages produce collective action.

2.2.3 ENTREPRENEURSHIP AND CLUSTER EMERGENCE

Entrepreneurship theory explains the factors that promote the establishment of new start-ups. The business environment plays an important role in the decision to establish a new company in a particular sector and location (Feldman et al., 2005). This environment is shaped by policies and regional factors (Pietrobelli and Rabellotti, 2004). Policies, institutions and local factors are important for cluster formation, the decision to start a new company and the location of it. Feldman, Francis and Bercovitz (2005) suggest that there are three phases in a cluster's development. First, individual entrepreneurs establish the initial start-ups, which are promoted by external factors, such as a change in policy. The second phase is characterised by the formation of linkages, self-organisation between the start-ups, and the emergence of venture capitalists. In this phase, social connections between the early entrepreneurs and other organisations is very important. The third phase

is the maturation of the cluster with public and private financing, and the deepening of social ties.

This model is consistent with Pitelis's (2012) proposition that clusters emerge because firms and entrepreneurs want to appropriate the value of co-created resources. The location decisions of entrepreneurs could help to develop an entrepreneurial ecosystem that might create a cluster endogenously. Yet location decisions in Pitelis's (2012) model are based on Dunning's OLI model (Dunning, 2001), which does not necessarily hold for small start-ups.

Clusters and firm agglomeration increase the creation of new firms in the same location (Pitelis, 2012; Porter, 2000). However, as Walker et al. (1997) suggest, there is evidence that social capital tends to reproduce network structures over time. They analyse the new relations between start-ups in the US biotechnology sector between 1984 and 1988. The persistence of firms' roles within a network could constrain entrepreneurship and knowledge diffusion within a cluster. As Uzzi (1997, 1996) implies, entrepreneurs and start-ups are embedded in a social structure that affects their economic outcomes. The embeddedness of firms allows them to manage their resources efficiently and to adapt to complex environments. Nevertheless, Uzzi identifies an inverted U of benefits. After a certain level of embeddedness (or over-embeddedness) between firms, there are negative effects – such as increasing collaborations with incumbent firms, reducing the renewal of the technologies used by firms, and limiting sources of external information and knowledge – called 'knowledge lock-in', making firms vulnerable to external shocks. Thus, the negative effects of networks should be borne in mind.

In relation to funding for entrepreneurs, results from Hsu (2007) on the information and communications technologies industry in the USA identifies the

importance of previous ties with venture capitalists to increasing the likelihood of being funded. These results are in line with results from Uzzi (1999), who identifies lower interest rates in credit extended to firms with social ties with their lenders. Therefore, it is possible to identify the importance of social networks for entrepreneurs and establishing a start-up, as well as for choosing a preferred location.

2.2.4 SOCIAL NETWORKS

Previous theories and literature suggest that clusters have network features and that social capital is fundamental to cluster creation. Rutten and Boekema (2007) argue that the capacity of local networks to transform local tangible assets into economic development depends on the network's social capital. Social capital has many definitions. According to Coleman (Coleman, 1990, cited in Durlauf and Fafchamps, 2004, p. 4), social capital constitutes part of social organisations, a set of elements that facilitates the achievement of individual and collective goals. Portes and Sensenbrenner (1993) define social capital with an economic focus as 'those expectations for action within a collectivity that affect the economic goals and goal-seeking behaviour of its members, even if these expectations are not oriented towards the economic sphere' (Portes and Sensenbrenner, 1993, p. 1323). Thus, social capital is important for the creation of groups, and for the relations between a group's members and its collective action, shaping its emergence and development.

As Ter Wal and Boschma state, 'inter-organisational interaction has always played a crucial role in the literature on regional innovation systems and clusters. However, the structure of this interaction has hardly been assessed empirically in

more quantitative terms' (Ter Wal and Boschma, 2009). Boschma and Fornahl (2011) state that future studies should focus on the analysis of firms' network structures and how they affect and interact with one another at cluster and regional levels. The comparative study by Saxenian (1994) of the electronic industries in Silicon Valley and Route 128 in Massachusetts shows that networks and interactions between firms and organisations are crucial for the dynamics and growth of a cluster.

Social Network Analysis (SNA) can explain and reveal important relations between actors in a cluster, and can be used as a complementary methodology to analyse the underlying social structure of a cluster (Reid et al., 2008). Recent articles have used SNA to analyse clusters. Almeida and Kogut (1999) argue that knowledge diffusion in clusters is a reflection of workers' mobility and social networks, which are only partially visible. Casper (2007b) analyses the formation of the biotechnology cluster in San Diego using secondary data on labour mobility. He concludes that social networks facilitate labour mobility, reduce the risks of working in a start-up and support innovation. D'Amore et al. (2010) analyse the biotechnology cluster in Italy using publications data. They find that universities have a central role to play in the cluster, but they also find a low degree of collaboration between firms. Both studies identify that personal relations are important for the dynamics of the cluster. However, strong assumptions are needed about the underlying personal relations when working with secondary data. The observed network is a reflection of other social structures that are not identified in the secondary data. Other studies of networks in the US biotechnology sector show that knowledge networks and information flows usually lie in personal relations and

informal interactions (Owen-Smith and Powell, 2004; Powell et al., 2002, 1996; Whittington et al., 2009).

In emerging countries, less research has been done on clusters using SNA. Felzensztein and co-authors (Felzensztein, 2008; Felzensztein et al., 2010; Felzensztein and Gimmon, 2009) have studied social networks and marketing strategies in the salmon cluster in Chile and Scotland. This literature concludes that elements such as trust and reciprocity are fundamental for marketing cooperation between firms. These studies also find that geographical proximity is not a key element for marketing collaborations; instead, personal relations and informal interactions seem to drive such collaborations between clustered firms. Giuliani and Bell (2005) study the Chilean wine cluster using SNA with data collected using original surveys. They show that knowledge flows are determined by the social structure of the cluster, identifying firms with different roles within the clusters, such as gatekeepers or isolated companies. The study also shows that personal interactions in informal settings between key workers in the wine industry determine knowledge flows. They find that the role of foreign firms in the cluster depends more on 'the duration of the location in the cluster than on their foreignness' (Giuliani and Bell, 2005, p. 62). Thus, the links that a new firm in a cluster is able to develop might depend on previous personal and business linkages, and the time the firm has been established in the same location. Although this work does not analyse the formation or dynamics of the cluster, it could give us an idea of how important social capital is for interaction between firms in a cluster. Over time, trust, reciprocity and social norms are built and strengthened. The analysis of relations between firms is therefore relevant to the study of cluster formation.

2.2.5 FORMATION OF LINKAGES BETWEEN FIRMS

The preceding literature highlights the network structure and the linkages between firms in a cluster, yet there is no explanation of how these linkages are created. The reasons for firms or organisations forming business relations are diverse. Different theoretical perspectives have analysed the formation of collaborations or alliances between companies. In particular, research partnerships have been analysed in-depth, since R&D is fundamental in enhancing firms' innovation (Hagedoorn et al., 2000). Research partnerships are a particular case of a business relationship between organisations; thus, it is possible to draw together literature on research collaborations to discuss the creation of other types of relationship. As Dantas and Bell (2011) indicate, to promote innovation by focusing only on R&D linkages may ignore the important role of other kinds of networks in contributing to firms' growth in terms of internal capabilities and productivity.

According to Hagedoorn et al. (2000), three theoretical perspectives on collaboration between firms can be distinguished: transaction costs; strategic management; and industrial organisation. Transaction costs theory highlights the role of minimising costs, achieving economies of scale or scope, and avoiding opportunistic market behaviour on the part of the potential partner. Industrial organisation theory focuses on the sector in which companies are embedded. The way in which firms compete may affect the probability that they will form collaborations. Firms competing on price reduction or product differentiation, or in a non-tournament setting will cooperate if they have internalised the existence of positive knowledge spillovers. In tournament settings, when firms enter a race to develop a product or technology that might become the main product used in the market, cooperation will not take place unless it is subsidised (Hagedoorn et al.,

2000). In the case of biotechnology, it is easy to assume that firms are in a tournament setting, since the pharmaceutical industry is characterised by 'winner-takes-all' competition (D'Amore et al., 2013; Hernández-Cuevas, 2007; Owen-Smith and Powell, 2004). This would imply that collaborations between competitors would not emerge. Yet collaborations might be formed between firms and research institutions in order to reduce research costs (D'Amore et al., 2013, 2010; Hagedoorn et al., 2000).

The strategic management literature emphasises different reasons for the formation of collaborations. For instance, strategic behaviour of firms might drive collaborations to deter entry of new competitors, accumulate resources, as well as to change the positioning of a firm in a network. Research and innovation partnerships can be explained by the desire to complement capabilities, pool resources, reduce or share costs, diversify sources of investment, and transfer knowledge and technologies (Hagedoorn et al., 2000; Vonortas and Okamura, 2009).

Within this conceptualisation of the reasons for creating a relationship between organisations, the characteristics of the partner are important, and not just the observed features of the partner, such as if it has complementary resources or if it is a direct competitor. Imagine an investor or a company choosing between two possible partners for a project, both of whom have similar observed features. If there were no market failures and complete contracts, the investor would be indifferent as to which is chosen. However, since there are incomplete contracts and market failures, such as asymmetries of information, the investor needs other factors in order to decide (Audretsch and Feldman, 2003). Ultimately, the investor would decide to collaborate with the firm that has a greater chance of fulfilling the conditions of the agreement. This decision might be based on trust. This is precisely

what Uzzi (1999) argues, concluding that business relations are embedded in the social attachments of a firm, affecting the interest rate obtained on financial credit by firms. As Owen-Smith and Powell (2004) conclude in their study of the Boston biotechnology sector, 'formal partnerships between organisations represent the outcroppings of informal social relationships in a community' (Owen-Smith and Powell, 2004, p. 17). Personal relations build that trust because they give extra information to each partner which is not usually observable.

This review highlights the importance of studying personal and business relations between organisations in a cluster to understand the role of social interactions in their emergence.

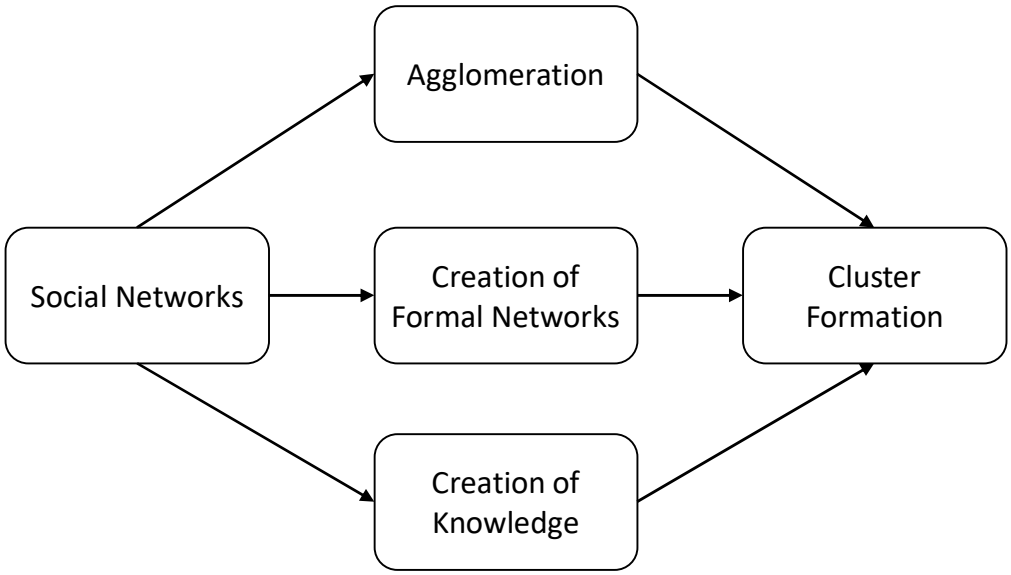
2.3 ANALYTICAL FRAMEWORK AND HYPOTHESES

The overview of the literature presented in Section 2 shows that, in each body of literature, social capital and social networks affect clusters. Therefore, social networks – understood as any type of network: personal, business, commercial, R&D, formal, informal, etc. – can affect and determine the emergence of clusters. However, this relationship has not been studied in sufficient detail in the literature due to data limitations and the focus in previous research on the effects of clusters on firms and the later stages of cluster development and growth.

It is also clear from the previous summary of the literature that the research has focused on clusters in industrialised countries. Research on other contexts, such as emerging economies, has focused on sectors related to natural resources. Despite the interest in promoting cluster emergence and technological upgrading from governments in less industrialised countries, high-tech sectors in emerging countries have been neglected in the research on clusters.

Therefore, the purpose of this thesis is to provide evidence of the role of personal and business relations in the formation of a high-tech cluster in the context of an emerging country. There are three main aspects of cluster formation that will be studied: agglomeration, the creation of networks, and the creation of knowledge (Figure 2.1). All of them contribute to the argument that social networks affect and determine the emergence of clusters.

Figure 2.1 Aspects of Cluster Formation Analysed



Firm creation and spin-offs in a cluster might be determined by social networks, supportive organisations and the entrepreneurial environment of the region (Fornahl et al., 2010; Menzel and Fornahl, 2009). Consequently, social networks affect the creation and location decisions of entrepreneurs. This might lead to co-location among firms, developing agglomerations in a sector, generating agglomeration economies and leading to higher rates of co-location and cluster emergence. Social capital and the networks created between firms and institutions in the earlier phases of a cluster are crucial to its development (Bercovitz and

Feldman, 2008; Feldman et al., 2005; Pitelis, 2012). The relationship between personal and business networks and the location decisions of start-ups has not been studied extensively. The general hypotheses that emerges from this are:

> *Hypothesis 1a: Entrepreneurs' social networks will reduce the transaction costs and the costs to access resources to establish a company. Therefore, it is more likely that a firm will be located where entrepreneurs' social networks minimise the costs to access required resources or, equivalently, where entrepreneurs maximise access to resources.*
>
> *Hypothesis 1b: The entrepreneurs' social networks will shape and determine opportunity recognition identified by entrepreneurs. Therefore, it is more likely that a firm will be located where the entrepreneurs' social networks facilitate the identification of a profitable opportunity.*

However, an agglomeration of firms does not necessarily constitute a cluster. The interactions and connections between firms and other relevant actors in a certain location and field is central to the cluster concept (Porter, 1998a). These interactions will determine the social structure that firms are part of (Uzzi, 1997). But, equivalently, the social structure underlying a cluster will shape the connections and collaborations between actors (Owen-Smith and Powell, 2004).

Personal connections can generate trust between actors, helping to create collaborations between firms (Audretsch and Feldman, 2003; Owen-Smith and Powell, 2004; Uzzi, 1999). The creation of linkages between companies may be largely based on trust and previous personal relations. So, personal networks can generate business networks in a cluster, meaning that personal networks will determine the collaborative pattern of a cluster and its future. The business network

of firms may be embedded in the personal network of a cluster, leading to the second hypothesis:

> *Hypothesis 2: DBFs are more likely to create business relations with other institutions with whom they have a previous personal relation.*

Finally, in a high-tech sector, the creation of new knowledge is crucial for the development of the sector and a cluster. High-tech firms geographically far from the countries closer to the technological frontier could develop knowledge new to the world. Innovation is a path-dependent process and breakthrough innovations are concentrated in a few developed countries (Keller, 2004). Therefore, international collaborations are essential to transferring knowledge to emerging countries. Uzzi (1997, 1996) also shows that clusters can usually be over-embedded in network structures, leading to a lock-in of knowledge and technologies; as a result, external linkages become relevant in the process of generating new knowledge (Boschma, 2005).

In addition, different collaboration processes are simultaneously found in clusters and lead to a multiplicity of networks. The types of partner and relation could play different and important roles in knowledge creation and diffusion. Giuliani (2013a, 2013b, 2005) argues that tacit knowledge diffuses through personal relations between workers in different companies, while formal connections between firms are the channel through which formal knowledge is diffused. As a result, intra and extra-cluster connections will have an impact on the knowledge generated in a cluster, determining its growth and development. Given this, the third and last set of hypotheses to test is:

Hypothesis 3a: Extra-cluster links, measured as international links, are likely to be positively related to the knowledge creation of firms in the Chilean biotechnology sector.

Hypothesis 3b: National links are likely to be positively related to the knowledge creation of firms in the Chilean biotechnology sector, but their magnitude or effects are likely to be lower than the effects of international links, given the importance of external sources of knowledge.

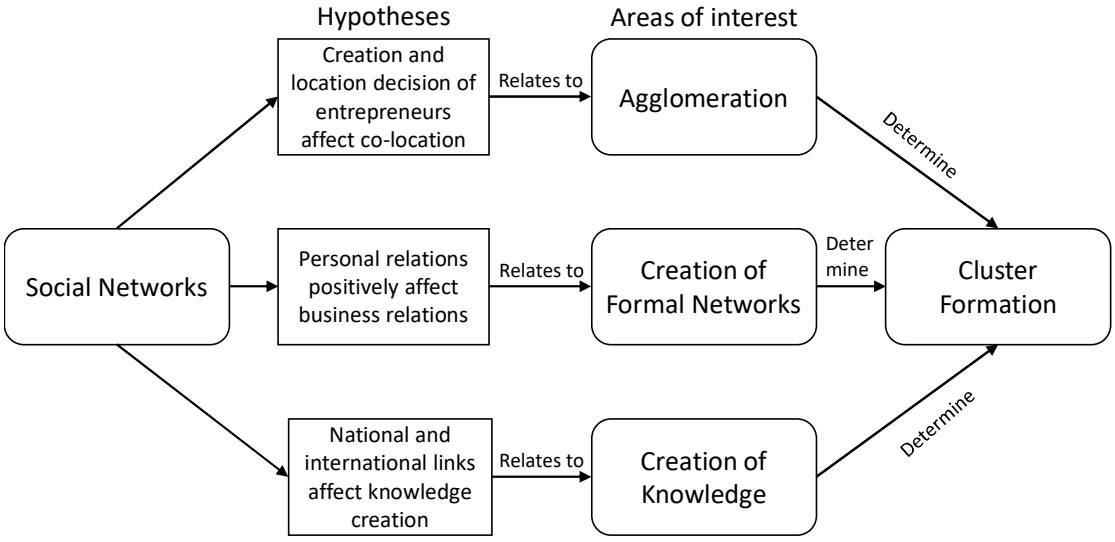
Hypothesis 3c: Links with partners that are R&D-oriented are significant and positively related to the knowledge creation of firms in the Chilean biotechnology sector.

Hypothesis 3d: Personal links are likely to be positively related to the knowledge creation of firms in the Chilean biotechnology sector.

Hypothesis 3e: International links with partners that are R&D-oriented are likely to be positively related to the knowledge creation of firms in the Chilean biotechnology sector and their relevance or marginal effect is likely to be higher than the effect of any other type of link.

Each set of hypotheses will be tested using different methodologies; however, all of them contribute to answering the main question in this thesis. These arguments and hypotheses can be summarised in Figure 2.2.

Figure 2.2 Diagram of the Hypotheses in the Thesis



Methodologically, most of the research on clusters and cluster emergence have mainly used case studies, SNA methods and econometric analysis. This study will also use these methods to provide evidence regarding the arguments and hypotheses presented above. Most past studies have used secondary data, such as patents or journal articles, to analyse networks in clusters. Data on patents and journal articles is reduced in emerging economies, but this does not necessarily imply that there are fewer connections among clustered firms in emerging than in industrialised economies. Only a few studies have collected primary data on networks in clusters in an emerging economy (Felzensztein et al., 2010; Giuliani, 2007; Giuliani and Bell, 2005), although these studies have focused on only one type of network. This research will use primary data on multiple networks in a cluster, collected in surveys and interviews, and will contribute to the existing literature on clusters by analysing different networks and the relation between them in the process of cluster formation.

2.4 SUMMARY

This chapter has reviewed the published literature related to the emergence of clusters. In all these scholarly works, social capital and social connections are related to the growth of clusters and to the benefits of clustering at the firm level. However, there is still a gap in the literature regarding the emergence of clusters, and the type of clustering studied.

This thesis brings together different bodies of literature to study the role of personal and business relations in a high-tech cluster formation in the context of an emerging country. The main hypothesis of this thesis is that social networks (personal and business networks) affect and determine the emergence of clusters. This hypothesis is desegregated into three aspects of cluster formation: agglomeration; the creation of networks; and the creation of knowledge. I use the social network framework to collect primary data on personal and business networks in the biotechnology sector in four regions of Chile. The methodological approach contributes to the literature by analysing multiple networks and their interactions in the process of the emergence of clusters. The following chapter details the methodologies used in the collection and analysis of the data used in this thesis.

3 METHODOLOGY FOR DATA COLLECTION AND DATA ANALYSIS

3.1 INTRODUCTION

In analysing the different stages of a cluster, from the creation of the first firms to the collaborative aspects of a mature cluster (Feldman et al., 2005), a single methodology would not provide a deep understanding of the different phenomena that take place simultaneously in this process. The dynamic nature of the processes requires mixed methodologies to study them. To analyse and study cluster formation, we should study not only how its features emerge but also the changing interactions between the agents involved.

The research in this thesis was carried out through the analysis of a case, an appropriate methodology to adopt given the nature of the research questions. The case study selected is the biotechnology sector in Chile, for the following two reasons. First, Chile is an interesting country for studying the emergence of clusters, since is an emerging economy that has had innovation-oriented policies for a decade, which may have promoted the emergence of clusters. Secondly, the biotechnology sector in Chile presents an interesting case since the emergence of high-tech sectors in countries with no apparent international comparative advantages for the development of such sectors has not been deeply studied in the literature on clusters. It is important to study the economic and social conditions that are necessary to establish new firms and create high-tech clusters in order to inform public policies relative to cluster promotion. In particular, studying a

knowledge-based sector in an emerging economy is significant for economic development policies and diversification of the production matrix.

Within the biotechnology sector in Chile, four regions in different geographical zones in the country were selected as emerging clusters. The main argument for considering these four regions is to acknowledge potential differences in the innovation and entrepreneurial ecosystems in the country. Also, 90% of DBFs in the country are located in these regions.

In this study, mixed methods are used for the collection and analysis of the data. A mixed-method approach is preferable since it complements, expands and corroborates the results from the different methodologies (Dominguez and Hollstein, 2014). According to Bamberger (2000), one of the benefits of mixing qualitative and quantitative methods is the possibility of contextualising quantitative results. Furthermore, one can use triangulation procedures to check certain results for consistency, improving their validity.

Quantitative data was collected from a survey and combined with data from secondary sources such as the Web of Knowledge (for publication records) and the World Intellectual Property Organization (for patent records). Qualitative data was gathered by in-depth interviews with the owners or managers of firms. The analysis of the information follows a sequential approach. First, descriptive statistics are used to describe the cluster in Chapter 4. Then content analysis of qualitative data from the in-depth interviews is presented in Chapter 5. This analysis shows the perceived importance of personal and business relations in the emergence of firms in the sector. In Chapter 6, a multilevel estimation of the data is used to determine the relative importance of personal relations, considering other control variables or monitoring for alternative factors, in the creation of business relations between

firms in the sector. Finally, an econometric analysis is conducted in Chapter 7 to identify the importance of connections in the creation of knowledge by firms in the cluster. A deeper description of the methodologies used in this study is presented in Section 5 of this chapter.

The following sections describe the selection criteria for the case study, the methodology used in the survey and interviews, and the representativeness of the data collected. In Section 5, a description of the methods used to analyse the data is presented. Limitations of the methodologies used are discussed in Section 6. Section 7 summarises the chapter.

3.2 SELECTION OF THE CASE STUDY

The research focuses on the formation of the biotechnological cluster in Chile. Chilean economic policies have been regarded as a success in Latin America. The country grew rapidly during the 1980s and at the beginning of the 1990s, due to the increase in the productivity of economic sectors, such as wine, fruits, salmon aquaculture, pulp and copper mining, which together accounted for around 67% of Chilean exports in 2015.[4] These industries are based on the exploitation of natural resources and have reached productivity levels similar to those of firms in developed countries (Bitran Colodro and Gonzalez Urrutia, 2010). However, since the end of the 1990s there has been stagnation in growth and productivity. This has led to the establishment of policies to increase productivity and the competitiveness of Chilean products by promoting the creation and growth of clusters in non-traditional economic sectors (Comisión Asesora Presidencial, 2013).

[4] Report of the Ministry of International Relations for 2015. Available at: https://www.direcon.gob.cl/wp-content/uploads/2016/02/reporte-trimestral-ene-dic2015.pdf

In this context, an emerging country aiming to diversify exports, it is particularly interesting to study the formation and development of a cluster that is not based on natural resources. The biotechnology cluster is a knowledge-based sector in which spatial location is of less importance than in sectors based on the exploitation of natural resources. The analysis of social networks in this cluster will not only help to clarify the importance of social capital to the formation of knowledge-based clusters, but also to develop policy recommendations.

There were two main criteria considered in the selection of the cluster. First, there is a time limit on carrying out the fieldwork. To gather information from every firm in the sector in a time-limited fieldwork period, the sector should have a small number of actors. Secondly, the history of the cluster must be easily traceable, implying that the cluster cannot have existed for many decades. This will facilitate tracing the history of the firms that are currently part of the cluster and make it possible to find entrepreneurs from earlier stages.

Government documents, university working papers, research articles and newspaper records were analysed for the selection of the cluster, given the criteria stated. Informal interviews with workers in government agencies involved in cluster-promotion policies were conducted to identify potential clusters matching the selection criteria. A summary of the biotechnological areas and actors across Chile, from governmental records available in March 2013, is presented in Table 3.1.

Table 3.1 Areas of Biotechnology in Chile Distributed by Geographic Region

Region of Chile North to South	Health	Food and nutrition	Aquaculture	Agriculture	Arid Zones	Patents, publications	Genetics	Classic fermentations	Bioinformatics	Total
Arica y Parinacota				2 UC 9 F	2 UC					2 UC 9 F
Tarapacá	1 RI. 1 F		1 RI	1 RI				1 F		1 RI 1 F
Antofagasta			1 UC 1 F	1 UC 1 F 1 TC	1 UC 1 F			1 UC 1 F		2 UC 1 F 1 TC
Atacama										None
Coquimbo		1 RI 1 TC	2 UC 1 RI 1 TC	2 RI	1 RI	1 RI	1 RI			2 UC 2 RI 1 TC
Valparaiso	3 UC 2 F 1 C	3 UC 1 RI 1 TC 2 F	4 UC 2 RI	7 UC 2 RI 1 TC 3 F	2 UC	1 UC 1 TC 2 F	1 F	2 UC 1 TC	2 UC	12 UC 2 RI 1 TC 5 F 1 C
Metropolitana	12 UC 1 RI 2 TC 28 F 1 TA 2 C	5 UC 1 RI 3 TC 15 F 2 TA	3 UC 1 RI 2 TC 10 F 1 TA	10 UC 3 RI 1 TC 26 F 3 TA 2 C	1 RI 2 F 1 TA	6 UC 1 RI 9 F 2 TA 1 C	3 UC 1 RI 3 F 2 TA	6 UC 10 F 1 TA	6 UC 2 RI 2 F 1 TA	26 UC 3 RI 6 TC 66 F 3 TA 3 C
O'Higgins				1 RI						1 RI
Maule	2 UC	1 UC		5 UC 1 RI 1 F		1 UC		1 UC	2 UC	6 UC 1 RI 1 F
Bío-Bío	9 UC	3 UC 1 RI	4 UC 2 F	12 UC 2 RI 5 F 3 C	1 UC 1 RI		2 UC	5 UC 1 F	1 UC	17 UC 2 RI 6 F 3 C
Araucania	2 UC 1 F	1 UC 1 RI	2 UC 1 TC	5 UC 1 RI 1 TC 2 F				1 UC		6 UC 1 RI 1 TC 2 F
Los Rios	1 UC 1 RI			4 UC			1 RI	1 UC		5 UC 1 RI
Los Lagos		1 TC	3 UC 1 RI 3 TC 4 F 1 C	5 UC 1 RI 1 F		1 RI	1 UC	1 UC		6 UC 2 RI 3 TC 4 F 1 C
Aisen				1 RI						1 RI
Magallanes				1 RI						1 RI
Total	29 UC 3 RI 2 TC 32 F 1 TA 3 C	13 UC 5 RI 6 TC 17 F 2 TA	18 UC 5 RI 7 TC 17 F 1 TA 1 C	51 UC 16 RI 4 TC 48 F 3 TA, 5 C	6 UC 3 RI 3 F 1 TA	8 UC 3 RI, 1 TC 11 F 2 TA 1 C	6 UC 3 RI 4 F 2 TA	18 UC 1 TC 13 F 1 TA	11 UC 2 RI 2 F 1 TA	

Source: Based on data from InvestChile Corfo (www.investchile.com), This is Chile (www.thisischile.cl)

Notes: UC = University Centre; RI = Research Institute; TC = Technology Centre; F = Firms or Private Companies; TA = Trade Association; C = Consortium. Aggregate data for private and public institutions and also aggregate data for national and international companies

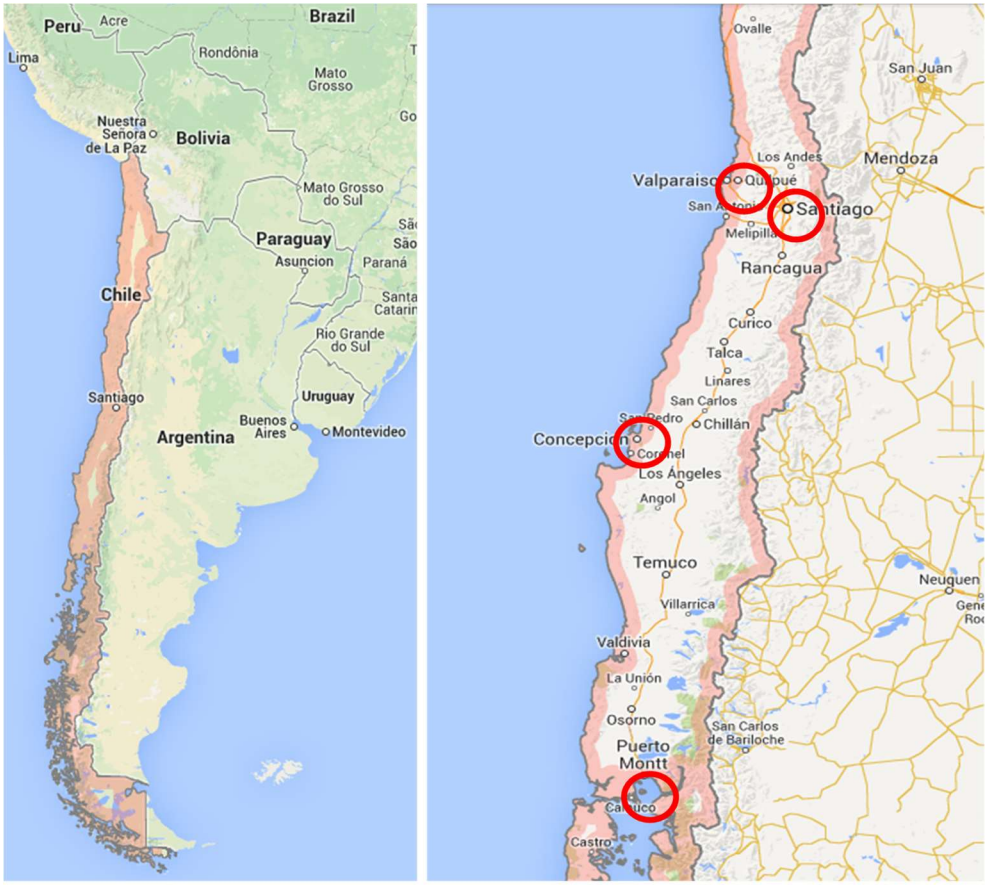
In Table 3.1 a geographic distribution of the population of firms and other actors in the Chilean biotech sector is presented. The Metropolitana region has the largest concentration of firms and different types of actors present in the cluster. In addition, the biotechnology areas with larger numbers of actors are agriculture, health, aquaculture, food and nutrition, and classic fermentation and bioprocesses. If we concentrate on the different types of firms associated with biotech, as shown in Table 3.2, it is possible to observe the same concentration pattern in the country.

Given the concentration of private firms and actors in a relatively small number of regions, the face-to-face research was focused on four regions: Metropolitana, Valparaíso, Bío-Bío and Los Lagos. A map showing the geographical location of the regions where fieldwork was conducted is presented in Figure 3.1. The rest of the firms in the country were contacted by email and telephone.

Case study-based research has advantages for studying cluster formation. A case study offers the possibility of presenting a holistic analysis and revealing dynamic research links and their evolution (Yin, 2003), which will be useful in understanding how the clusters started and the different type of relations present in the clusters, one of the aims of the research.

Yin (2003) proposes that the qualitative data of a case study can be collected in several ways, via documents or archive records, interviews, direct observation and participatory observation. Gathering data on the case study from different sources allows for a triangulation of the information, making the analysis more robust (Hollstein, 2014). The data for this research uses a mixed-methods approach combining data from a survey (quantitative), interviews (qualitative) and secondary sources (qualitative and quantitative). Detailed methodological aspects for the survey and interviews conducted are presented in the next section.

Figure 3.1 Map of Chile and the Locations of the Biotechnology Clusters Studied



Note: Source Google Maps. Circled areas are a general representation of the location of fieldwork.

Table 3.2 Regional Distribution of Firms Related to Biotechnology in Chile

Region (North to South)	Dedicated Biotech Firms	Lab Services using Biotech	Research Services using Biotech	Consortia	Firms using Biotech Processes	Pharma-ceuticals	Commercial Rep. of Int. Firms	Services to Biotech Firms	**Total**
Arica y Parinacota	1	0	0	0	0	0	0	0	**1**
Tarapacá	3	0	0	0	0	0	0	0	**3**
Antofagasta	2	0	1	0	0	0	0	1	**4**
Atacama	0	0	0	0	1	0	0	0	**1**
Coquimbo	1	0	0	0	1	0	0	0	**2**
Valparaíso	3	1	2	1	5	1	0	1	**14**
Metropolitana	42	13	5	7	29	11	6	28	**141**
Maule	2	0	0	0	2	0	0	0	**4**
Biobío	4	0	1	2	2	0	0	2	**11**
Araucanía	1	0	0	0	2	0	0	0	**3**
Los Ríos	1	0	0	1	2	0	0	0	**4**
Los Lagos	2	4	1	0	5	0	0	0	**12**
Magallanes	0	0	0	0	1	0	0	0	**1**
Total	**62**	**18**	**10**	**11**	**50**	**12**	**6**	**32**	**201**

Note: Data at firm level. Firms part of a Corporation or group of firms are considered as different firms for the elaboration of this table.

3.3 DATA COLLECTION

During the study, I conducted a survey as well as in-depth interviews. Additionally, I gathered information about patents and journal publications in the sector from secondary sources. Overall, the data collection process seeks to obtain information on three main areas: the process of the creation of firms, the networks and relations between actors in the clusters; the features of the firms in the cluster; and the knowledge created in the sector. The data on the process of firm creation was collected through in-depth interviews, while the data on the relations between firms and their features was gathered by a survey conducted for this study. Information about patents and publications was extracted from databases in World Intellectual Property Organization and Web of Knowledge respectively. Methodological considerations concerning the conducting of the interviews, the survey, and the retrieval of data from secondary sources are described in this section.

3.3.1 THE SURVEY

When conducting a survey, several factors should be considered. The most important relate to the sampling methods, the methodology for conducting the survey, access to the interviewees and the questionnaire (Krosnick, 1999). In addition, it is important to note that gathering relational data on a network, or a cluster in this case, presents significant differences in comparison to a traditional survey. These differences and the methodology used in the survey will be explained below.

NETWORK DATA

One of the main features of social network methods is that they assume complete information on the network, i.e. that information on the relations for every actor and

pair of actors (dyads) is available (Marsden, 1990; Wasserman and Faust, 1994). Also, they require a previous conceptualisation and definition of the linkages and relations among actors (Wasserman and Faust, 1994, pp. 5–7).

There are two main methods for collecting network data: primary and secondary (Ter Wal and Boschma, 2009a). The primary data collection methodology mainly consists of conducting a survey to gather information about actors and their relations. Secondary data refers to data collected without interviewing the actors in a network and is usually gathered by an institution outside the network. Secondary network data has been used in several studies of knowledge networks and knowledge diffusion. Patent data has been used more often, as it has information on researchers and the owners of patents, as well as location (Balconi et al., 2004). Information about patents can be used in sectors that protect their knowledge by patenting (Ter Wal and Boschma, 2009a, pp. 752–753). However, in the case of emerging countries, firms tend to patent less than in developed countries.

Publication records are another source of secondary data (D'Amore et al., 2010). However, only in the cases where firms and research centres in the cluster publish constantly would this be a good measurement of the relation between actors. Information on labour mobility is another source of secondary data, because it is one element of knowledge transfer in a cluster. Casper (2007b) uses public data on the executive managers and key directors of biotechnology companies. However, these types of data are usually non-existent or unavailable for emerging countries, as is the case with Chile. Additionally, when using secondary data, linkages are inferred rather than observed. For example, using data on workers' mobility between firms to infer a relation between two or more companies assumes that the

employee leaving a company will maintain a good relationship with his previous employer and colleagues, which might not be the case.

Primary data is used in this study, which is the third research project to conduct a survey with a network focus on a Chilean cluster. Previously, Giuliani and Bell (2005) researched a wine cluster, and Felzensztein and Gimmon (2009) studied a salmon cluster. During this study, I conducted a survey to collect information on business and personal relations. The survey collects information on relations between firms in the cluster at the time of the survey, which implies that the data is cross-sectional and that it will not be possible to conduct a dynamic analysis.

DIRECTORY OF FIRMS

A cluster will be defined following Porter (1998a), who described a cluster as 'a geographical concentration of interconnected companies and institutions in a particular field' (Porter, 1998a, p. 78). Given this definition of a cluster, not only do biotechnology firms belong to the cluster, but also other firms and institutions that are related to the biotechnology sector, such as venture capital firms, investors, suppliers and clients of biotech firms, and firms that provide services to biotech firms. According to the OECD (2009, p. 10), biotechnology firms are those that use biotechnology techniques in the production of goods or services. DBFs are firms whose main product or service is a biotechnology product.

Information on biotech and related firms was collected using a sequential method. First, a list of all firms related to biotechnology was extracted from governmental records. In particular, two sources of information were key. The Chilean Economic Development Agency (CORFO) had a programme to promote innovative biotechnology projects and surveyed the number of biotech firms in

2007. Also, several official documents regarding biotechnology were released, the last one based on 2010 records. Another source of information is the Foreign Investment Committee of Chile, which together with the Industrial Association of Biotechnology Companies of Chile (ASEMBIO – the Asociación de Empresas de Biotecnología), launched a programme to promote foreign direct investment in biotechnology firms in Chile. In 2013, they compiled a list of firms involved in biotechnology, extracted from a list of publicly funded research projects in the field. All these companies entered the list of firms involved in biotechnology in the country as a starting point. Second, a web search was carried out with two purposes: 1) to identify other biotech firms and related firms; and 2) to confirm that the firms listed in governmental records were still active.

This procedure resulted in a list of 201 firms (see Table 3.2), concentrated again in the four regions in the country selected for this thesis. From this universe, the sample of firms was chosen.

SELECTION OF THE SAMPLE

With regards to the sample methodology, there are three possible alternatives commonly used in SNA (Ter Wal and Boschma, 2009a). The first is to select some actors within the network, randomly or purposively, for example larger or older firms in a cluster. This methodology will then generate *ego*-network data. A major drawback of this selection method is that it will give a partial view of the complete network. How close the results are to the whole network depends on the actors selected for interview. The second alternative is the snowball sampling technique. However, this procedure usually does not include isolated actors in a network and

it is common that networks are unevenly distributed among firms (Giuliani and Bell, 2005).

The third method is the roster-recall methodology, which seems more able to collect complete information about a network. In this case, all the actors in a network are part of the sample. Each actor is asked to list the relation with every other actor in the network (roster) and then to list any other relation with any other actor (recall). The advantages of this procedure are the generation of robust information about the relationship between two actors and the possibility of gathering different information for every relation (Ter Wal and Boschma, 2009a, p. 747). However, there are some drawbacks of this method as well (Ter Wal and Boschma, 2009a, pp. 746–748). First, it requires a high response rate, otherwise the information will be insufficient to generate a good understanding of a network. Another pitfall is that it is a time-consuming methodology, since it involves conducting face-to-face interviews. The implication of these issues on this study is that a small cluster must be chosen. A third problem is the type of questions that are asked to identify the relations between actors (Marsden, 1990; Ter Wal and Boschma, 2009a). In the cases of big firms, the results will depend on the respondent and the number of years that the respondent has been in the company. This issue must be taken into account here when attempting to interview owners, executive managers or directors who have knowledge about the formation of the company. Finally, this procedure gathers information about a specific time-frame of a network, not the dynamics of it. Nevertheless, the dynamics of a network are extremely important in studying cluster formation, which is a dynamic process. This reinforces the necessity of conducting personal interviews to capture the history and evolution of firms, and to reconstruct the formation of the cluster.

In this study, the selected sample were all private firms in the biotechnology sector in Chile; therefore, the study aimed to be a census of the biotech sector. However, if not all the firms in the sector are surveyed, there will be issues around the representativeness of the information, which will be discussed in the next section.

Given that the number of firms related to biotechnology identified in the analysis of Chilean governmental information was about 200, it was unfeasible to use the roster-recall methodology for collecting relational data. Therefore, the methodology chosen to gather information on the relations of the firms interviewed was a free recollection method. The interviewee was asked to freely recall all the connections of the firm and all her or his personal connections in the biotechnology context. This recollection method has also disadvantages, which will be discussed further in the chapter.

COLLECTION OF INFORMATION

It is usually the case that online or mailed surveys have lower response rates (Krosnick, 1999, p. 538). One's confidence in the accuracy of the answers given in an online questionnaire may be lower than for face-to-face interviews. However, when the interviewee has a high level of education, it may be that the information collected online has a higher level of accuracy. In this survey, the questionnaire was answered in several ways depending on the preference of the interviewee and the location of the company. Three different collection methods were used: in person; by telephone or video call; by email.

The survey was conducted in two waves. The first wave was between June and September 2011. In that instance, only biomedicine firms in the Metropolitana

region were contacted. This survey was part of a previous study[5] and was useful as a pilot. The second wave of the survey was done between April and July 2013. In this wave, the sample included all biotech firms in the country from all regions and biotech areas, but face-to-face interviews were conducted only in the four regions were most biotech companies are located, i.e. Metropolitana, Valparaíso, Bío-Bío and Los Lagos.

The first contact with the firms in the sample was made by sending a personalised email to the potential interviewee – the CEO or manager of the firm – with information about the research project, asking for a face-to-face meeting in the case of firms located in the four regions mentioned before. For firms located outside these regions, a video-conference or telephone meeting was suggested. A telephone call was made if there was no response to the first email. All meetings were confirmed by telephone. If it was not possible to arrange a meeting, the offer was made to send the questionnaire by email to be completed by the interviewee. This last resource was also used in the event that parts of the questionnaire were not completed during the interview. Reminder emails and telephone calls were carried out if the questionnaire was not completed; however, there were still incomplete questionnaires at the end of the fieldwork.

Despite all the efforts to obtain a positive response to the survey request, it was possible to engage only a limited number of firms (see representativeness of the study in Section 3.4). To increase the number of surveyed firms two research assistants, with experience sending surveys to firms, were hired to help in the

[5] See 'The role of social networks in the formation of clusters: a study of the biotechnology sector in Chile' by Carmen Contreras-Romero, thesis (MPhil in Development Studies), University of Oxford, 2012.

Metropolitana region. The assistants were recently graduated sociologists who had worked as pollsters during their undergraduate studies. A training session, which lasted three hours, was done personally with each assistant before the start of the project. The usual checks for the consistency of the answered questionnaire, confirmation that the interview had taken place, and checks on the information in the questionnaire were systematically applied to the surveys carried out by the research assistants, and no significant errors were found.

RESPONDENTS

As established above, the survey should ideally be answered by owners or executive managers of the companies sampled – the directors of research consortia (groups of firms), R&D managers from big companies such as pharmaceuticals, managers of firms providing services to biotechnology, firms including venture capital firms, and the director of the trade association, which is part of the biotechnology sector in the country. The survey was actually answered by owners or executive managers of biotechnology firms, the owners or directors of research centres, the investment directors in venture capital firms and research managers in pharmaceutical companies and other big companies. The results might show a potential self-selection bias, since respondents could choose whether to participate in the study or not.

THE QUESTIONNAIRE

In network analysis, it is important that the study defines a 'relation', whether social and commercial, between actors (Ter Wal and Boschma, 2009a). In this study, a personal relation is defined as any individual relation that owners or directors in a company have with other owners or directors of any other company in the cluster.

In this case, for example, they could be former university or school classmates, or members of the same religious community, or there could be family connections. A business relation is defined as a formal agreement between companies or actors to realise any activity such as research, investment, the provision of a service, sale or purchase, export or import, or cooperation in the firm association, among others.

The questionnaire has five sections. The first gathers general information about the organisation, such as sales, number of employees and level of exports, among others. There is a section in this part of the questionnaire that asks DBFs and research-based firms about the origins of the company and the determinants of location. Section two in the questionnaire gathers information about the owners and CEOs of firms. Section three collects information on obstacles faced when the company was established as well as difficulties experienced in terms of the growth of the company today. The fourth section identifies the business relations, while section five seeks to identify personal relations between the actors. In both cases the free recall methodology is used to identify any business and personal relations. The last section asks three open questions about the importance of social relations (considered as all type of relations) in starting a company in Chile and especially in the biotechnology sector. The questionnaire is presented in Appendix 1.

3.3.2 INTERVIEWS

In addition to the survey, I also conducted in-depth interviews to gather information on the history of the sector and the perceived importance of social relations (personal and business relations) in the creation process of biotechnology firms. Through this mixed methodology, I gathered information on the relation between context and firms in the clusters analysed (Yin, 2003). The main objective of the

interviews was to establish the history of the firms and, through this process, to reconstruct the history of the clusters in the different regions. Interviews were semi-structured, which means that some questions and topics were predefined but were flexible depending on the interaction during the interview (Wengraf, 2001). This approach facilitates the exploration of subjects that could be more important for a particular company.

The selection of interviews was done to ensure that there were interviews with firms focused in different biotech areas, and across all the regions. There were also other important actors interviewed, such as directors of universities' research centres and other institutions such as ASEMBIO. In addition, I included other important actors and experts who were not previously considered or were not part of the cluster analysed if interviewees mentioned them as relevant to the emergence of the biotechnology sector in the country or the regions.

These are considered 'elite interviews' as interviewees are in a position of power compared to the researcher (Desmond, 2004). As the lead researcher in this study, I conducted all the in-depth interviews personally. In the case of the interviewees with whom I conducted the surveys and the interviews, the in-depth interview was done first. To conduct the interview first was more logical, since it started by discussing the history of the organisation. Additionally, the interview generated more trust between the interviewee and the researcher. This trust was crucial to obtaining honest answers for the survey, particularly in relation to the personal relations of the interviewee.

The topics covered in the interview were: the history of the company and the sector; the decision on the company's location; and the importance of the owners' relations to those processes. Additionally, the interview addressed general issues

such as: perceived labour mobility in the sector; new attitudes towards entrepreneurship in the scientific community; and the role of governmental agencies in the promotion of networks in the sector. Structured questions asked in the interviews are presented in Appendix 2.

3.3.3 Information and Data from Secondary Sources

Additional information was collected about the sector from different sources. Information about the number of firms, universities and the areas of biotechnology present in Chile was collected from official governmental documents, mainly from CORFO and the Foreign Investment Committee of Chile. Other information about the sector was collected from news sites on the internet. This information was mainly about new products being developed and new firms created or scientific news concerning the main actors in the biotechnology sector in Chile.

In addition, information about patents and the number of journal articles published by biotech firms was collected online. Information about patent applications was gathered using the online search tool of the National Institute of Intellectual Property for national patents, and from the online database of the World Intellectual Property Organization for patents filled in other parts of the world. The collection of the number of journal articles was done using the database of the Web of Knowledge, including Thompson ISI journals and also journals in the database Scielo, which includes journals that are important for emerging economies although not ranked in the ISI index.

Finally, information about the location of companies was retrieved online during the web search for companies in the cluster. This was also done for all the firms named as national contacts; however, not all contacts were found. The

attrition in the number of firms could be due to several reasons, for example, if the firm does not have a web page, if it has closed, or if its name was misspelled or miswritten during the survey. All directions were then inputted into Google Earth GPS to obtain latitude and longitude coordinates for each firm. This information was used to create a variable of distance between actors in the Chilean biotechnology sector.

3.3.4 ETHICAL CONSIDERATIONS

As mentioned above, interviewees were contacted beforehand by email and telephone to agree on a date and time to conduct the interview and survey. Every person that agreed to the interview and the survey was given a confidentiality agreement signed by the lead researcher before the interviews. The confidentiality agreement stated the objective of the research project and that the information collected about the firms would be used only for research purposes and would not identify individual firms. Only information from secondary sources, such as government documents or news reports, which identify firms by name was used to describe the sector and analyse the different regions. In this case, the names of the important actors and firms were included since they were already public. In addition, the research assistants who helped with the collection of information were asked to sign a non-disclosure agreement together with their contract. The non-disclosure agreement specifically stated that the assistants could not use, for any purpose, the information given to them as part of this research project, including the information provided by the firms and the directory.

3.4 DATA REPRESENTATIVENESS

As mentioned in the previous section, the sample of the study was based on a list of firms in the biotechnology sector from different governmental sources. The list was updated through the fieldwork process, which consisted of verifying the information from different sources. First, company details were confirmed by a web search. Some firms contacted explicitly stated that they did not have connections to the biotechnology sector or used biotechnology techniques in their production process; these firms were excluded from the list. These processes resulted in a new distribution of important organisations to be included as part of the biotechnology sector in Chile (see Table 3.3).

The rate of response for the survey is 43% overall (Table 3.3). However, higher rates of response are found for firms that are based on research, such as DBFs (50%), laboratories (56%) and research services (80%), which will be considered as the centre of the sector. The lowest response rate (18%) is for firms that use biotechnology technologies in their production and that might be clients of DBFs.

The last section of Table 3.3 shows the column percentage of firms, presenting the distribution of the surveyed firms compared with the total distribution of firms. Therefore, the distribution of surveyed firms over-represents DBFs, laboratories and research firms, but under-represents bigger firms using biotechnology products and technologies within their production processes. This distribution of surveyed firms does not pose a problem for my research or for the comparability to other studies of biotechnology clusters, since most studies of biotechnology clusters in industrialised countries focus only on DBFs (e.g. Casper, 2007; Feldman, 2005).

Therefore, the data appropriately represents the main core of the biotechnology sector in Chile.

Table 3.3 Distribution of Organisations and Rates of Response

	Surveyed		
Type of Firm	**No**	**Yes**	**Total**
	Frequency		
Dedicated Biotech Firm	31	31	62
Lab Services using Biotech	8	10	18
Research Services using Biotech	2	8	10
Consortium	5	6	11
Firms using Biotech processes	41	9	50
Pharmaceuticals	5	7	12
Commercial Representative	3	3	6
Services to Biotech Firms	19	13	32
Total	114	87	201
	Row Percentage		
Dedicated Biotech Firm	50.0%	50.0%	100.0%
Lab Services using Biotech	44.4%	55.6%	100.0%
Research Services using Biotech	20.0%	80.0%	100.0%
Consortium	45.5%	54.5%	100.0%
Firms using Biotech processes	82.0%	18.0%	100.0%
Pharmaceuticals	41.7%	58.3%	100.0%
Commercial Representative	50.0%	50.0%	100.0%
Services to Biotech Firms	59.4%	40.6%	100.0%
Total	56.7%	43.3%	100.0%
	Column Percentage		
Dedicated Biotech Firm	27.2%	35.6%	30.8%
Lab Services using Biotech	7.0%	11.5%	9.0%
Research Services using Biotech	1.8%	9.2%	5.0%
Consortium	4.4%	6.9%	5.5%
Firms using Biotech processes	36.0%	10.3%	24.9%
Pharmaceuticals	4.4%	8.0%	6.0%
Commercial Representative	2.6%	3.4%	3.0%
Services to Biotech Firms	16.7%	14.9%	15.9%
Total	100.0%	100.0%	100.0%

As mentioned above, some of the surveyed firms were also interviewed. There are some organisations that were interviewed first but decided to answer the survey later because of time restrictions. Unfortunately, not all of them returned the survey, even after several contact emails and calls, reducing the number of completed questionnaires. Therefore, there are 66 fully answered questionnaires, which will

be a restriction on the analysis of the data when important questions have a low number of responses. The restrictions imposed on the methodologies of analysis by a lower number of observations will be discussed in each chapter.

The distribution by region of surveys and interviews conducted are summarised in Table 3.4 and Table 3.5 respectively. The distribution of types of firm was made according to an initial classification of firms based on their web pages. This information was later corrected using a question from the survey, in which the interviewee was asked to classify the firm in question in terms of position in the biotechnology sector. If a company has more than one classification, the most technological classification will be used for the analysis. For example, if a firm classified itself as a DBF, as a laboratory that uses biotech, and as a commercial representative of foreign reagents, then it will be considered as a DBF for the analysis.

Table 3.4 Surveyed Firms Related to Biotechnology by Region Studied

	Dedicated Biotech Firms	Lab Services using Biotech	Research Services using Biotech	Consortia	Firms using Biotech Processes	Pharma-ceuticals	Commercial Representa-tives	Services to Biotech Firms	**Total**
Metropolitan Region									
Total Number of Firms	42	13	5	7	29	11	6	28	**141**
Surveyed Firms	24	8	4	3	8	6	3	13	**69**
Valparaiso Region									
Total Number of Firms	3	1	2	1	5	1	0	1	**14**
Surveyed Firms	2	1	2	1	0	1	0	0	**7**
Maule Region									
Total Number of Firms	2	0	0	0	2	0	0	0	**4**
Surveyed Firms	1	0	0	0	1	0	0	0	**2**
Bio-Bio Region									
Total Number of Firms	4	0	1	2	2	0	0	2	**11**
Surveyed Firms	3	0	1	2	0	0	0	0	**6**
Los Lagos Region									
Total Number of Firms	2	4	1	0	5	0	0	0	**12**
Surveyed Firms	1	1	1	0	0	0	0	0	**3**

Note: Data at firm level. Economic groups are not grouped and will be considered as one main company for analysis

The rate of response is 20% for interviews and 49% for the survey in the Metropolitana region, while it is 50% for interviews and surveys in Valparaíso, 55%

in Bío-Bío, and 25% in Los Lagos. In Maule, there is a 50% of rate of response in the survey and 25% in the interview. The representativeness of the survey is more than 50% for the DBFs in each region and 50% nationally. Taking the most technology-based firms (DBFs, laboratories using biotech, and firms carrying out research using biotech) as the core of the sector, the national rate of response for this group is 54%. Therefore, it is possible to claim that the survey covers the core of the biotechnology sector in Chile at the national level, and in three out of four regions where the study was conducted – Bío-Bío, Valparaíso and the Metropolitana region (Table 3.4).

Table 3.5 Interviewed Firms Related to Biotechnology by Region Studied

	Dedicated Biotech Firms	Lab Services using Biotech	Research Services using Biotech	Consortia	Firms using Biotech Processes	Pharma-ceuticals	Commercial Representa-tives	Services to Biotech Firms	**Total**
Metropolitan Region									
Total Number of Firms	42	13	5	7	29	11	6	28	**141**
Interviewed Firms	10	3	1	2	1	4	1	6	**28**
Valparaiso Region									
Total Number of Firms	3	1	2	1	5	1	0	1	**14**
Interviewed Firms	2	1	2	1	0	1	0	0	**7**
Maule Region									
Total Number of Firms	2	0	0	0	2	0	0	0	**4**
Interviewed Firms	1	0	0	0	0	0	0	0	**1**
Bio-Bio Region									
Total Number of Firms	4	0	1	2	2	0	0	2	**11**
Interviewed Firms	3	0	1	2	0	0	0	0	**6**
Los Lagos Region									
Total Number of Firms	2	4	1	0	5	0	0	0	**12**
Interviewed Firms	1	1	1	0	0	0	0	0	**3**

Note: Data at firm level. Economic groups are not grouped and will be considered as one main company for analysis

A total of 45 interviews in firms were conducted. Six additional interviews were carried out. Experts on biotechnology in Chile and owners of companies not in the sample were part of these supplementary interviews. These interviewees were with a researcher and an academic, the former CEO of one technological consortium, the former director of the earlier governmental biotechnology division at CORFO, a director of one incubator with a focus on biotechnology start-ups, and the director of the Biotechnology Centre at the University of Concepción in Bío-Bío (Table 3.5).

These experts were included in the interviews since they were identified as important actors by other interviewees. The final number of successful interviews was 51.

3.5 DATA ANALYSIS

The analysis will be carried out with *ego*-network analysis, econometrics estimations, statistical tests and content analysis of in-depth interviews, in order to understand the possible causal relationships between social networks and cluster formation. Therefore, throughout the project, a mixed methodology will be used. Such a methodology allows us to triangulate, complement, develop and expand on data; given the exploratory nature of this study, there is no one unique methodology that could inform us about all the possible effects and relationships that might be happening at the same time in the creation of a cluster of firms.

This section explains the methodologies applied in this thesis to analyse the data collected. Each methodology will be described in a subsection to explain how it contributes to addressing the main research question and how these methods are combined for the analysis of social relations and cluster formation. Methodologies will be further explained in each chapter.

3.5.1 SNA AND *EGO*-NETWORKS DATA ANALYSIS

The framework of SNA, and in particular the *ego*-network framework, is used in Chapter 6. As Wasserman and Faust state, 'a social network consists of a finite set or sets of actors and the relation or relations defined on them. The presence of relational information is a critical and defining feature of a social network' (Wasserman and Faust, 1994, p. 20). Actors are social entities – individuals,

corporations or collective social units (Wasserman and Faust, 1994, p. 17). Relations among actors are the central feature and the focus of analysis of the social network theory. Relations are defined as linkages between units or actors. Actors are assumed to be interdependent and the linkages or relations between them are channels for the transfer of resources, which can be material or not (Wasserman and Faust, 1994, p. 4).

As described above, a consequence of the companies' self-selection in the research is that the data does not account for the complete network of the clusters. As explained earlier in this chapter, SNA requires complete information on a network. An alternative is to consider for the analysis what in SNA is defined as an '*ego*-network' of the firms interviewed.

As defined by Wasserman and Faust (1994), an *ego*-network is created when some firms (the *egos*) are interviewed and asked for their contacts (*alters* or *neighbours*) and also the relation between these contacts. Each *alter* can be interviewed and asked about their relations, repeating this procedure until no new important *alters* are included. Using this last methodology to obtain information about a network can result in a biased network, depending on the *egos* selected in the first round. In this study, the previous selection of some firms or *ego*s was not possible in this case because no information about the firms' features was available prior to the fieldwork.

The data collected does not exactly match the *ego*-network description presented above: it falls in-between a full network and an *ego*-network, since there is an overlap of *alters* between the interviewed firms. However, it is possible to study the relation network of each respondent as if it were an *ego*-network by using recent statistical procedures. Thus, in Chapter 6, the data will be analysed assuming *ego*-

network data. The main differences with SNA are that some of the networks' statistics cannot be obtained or that its analysis is not possible, precisely because there is incomplete information on the network.

3.5.2 ECONOMETRIC ANALYSIS

Econometric estimations are conducted in Chapters 6 and 7. The statistical models tested are also part of the statistical tools used for analysing social networks (Crossley et al., 2015; Lazega et al., 2012; Lazega and Snijders, 2016; Snijders, 2011).

In Chapter 6, a multilevel logistic model was estimated to assess the importance of personal connections in business creation in the biotechnology sector in Chile, controlling for features of surveyed firms and their *alters* (called 'nodes' attributes' in SNA). The dependent variable was a dichotomic variable that identified the existence of a business relationship between organisations; therefore, results identified the probability of creating such linkages between this group of firms. The variable of interest is the existence of a personal relation between the owners of the surveyed firms and another person working in the *alter* firm. This variable is assumed to be exogenous and given in the model.

A multilevel estimation is the appropriate statistical estimation to follow, since a firm's connections are nested within each firm; as a result, the observations are not independent and other econometric models would fail to account for the non-random structure of the data (Crossley et al., 2015; Lazega and Snijders, 2016; Snijders and Kenny, 1999).

In Chapter 7, another model is estimated. The research question in this chapter is about the effect of different connection partners at the national and international level on the creation of knowledge by Chilean biotechnology firms. The dependent

variables were the number of journal articles published (as a proxy for scientific knowledge created) and the number of patent applications (as a proxy for knowledge created closer to the market). The count nature of the dependent variables implied that the estimation was carried out using a negative binomial model. In this case, the dependent variable is an attribute of firms (nodes) and an econometric model is appropriate if the network of each firm is also considered an attribute of it (Carrington et al., 2005). The *ego*-network of each biotechnology firm surveyed is a feature of it and we considered each firm as an independent observation.

The model estimates the effect of the *ego*-network features on the behaviour of firms, in this case knowledge production. The network was divided into different categories. First was the personal and the business networks. Then, a distinction was made between R&D-intensive *alters*, such as universities and other DBFs, and other type of *alters*. Finally, a distinction between national and international firms was also introduced. Therefore, there were eight separate *ego*-networks when all the differentiations mentioned were included: business R&D national networks; business R&D international networks; business non-R&D national networks; business non-R&D international networks; personal R&D national networks; personal R&D international networks; personal non-R&D national networks; and personal non-R&D international networks. The model also controlled for other features of firms affecting knowledge creation according to previous evidence from literature. Estimations were done by separating personal networks and business networks, on the assumption that there was some correlation between them.

3.5.3 NON-PARAMETRIC TESTS

Non-parametric correlation tests, such as Kendall tau-b and Kruskal-Wallis, were used in Chapters 5 and 7. These tests were an additional procedure to supplement results from other methodologies, increasing the robustness of the results. The use of non-parametric tests instead of the parametric version of the tests followed on from two facts: 1) in the analysis of data at the regional level the low number of observations does not make it possible to conduct parametric tests, and the normality distribution assumption of variables in parametric tests is not met; and 2) when testing the relation between two ordinal variables, it is preferable to use non-parametric tests over traditional parametric tests such as the Chi-square test or ANOVA.

Kendall tau-b correlation is a non-parametric association measure between two variables, applied when at least one of them is an ordinal variable. Therefore, it is a rank correlation measure appropriate for paired variables. It is an alternative to Spearman's correlation where both variables correlated are ordinal or discrete; it also does not assume a distance between the ranks. The Kendall tau-b correlation coefficient is used when observations have similar ranks in both variables. It is possible to test for the hypothesis of a statistical monotonic relationship between the two variables correlated using the Kendall tau-b coefficient.

The Kruskal-Wallis test is similar to the parametric one-way ANOVA but is performed on ranks and is used to determine if there is a statistically significant difference between groups of observations from an independent variable on a continuous or ordinal dependent variable. It is suitable when the variables do not have a normal distribution or when the dependent variable is ordinal. It is also

preferred over the Mann–Whitney U test when the independent variable identifies more than two groups of observations.

3.5.4 Principal Component Analysis

Principal component analysis (PCA) is used to obtain orthogonal uncorrelated sets called 'principal components'. The transformation is conducted to maximise the variance of the data explained by the different principal components. It is used typically to reduce the number of variables in a regression, or to reduce multicollinearity between them. In this thesis, it is used to identify different groups of relations between firms, classifying the features of the relations by different principal components that explain the variance of the data on the relations collected.

3.5.5 Content Analysis

The analysis of qualitative information from in-depth interviews and open-ended questions in the survey was done using content analysis. It was carried out using the software NVivo 10. Content analysis of the open-ended questions in the survey was done in Chapter 5. The coding indicated the importance (high, neutral, low) and the attitudes (positive, neutral, negative) of interviewees towards the relative importance of social connections in the creation of firms in Chile, and also in the creation of biotechnology firms in Chile. Furthermore, the coding identified the areas that were important in the process of firm creation for the interviewees, such as referencing resources (financial capital, skilled workers, access to knowledge, etc.) or in the identification of entrepreneurial opportunity (access to clients, access to networks, etc.). The codes created were then cross-tabulated to identify important areas where social and personal connections were more significant in the

process of creating biotechnology firms in Chile. Also, qualitative information was used to contextualise and illustrate the results presented in Chapters 5, 6 and 7.

3.6 LIMITATIONS

As mentioned in some sections of this chapter, there are some limitations on the methodologies and data used in the analysis that need to be taken into consideration. The first limitation relates to the network data collected. It is always challenging to obtain network data from surveys in emerging economies given the lack of secondary data sources and the potentially low rates of response. The methodology for collecting network data implemented in this thesis resulted in limited network data since response rates were lower than 80%; therefore, there is not full information on the networks but a collection of *ego*-networks. However, the *ego*-networks collected overlap between them, since all *ego*s are part of the same network and some of the *alters* of one interviewed firm might be the same *alter* of another interviewed firm. This led to obtaining a dataset that incorporates neither pure network data nor pure *ego*-network data. The main difficulty in working with such data is that statistical methods that deal effectively with it are still being developed and have not been used widely to estimate models. Therefore, the methods used to analyse the data and estimate the relations between variables are the best available methods that could be implemented at the time of the analysis. Also, non-parametric tests were used to provide complementary evidence and increase the robustness of the results. SNA is rapidly developing and including new statistical methods for estimations; future work should use these new methods with this dataset to study further the relation between social networks and cluster emergence.

A second limitation involves the representativeness and potential bias of the data collected. Despite the relatively high rate of response, network data needs at least an 80% of rate of response if the information collected is to be considered to represent the entire network. Also, since responding to the survey was voluntary, an auto-selection bias in the data might arise. Unfortunately, the lack of information on firms' characteristics for the full universe of firms makes the estimation of the magnitude and direction of the bias difficult and also impedes the potential use of other statistical methods that deal with selection bias. Most firms in this sector are private firms but do not have shares traded in the stock market, which implies that they do not report information on their finances and structure publicly, only privately to their partners. Therefore, secondary information about the number of employees and sales are not available, making an estimation of a selection bias equation, to determine the magnitude and direction of the biases, not possible. As mentioned above, statistical methods used in SNA have always worked with full network data and do not provide alternative estimation procedures that correct the estimations by selection biases similar to 'à la Heckman' procedures. Therefore, the analysis of the results and the conclusions derived from them should take into account that there might be a bias towards firms more motivated to participate in this study because of unobserved features. It is also possible that this potential selection bias is minimal or random and the results are not highly biased; however, this cannot be tested with the data available. Nonetheless, given the methodology used in the survey, it is possible that companies that agreed to participate were the ones that had more interest in the research. It is likely that entrepreneurs with more connections and who participate in different realms of the sector, such as in the sectoral association or by promoting the development of the sector with public

agencies, would be more willing to participate, in contrast to isolated firms. If this is the case, the results could overestimate the importance of social relations in the development of the sector.

A third limitation emerges from the collection of network data through surveys. The survey asked about current and past events and relations. When asking about past relations and events, there is an increased probability of remembering only the most important relations and events, which generates a bias in the collected data (called 'recall bias'). McCormick et al. (2010) mentioned that it is common for relations to go under-reported when surveys to collect network data are being carried out. However, it is not possible to estimate the size and direction of this bias in the final results. Also, the order and wording of the questions may influence the answers obtained. The survey asked first for all the business relations of the firm, and then for the personal relations of the interviewee with workers, entrepreneurs or researchers in other firms and institutions in the biotechnology sector. It is possible for the personal relation network to be a sub-group of the business network, precisely because respondents have the business network in their minds, and they might omit personal relations relevant for the study. Again, this bias cannot be quantified but it might increase the correlation between the personal and business networks in the results.

Finally, another limitation emerges from the case study nature of the research, which implies that it was possible to analyse only one sector in one country during this research. There is always a question about how generalisable results from case studies are. To overcome this limitation, the results have been compared, whenever possible, with available studies from the same sector in different countries, particularly in industrialised countries, and with similar studies from different

sectors in Chile and other countries. However, there is still scope to understand sectoral and country differences with respect to the role of social networks in the emergence of new sectors and clusters. Future research should focus on this aspect.

3.7 SUMMARY

This chapter has described in detail the process of the collection of data and has briefly defined the methodologies used through the thesis in the analysis of the data. Since the analytic chapters are written in a journal article format, a brief description of the data relevant for each analysis will be presented in each chapter. An account of the methods used in each chapter will provide additional explanation of them. The different methodologies of analysis will provide support for the main hypothesis of this thesis. Each methodology will support the findings of the others, providing solid results and conclusions.

The next chapter describes the features of the biotechnology sector in Chile and the firms interviewed, establishing the setting for the analysis conducted in the subsequent chapters.

4 THE BIOTECHNOLOGY SECTOR IN CHILE

4.1 INTRODUCTION

The biotechnology sector in Chile started to develop during the 1980s, though biology research in universities dates back to the beginning of the twentieth century. This chapter will present information about the Chilean biotechnology sector from reports, official documents and descriptive statistics from the survey conducted in this thesis; it will also provide an analysis of the main actors and their interactions. The biotech clusters and agglomerations in the country will be presented, analysing the different actors and their relations in each of the regions selected for this thesis.

Biotechnology cannot be considered an industry in itself since it is a group of technologies applied to many separate industries, such as human and animal health, agriculture, food and mining (OECD, 2009). According to the OECD (2009), biotechnology is 'the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services' (OECD, 2009, p. 9). This is a broad definition, but the OECD has established a list of scientific technologies considered to fall within the biotechnology research; this includes genomics, gene therapy, DNA/RNA sequencing, the sequencing of proteins and molecules, cell and tissue culture and engineering, bioreactors, bioleaching, bioinformatics and nanobiotechnology, among others (OECD, 2005). Given these distinctions, I will refer to the biotechnology sector to indicate the firms involved in the technologies described above.

The biotechnology sector started to develop in the USA at the beginning of the 1970s (see Vettel, 2006, for an account of the emergence of biotechnology in the USA). This was possible thanks to the scientific developments made in the 1950s and 60s in universities in the UK and USA in the sequencing of DNA and molecules. The development of biotechnology firms was concentrated particularly in the biopharmaceutical sector, where small start-up firms conducted research and developed innovations at a higher rate than large pharmaceuticals, therefore creating a high level of relations between these two types of firms in the biomedicine industry (Powell et al., 1996; Walker et al., 1997).

Biotechnology is relatively new within the economy of Chile; however, it has developed to a stage where there are different actors present in this sector, such as production firms, service firms, pharmaceutical laboratories, private research centres, universities with specialised undergraduate and graduate courses, and trade associations. Within biotechnology, there are several sub-sectors; of these, agriculture and health are the most important in relative terms in Chile. The purpose of this chapter is to present an account of the biotechnology sector in Chile, which will be studied in-depth during this thesis.

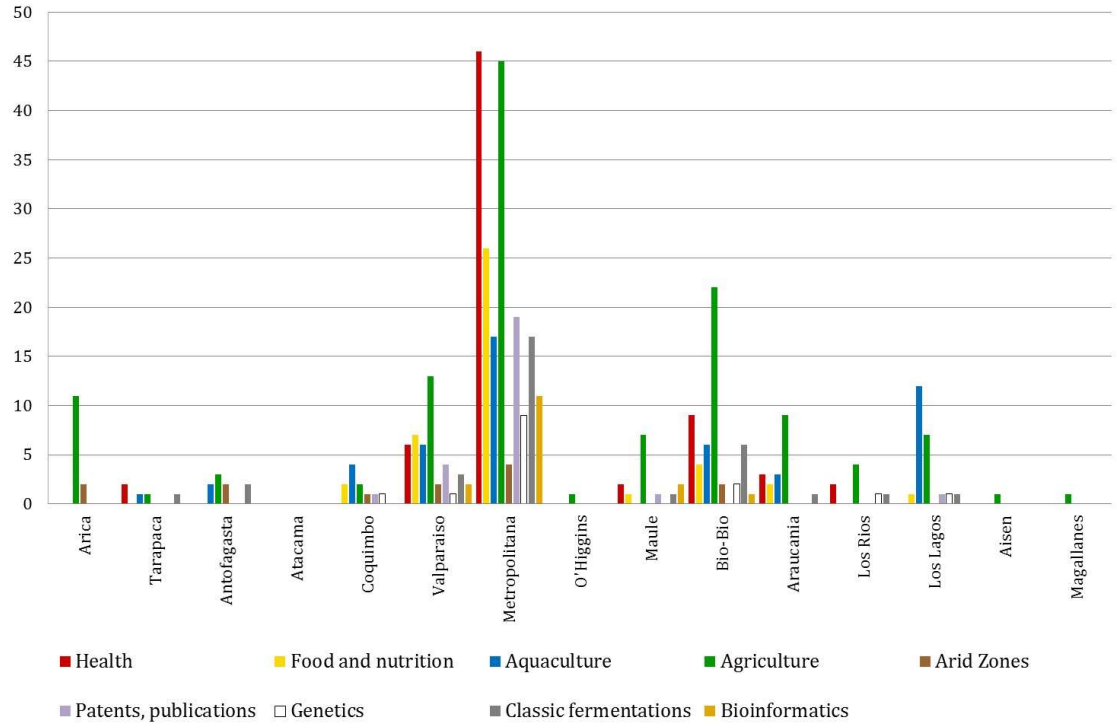
The next section presents a brief historical account and a description of the biotechnology sector in Chile. Section 4.3 presents a description of the public policies important for the sector. Section 4.4 describes biotechnology firms and relevant actors in the four regions of Chile studied. In Section 4.5, the differences between the regions selected are highlighted. Finally, Section 4.6 briefly concludes.

4.2 BIOTECHNOLOGY IN CHILE

Biotechnology is considered a transversal platform for the development of other industries such as food, mining, agriculture, pharmaceuticals and animal health. Within the biotechnology sector there are several sub-areas. It is common to identify biotechnology with different colours according to the industrial sectors in which it is applied. Therefore, health and diagnosis is called red biotech; food and nutrition yellow biotech; aquaculture and marine biology blue biotech; agriculture, environmental and biofuels green biotech; arid zones biotech brown biotech; industrial uses white biotech; bioinformatics and nanobiotech gold biotech; and finally, classic fermentation processes and bioprocesses grey biotech (CORFO, 2007, 2006).

The first Chilean biotechnology companies were set up in the Metropolitana region in the mid-1980s, a decade after the first biotech firms were established in the USA. The first firms focused on animal health, biomedicine and medical diagnosis. The sector has experienced rapid growth over the last decade. According to CORFO, in 2003 there were 32 biotechnology companies, while in 2010 there were 110. CORFO made a census of the biotechnology sector in Chile in 2007 (CORFO, 2007). The sub-sector distribution of biotechnology agents is presented in Figure 4.1. These organisations are private firms, research centres, public research institutions, and consortia between firms and universities, among others. Biotechnology related to agriculture, food and nutrition is important on a national level. One of the main actors in agricultural biotechnology is the National Institute of Agricultural Research (INIA in Spanish). INIA is a public research centre and technology transfer office with a regional presence through the country; it also collaborates with universities and firms in research projects.

Figure 4.1 Distribution of Organisations Related to Biotechnology in Chile (2007)



Notes: Data from CORFO (2007). Regions are ordered from north to south of the country.

The Metropolitana region, where the capital of the country is located, has the largest concentration of organisations related to all areas of biotechnology (see Figure 4.1). Other regions with a relative concentration of organisations are Valparaíso, Bío-Bío and Los Lagos. The greatest concentration of organisations is found in the health biotechnology sector in the Metropolitana region of the country.

Table 4.1 shows the number of research groups, institutions and highly skilled workers in different areas at the national level. The largest biotechnology area in Chile is related to agriculture, environmental technology and biofuels. However, this area is very broad and in some regions the focus of biotech firms within this area is on agriculture, as in Valparaíso and Maule, while in others it is on forestry and biomass, as in Bío-Bío. Health and diagnostics in biotechnology is the second largest sector by number of institutions, accounting for 40% of sales in biotechnology

(CORFO, 2007). It is also the area where most professionals with doctorates work. According to a prospective study from CORFO (2006), there is a consensus that there is a sufficiently large pool of highly skilled workers to develop the biomedicine sector. However, other studies have highlighted the lack of qualified human capital as a restriction on the sector's growth when the biotechnology sector as a whole is analysed (Interlink Biotechnologies LLC, 2008; Santibáñez, 2010a, 2010b). According to CORFO (2007) statistics, between 1995 and 2006, the number of professionals working in biotechnology-related fields rose by 17%. There are 48 undergraduate programmes in the country related to biotechnology issues, while there are 17 masters and 14 doctorate programmes with a focus on biotechnology.

Table 4.1 Human Resources in the Biotechnology Sub-Sectors in Chile (2007)

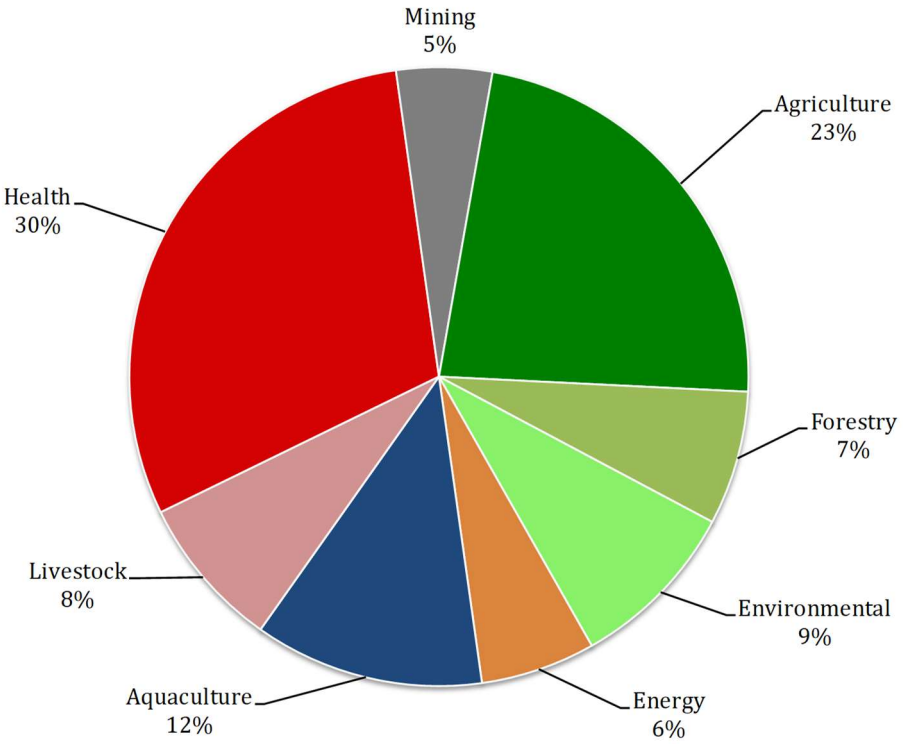
Biotech Area	Research Groups	Institutions *	Human Resources	
			M.Sc.	Ph.D.
Health and Diagnosis	57	22	96	172
Food and Nutrition	18	13	26	40
Aquiculture	16	12	37	68
Agro biotechnology, green biotechnology, bioufuels	88	42	120	160
Dry zones biotechnology	9	7	13	20
Genetic based industries	7	7	5	64
Informatics, nano-biotechnology	11	9	17	25
Fermentation and bioprocesses	9	7	16	37
Total	215	61 **	330	586

Source: CORFO (2007)

Notes: * a division or regional branch of firms or other research institution. ** Several institutions work on more of one research area. The total considers institutions without repetition.

In 2014, the Foreign Investment Committee of Chile published a brochure on the biotechnology sector in the country. By that year, there were 101 biotech firms in the country, 79 of them private firms and 22 consortia between other firms and universities. The distribution of the firms by sector is presented in Figure 4.2. From the data, it is possible to observe that two sectors dominate Chilean biotechnology: agriculture and health. Health accounts for 30% of biotech firms in the country. This sub-sector is the biggest within the biotechnology sector in Chile (Foreign Investment Committee, 2014; Santibáñez, 2010a, 2010b). There is great potential in biomedicine research; the impact of publications in ISI journals between 2000 and 2004 is 2.8 on average, a figure similar to that of Finland for the same period (Santibáñez, 2010b, p. 59).

Figure 4.2 Percentage of Biotech Companies by Sub-Sector (2014)



Note: Data from Foreign Investment Committee (2014).

The reduction in the number of firms between 2007 (110) and 2014 (101) is the result of two factors: the departure of some firms from the market; and that in 2007 several firms considered biotech firms were not actually working in the field. This is particularly the case in Arica, for example, where the firms included in 2007 as biotech firms were mainly firms that produced genetically modified seeds. These firms are given the seeds, which they reproduce through cultivation; they do not conduct any internal research into this process.

It is important to state a distinction between the different types of biotech firms and firms related to them. According to OECD (2009, p. 10), biotechnology firms are all firms that uses biotechnology techniques in any part of their production process, to provide products or services. Given this definition, it is also possible to consider large firms that use biotechnology only in a small part of their production process as biotechnological companies. Within biotech firms, the OECD also distinguishes between DBFs – biotech firms whose main activity involves the application of biotech techniques to produce products or services – and biotechnology R&D firms, which pursue biotechnology R&D as their main activity.

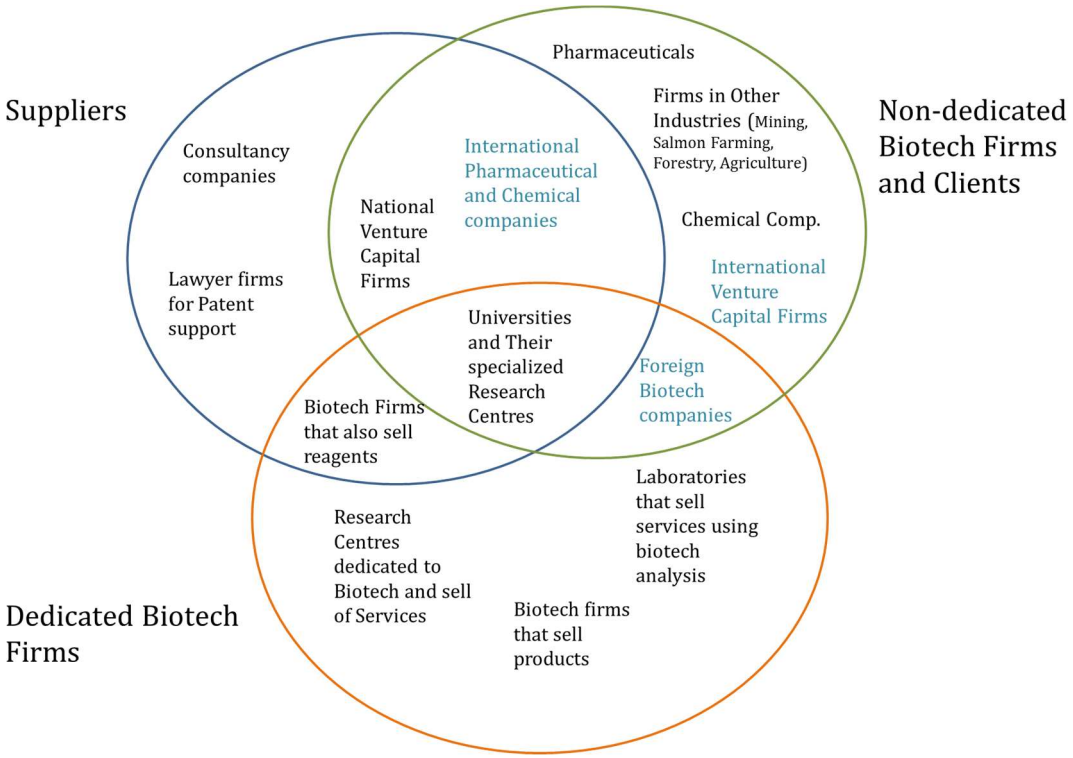
Also, within a cluster, there are different important actors, besides firms, in a particular location. A cluster, according to the definition given by Porter (Porter, 1998a), is 'a geographical concentration of interconnected companies and institutions in a particular field' (Porter, 1998a, p. 78). Other institutions important to a cluster are clients, suppliers, public agencies and trade associations, among others. However, in the Chilean case firms and other actors do not always have only one role within the cluster. For example, universities are not only actors that participate in biotechnology research, but are also the clients of some biotech firms and in some cases research partners or suppliers of research for other firms.

Another example of this mixed role is the foreign DBFs established in the country. Their local role is mainly to commercialise their biotechnological products locally. Their clients can be local biotech firms, universities, hospitals, and local pharmaceutical companies, among others. However, in some cases they collaborate with local universities on biotechnology research. Therefore, it is possible to outline the different types of firms and actors, and their different roles associated with biotechnology, as in Figure 4.3.

Most of the research on biotechnology clusters has focused on DBFs; the sub-sector studied the most has been health and biomedicine. Regarding the biotechnology sector in health, there are at least three sets of actors: universities, pharmaceuticals companies and DBFs. There is a high frequency of relations between firms in the biomedicine sector, especially between large firms such as pharmaceuticals and small and entrepreneurial start-up firms (Walker et al., 1997). Also, universities collaborate with biotechnology companies in research while they collaborate with pharmaceutical companies in the testing of drugs or the conducting of clinical trials. It is possible to consider pharmaceuticals as biotechnology firms if they use biotechnology techniques to develop new drugs. There are only a few big pharmaceuticals in the world, which dominate the market for new drugs, and they are the clients or buyers of smaller DBFs. In Chile, the main pharmaceutical companies that produce drugs locally were established at the beginning of the twentieth century. They have developed some local products. However, they are not research-intensive and usually produce generic drugs, although in the last ten years two national pharmaceutical companies have been collaborating in biotech research with universities, research centres and DBFs. Only one bought a DBF in 2012. Most international pharmaceutical companies established a subsidiary in Chile during the

last decades of the twentieth century, and these focus on commercial activities. Relations between pharmaceutical firms and other organisations are mainly supplier–client. In 2015 Pfizer established a research centre in Chile, with the support of a public grant, which could change the role of international pharmaceutical companies in the Chilean biomedicine sector.

Figure 4.3 Diagram of Firms and Actors and their Roles within the Biotechnology Sector in Chile



Source: Author, based on information about firms and institutions from websites and interviews.

These types of actors – DBFs, big client firms and universities – are also found in other areas of the biotechnology sector in Chile. For example, in mining, there are a few big companies in the country that are the major potential clients of DBFs in this sub-sector. The same occurs in forestry and aquaculture. However, in other

sectors such as agriculture or bioprocesses, there are usually several small, medium and large firms that could be the clients of DBFs.

Table 4.2 Regional Distribution of Firms Related to Biotechnology in Chile

Region (North to South)	Dedicated Biotech Firms	Lab Services using Biotech	Research Services using Biotech	Consortia	Firms using Biotech Processes	Pharma-ceuticals	Commercial Rep. of Int. Firms	Services to Biotech Firms	**Total**
Arica y Parinacota	1	0	0	0	0	0	0	0	**1**
Tarapacá	3	0	0	0	0	0	0	0	**3**
Antofagasta	2	0	1	0	0	0	0	1	**4**
Atacama	0	0	0	0	1	0	0	0	**1**
Coquimbo	1	0	0	0	1	0	0	0	**2**
Valparaíso	3	1	2	1	5	1	0	1	**14**
Metropolitana	42	13	5	7	29	11	6	28	**141**
Maule	2	0	0	0	2	0	0	0	**4**
Bío-Bío	4	0	1	2	2	0	0	2	**11**
Araucanía	1	0	0	0	2	0	0	0	**3**
Los Ríos	1	0	0	1	2	0	0	0	**4**
Los Lagos	2	4	1	0	5	0	0	0	**12**
Magallanes	0	0	0	0	1	0	0	0	**1**
Total	**62**	**18**	**10**	**11**	**50**	**12**	**6**	**32**	**201**

Note: Data at firm level. Economic groups are not grouped and might be considered as one main company for analysis

A summary of the different actors related to biotechnology in Chile, based on the fieldwork conducted the first half of 2013, is presented in Table 4.2. While most actors are private companies, national DBFs represent about 30% of the sector. Also, firms involved in biotechnology research (DBFs, laboratories and research centres using mainly biotechnology for their services and processes) represent 45% of the sector. The presence of foreign companies is reduced and mostly focused on the supply of products to universities and health centres. As mentioned in the previous chapter, following the geographical concentration of firms, this study will focus on the regions of Valparaíso, Metropolitana, Bío-Bío and Los Lagos. The interaction between these actors is described in the next sections.

4.3 ROLE OF PUBLIC POLICIES ON BIOTECHNOLOGY

National policies that promote the development of the biotechnology sector have not been developed systematically in Chile. As described by Feldman, Francis and

Bercovitz (2005), policies are fundamental and can change the conditions for entrepreneurs, establishing the conditions for the development of a cluster. Porter (1998a) also considers the role of institutions as key in the development of clusters.

Specific public policies towards the promotion of an innovation system were not structured in the country until the creation of the National Innovation Council of Chile (Consejo Nacional de Innovación para la Competitividad, CNIC) in 2005. Before that, policies promoting the creation of firms and scientific research functioned as two separate policies, run by two distinct national agencies. The National Commission for Science and Technology (Comisión Nacional de Ciencia y Tecnología, CONICYT) promotes scientific research through different competitive research grants. CORFO, on the other hand, promotes innovation and productivity through competitive grants, subsidies and loans offered at low rates. These agencies, created in 1967 and 1939 respectively, did not interact under an umbrella of innovation policies until the creation of the CNIC. Nevertheless, since 1990, public policies have focused on increasing technological innovation in Chilean firms in order to foster their productivity and aid the country's economic growth.

In the life of this cluster, public policies for biotechnology development can be broken down into three distinct periods.[6] The first encompasses the promotion of different productivity sectors and the beginning of competitive research funds between 1981 and 1992. In 1981, the government created the CONICYT, which grants public funds for research at universities based on the competitive selection of projects. The majority of competitive research grants given by CONICYT between

[6] This classification of policies in periods was developed based on the information presented by Rivas and Sierra (2009)

1982 and 2007 were related to biology and medical sciences,[7] establishing the foundations of a solid scientific research community in Chile in these areas. Yet there has not been a consistent policy to explicitly promote biotechnology research and industry in the country. During this period, the Ministry of Economics and Fundación Chile, a public-private organisation, mainly promoted the development of sectors such as salmon farming and forestry, although support for innovation and research in the private sector was not directly targeted. In this setting, the first biotechnology companies in Chile were established.

The second period can be thought of as the industrial policies promoted under the 'Concertación' governments in Chile between 1992 and 2009. This period was characterised by an increase in matching grant programmes run by CORFO targeting firms and gradually moving the focus from productivity and technology adoption towards innovation. In 2001, the Chilean government established the Development and Technological Innovation Program, which was the first attempt to put in place a coherent national policy to promote technological innovation in the private sector. The programme conducted prospective studies, concluding that biotechnology was a platform industry that had applications in several economic sectors important to the country, such as mining, forestry, agriculture and aquaculture, among others. Consequently, in 2003, a new unit was established within CORFO which focused on promoting technological innovation in biotechnology, although it was closed in 2010. The creation of this unit in CORFO was an important signal to the market. During this time, several research centres with an orientation towards biotechnology research were created and financed by public research grants from

[7] Source www.fondecyt.cl.

CONICYT. In 2006, a technological park focusing on biotechnology was financed by CORFO and established in Santiago, in the same location where the biggest biotech company – BiosChile – is based. Public research grant schemes have therefore helped to establish biotechnology research foundations in universities and the private sector.

The National Innovation Strategy established by the CNIC between 2006 and 2008 did not consider the biotechnology sector as a priority strategic sector; the focus of the policy was on sectors with high growth potential. The Council selected and promoted the creation of several clusters in mining, aquaculture, food industry, tourism and offshoring. These policies had two important impacts on the sector. First, older biotech firms in the biomedicine sub-sector had to broaden their research lines to include research focused on the clusters prioritised by the government, including salmon and animal health or agriculture. Companies have pursued research on vaccines and the health of salmon, fruit and vines in order to obtain funds from government grants. Secondly, new biotech firms were established around these sectors, specialising mainly in agricultural biotech, biomedicine for animal health, and bioprocesses for the mining industry.

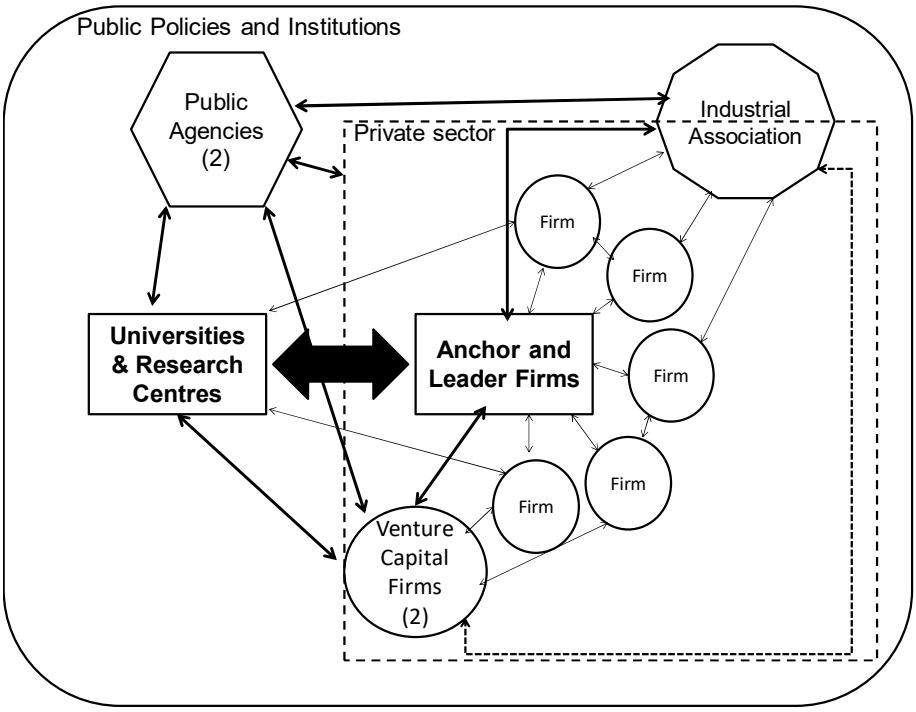
During the third period, since 2010, innovation and industrial policies have departed from the direct support of certain sectors, eliminating the cluster policy developed in the past, and closing the unit specialising in biotechnology at CORFO. However, the support for innovation in firms and programmes established in the previous period has been continued under this government. Also, it is important to note that in this period a specific public competition for bioenergy projects has been run by the Ministries of Energy and Economics, through which four private research consortia focusing on biodiesel were financed. Additionally, entrepreneurship

programmes have been established, such as the 'Start-up Chile' programme. This programme aims to attract international entrepreneurs to Chile in order to create an entrepreneurial culture. Although the capital given to this project has been low, and so has not enabled the participation of numerous biotechnology entrepreneurs, a few bioinformatics and biotechnology firms have emerged from the programme (VERDE, 2016). The influence of these policies on the different regions studied will be discussed in the next section.

4.4 MAJOR ACTORS AND REGIONAL ENVIRONMENT

This section briefly describes the main actors and the main relationships between them in the biotechnology sector in the four regions of the country studied, contributing to contextualising the analysis of the following chapters. The type of actors in each region and their interactions varies greatly. Figure 4.4 presents a diagram of the ecosystem of the biotechnology cluster in the Metropolitana region.

Figure 4.4 Diagram of the Biotechnology Ecosystem in the Metropolitana Region of Chile



Source: Author; based on fieldwork notes

It can be seen that there are five main actors in the ecosystem: leading or anchor firms; universities; venture capital firms; industrial association; and public agencies. Each actor will be analysed in detail by region below (although not all actors are present in each region and the type of interaction among them varies greatly). The case of the Metropolitana region will be described in detail and will then be compared to other regions to identify missing actors and interactions. Table 4.3 presents the main features of the biotechnology ecosystem by region.

Table 4.3 Main Regional Features and Description of Biotechnology Actors by Region Studied

Region	Main Economic Activities	Main Actors in Biotech	Universities with Biotech Research	Orientation of Biotech Firms	Regional-National Capitals Distance
Valparaíso	Agriculture, food industry	A university research centre focus on biotech. Three universities with biotechnology research areas. One public research centre on agriculture	Seven universities, focused on engineering	Bioprocesses, agriculture	115.2 km
Metropolitana	Industry, financial services, commerce	Two venture capital firms. National biotechnology association. Biotechnology park	Three traditional universities. Four newer, private universities	Health (human and animal), bioprocesses, agriculture	0 km
Bío-Bío	Forestry, industry, agriculture	Two large universities. One biotechnology research centre in a university. One industrial park. Two forestry firms	Two major universities, focused on agriculture, engineering and forestry	Forestry, agriculture	499.3 km
Los Lagos	Aquaculture, agriculture, food processing	Two universities, one national salmon association, one research centre in a university. Three major salmon-farming companies	Two traditional and public universities	Animal health (salmon and cattle)	1,032.1 km

Source: Based on information from interviews and fieldwork

4.4.1 LEADING OR ANCHOR ACTORS

The central actors in this cluster are universities and anchor firms. Lead or anchor firms can attract other entrepreneurs and create spin-off companies because of their size and importance in a cluster (Baglieri et al., 2012; Feldman, 2003; Gertler and Vinodrai, 2009). In this context, anchor firms are seen as the starting point from which a cluster develops (Felzensztein and Gimmon, 2009). In Denmark (OECD, 2009) and in some regions of Canada (Gertler and Vinodrai, 2009), the role of anchor firms is important for the development and growth of biotechnology clusters. The role of universities has also been central in the development of many biotechnology clusters in the world; they have taken on the role of an 'anchor', leading to the formation and location of new firms (Feldman, 2003; Gertler and Vinodrai, 2009; Todtling and Trippl, 2009). However, the most important push for the sector in some regions in Chile comes from a leading actor or anchor firm. The type of anchor firm, however, varies by region.

In the case of the Metropolitana region, the leading or anchor firms are the biotechnology companies established first. In Chile, the first biotechnology companies were established in this region in biomedicine – human and animal health – in the mid-1980s. These anchor firms are the oldest firms in the cluster and their owners have played a major role in the evolution of the sector. The history of BiosChile is a clear example of a leading firm in the biomedicine cluster of Chile. It was founded in 1986 and has grown to be a large firm in terms of sales and number of employees. It is a key firm in the cluster and the first that has generated a spin-off in the same sector. The owners of the company are renowned as scientists and professors at the best universities in Chile. Additionally, they founded Fundación Ciencia Para La Vida in 1997, a private non-profit research institute. This created

the foundation for the establishment of a biotechnology park in 2006, in the same location in which the firm and institute are based. BiosChile is the biggest biotechnology company in Chile, exporting its products to the USA, Latin America and Europe. They also founded a commercial company in the USA to facilitate the import and export process. In 2008, they founded a spin-off of the company, Andes Biotechnologies, which aims to develop new diagnostic devises and treatment therapies for cancer.

Furthermore, its owners are what could be called 'star scientists', i.e. leading national or international scholars in biotechnology research (Gertler and Vinodrai, 2009). Owners of BiosChile are renowned scientists at national and international level, with continuous linkages with international biotech firms and universities, keeping them in a leading position. One of the owners, Pablo Valenzuela, received the National Award in Applied and Technological Sciences in 2002. He studied biochemistry in Chile and received his PhD from Northwestern University before continuing with his postdoctoral studies at the University of California in San Francisco. He was co-founder of a leading biotechnology company in San Francisco, USA, the Chiron Corporation, in 1981. Pablo Valenzuela, together with other two renowned scientists, Arturo Yudelevich (a former undergraduate classmate) and Luis Burzio, established BiosChile in 1986. Arturo Yudelvich studied biochemistry and completed his doctoral studies at the Albert Einstein College of Medicine of Yeshiva University in the USA. Luis Burzio, also a biochemist, has held a postdoctoral position in the Population Council of Rockefeller University and was the recipient in 2004 of the Pasteur Institute Biomedicine Award. They are also renowned professors in two of the main universities in biotechnology, with academic linkages to almost every university and research centre. Their sustained leadership comes

from their social capital – they are part of an international knowledge flow in biotechnology, academia and business.

The leadership of these owners is so important in the national biotechnology realm that one of them, Pablo Valenzuela, is also a counsellor for investment companies and has acted as angel investor in other companies. They also participated in the creation of the national industrial association (ASEMBIO). His role, and the role of his biotechnology partners and students in the region and in the country, is highly important. They connect with competitors, investors, university researchers and employees of public institutions, with the objective of promoting the development of the sector.

In Valparaíso, in contrast, it is not clear that there is a leading actor or anchor firm. There is one particular entrepreneur, Patricio Araneda, who connects more with institutions and firms in the Metropolitana region, but his firms have been established recently and still need to grow or increase their local network to start attracting other entrepreneurs and help in the creation of new firms. Universities and academics are more influential in the biotech sector in Valparaíso. There are three research centres in biotechnology, each based in one of the three main universities in the region. The main research areas in these centres are in plant biotech, bioreactors and bioprocesses. This is probably due to the importance of engineering schools in these universities. One of these research centres is larger and was established in a technological park founded by CORFO. However, this important pole of biotechnological research has not necessarily led to an increase in the emergence of local start-ups, and has not played a leading role in the agglomeration process.

Concepción, the capital of the Bío-Bío region, has a different setting in terms of biotechnology. Few biotechnology firms have emerged there, but it is possible to observe an increase in them in recent years. The main economic activity in the region is forestry and the pulp industry, which is dominated in the country by only two big companies. It was clear from the interviews that there are three main players: the biggest university in the region (and the third most important university of the country), the University of Concepción, which has a biotechnology research centre – and the two main forestry companies of the country. New companies are oriented towards biotechnology as applied to the forestry sector, and most of them are consortia between the main firms and the University of Concepción. Also, within the regional university, one scientist, Dr Jaime Baeza, has been fundamental in the creation of the Biotechnology Centre in the region and the connection of the university with the forestry industry. However, this is a small pole with a narrow focus. There are a few biotech companies in the regions that have other focuses – agriculture, bioprocesses and cosmetics – but they do not interact with the Biotechnology Centre at the University of Concepción or with the forestry firms. In this region, the university has been the leading actor; however, its role has been modest in the creation of new firms since the three firms associated with the centre are consortia financed by the government and the forestry industry.

Los Lagos' biotechnology sector is also closely related to the main economic activity of the region – salmon aquaculture – although recently a new company was established in the region with a focus on manufacturing biofuels from giant algae.[8] I could not observe in this region a main or leading biotechnology firm or centre. The

[8] Two firms producing biofuels from microalgae have been established in the north of the country.

salmon farming industry has been influential in the development of a few biotech firms, mainly because there was a virus outbreak in 2007 that killed thousands of salmon.[9] This emergency lead to the establishment of external laboratories and companies whose main focus is testing the salmon, researching new vaccines and antibiotics, and selecting improved breeds. In this process, the Salmon Industry Association (SalmonChile) has been a key agent promoting the research that salmon firms need, but it has not promoted the creation of new biotech companies. Although there are two important universities in the region and both have research centres and careers related to aquaculture, they have played a limited role in the creation of new biotechnological firms in the region.

4.4.2 UNIVERSITIES AND RESEARCH CENTRES

As mentioned earlier, other important actors in biotech clusters are universities. The scientific knowledge base provided by local universities has been fundamental to the creation of biotechnology clusters in the USA, Canada and Austria (Feldman, 2003; Gertler and Vinodrai, 2009; Todtling and Trippl, 2009) and has been observed in the Chilean case as well. As mentioned earlier, each region has at least one large university. The scientific research base for biology, biochemistry and medicine has a long tradition in the oldest universities in Chile. Universities have three main roles in the biotechnology sector. First, they educate the scientists who will work in the cluster in the future, providing the human capital that the sector needs. Secondly, the social capital of scientists is built on the interaction between teachers and students as well as among students. Finally, scientists at universities conduct

[9] For detailed information on this outbreak and its consequences in the region, refer to The World Bank (2014) *Reducing Disease Risk in Aquaculture*.

research not only at universities but also with biotech firms, reducing costs and exploiting economies of scale in research activities. These roles will be analysed below.

Labour pool

An important role of universities is to provide scientists and a labour pool for the cluster. Biomedicine entrepreneurs, who are also professors at different universities in the Metropolitana region, promoted the creation of the biotechnology degree at the University of Chile in 1996. Today, there are 15 universities in the country offering a degree in biotechnology or biotechnology engineering, contributing, together with biochemistry and other biology-related studies, to creating an important pool of human resources for the sector.

In the Metropolitana region, there are the two oldest and best ranked universities – the University of Chile and the Catholic University of Chile – with a strong knowledge base in biological and medical sciences as well as in engineering and agriculture. They also have the highest proportion of graduates in disciplines associated with the biotechnology sector in the country. In Valparaíso, there is also a large concentration of universities, with three old, well-recognised universities, mainly specialising in engineering and biological sciences. In Bío-Bío there are also three traditional universities, although one public university – the University of Concepción – is the most important in terms of research and undergraduate and graduate programmes related to biotechnology. In Los Lagos, there is a campus of the Austral University, the fourth biggest university in Chile in terms of research; however, the main campus of this university is situated in another region in a city 213km north of Puerto Montt, Los Lagos' capital. The local university – the University of Los Lagos – is focused on research and careers related to aquaculture

and agriculture; however, it is not the main generator of research in those areas in the country and researchers usually collaborate with academics in other universities.

Social capital

Universities' role in firm creation is mainly evident in the access to academic and professional networks. Most entrepreneurs in the initial stages of the cluster in the Metropolitana region studied biochemistry at the University of Chile. They met there and established long-term friendships. Young entrepreneurs or managers of new start-ups also met the first biotech entrepreneurs in the country, who were their university professors and became their mentors. Thus, universities have an important role to play in generating networking and social capital for scientists. These role is evident in the Metropolitana and Bío-Bío regions, as analysed in the previous section. However, there is less clarity in the case of Valparaíso and Los Lagos. In Valparaíso, there are strong universities and research centres; however, the linkages with the current biotech firms in the region seem less strong. Los Lagos, on the other hand, also has a low level of social linkages between the local university and the managers and owners of biotech companies in the regions, since most of them studied in other regions in the country, particularly in the Metropolitana region.

A missing element in the Chilean biotechnology clusters in every region studied is the creation of spin-offs from universities. This has been an important feature in the development of other biomedicine clusters, as in the Canadian case (Gertler and Vinodrai, 2009), and the lack of a culture and institutions to promote such university spin-offs might hinder the sector's growth.

Research and collaborations

The third and final role of universities in this sector is the research conducted in several areas of biotechnology. As research centres, universities act as clients of biotech companies since they require reagents and inputs for the research process. Some of these inputs can be acquired from biotech companies that are also commercial agents for international supply companies. Furthermore, universities are research partners for many biotech companies. These alliances can offer the advantage of reducing research costs for both partners and increasing the probability of obtaining resources from public research grants. Additionally, they may allow for the exploitation of economies of scale in the use of equipment and inputs for research. A possible disadvantage is that research conducted in universities works to different timetables and has different objectives than research with a productive orientation. Collaboration in research between universities and biotech firms was evident in all the regions studied, although many research collaborations between firms in regions outside the Metropolitana area are with the two biggest universities in the country, based in Santiago, the capital of the Metropolitana region and the country.

University research centres seem to be sensitive to public funds. Some research centres with a focus on biomedicine which were funded with public funds in 2006 were no longer functioning in 2011 after the public funding ended. Those centres were located in departments of the main universities, which implies that researchers working in the centres continued to do so within the university. In contrast, the establishment of private research centres has increased research competition; they represent a group of important actors in the sector. In the Metropolitana region, for example, Fundación Ciencia Para La Vida, formed by the

leading firm BiosChile, is the first world-class private research centre in biotechnology in Chile. It has been a recipient of public research grants since its creation and has established international agreements with universities in the USA for research and student exchange. In the other regions, the presence of private research centres is limited. There is one private research-oriented firm in Valparaíso which is part of a group of firms oriented towards biotechnology; however, it was created in 2012 and its local links in research were still weak at the time of interview. In Bío-Bío and Los Lagos, the main research centre outside universities is the public research centre in agriculture, INIA, which has links with universities and firms.

4.4.3 VENTURE CAPITAL FIRMS

There are 23 venture capital companies in Chile, all of them located in the Metropolitana region, but only two of them invest in the biotech sector.[10] Two venture capital firms, Aurus and Austral Capital, were founded in 2007 and 2008 respectively, and are new actors in the sector. The reduced number of venture capital companies investing in biotechnology businesses might be due to the high risks involved in the sector, as well as information asymmetries between scientists and investors. Venture capitalists need to know about the sector, research time and the production process. If investors do not have knowledge of the sector, they need advisers who do. In the biotech sector, advisers should not only be scientists, but, most importantly, they should have experience in the biotechnology business. Since the sector in Chile is small, not many persons fulfil these requirements. As

[10] Information available at http://www.corfo.cl/programas-y-concursos/intermediarios-y-consultores/capital-de-riesgo-corfo

mentioned before, Pablo Valenzuela, the pioneer scientist in the sector, has been a consultant for venture capital firms and is also an angel investor in biotech start-ups.

Managers of venture capital funds meet with various entrepreneurs to listen to their business plan and ideas. The information provided by scientific assessors is crucial to venture capital managers in determining whether the project has commercial value and scientific feasibility. Also, if another manager, investor, client or business partner previously recommends the person and the project, they will consider that the business idea 'has passed a first filter' and might have a higher probability of success. One of the venture capital managers explained that 'if another investor is funding a company and has already completed the analysis and research of the project, it gives more credibility [to it]'. Another manager said that 'in general you work very much based on relationships because there are few companies, few investors'. It is important to know the person you are investing in a business with and it is crucial to build trust. One interviewee commented, 'life is based on relationships with people and in a globalised world like this, knowing another person is our main asset.' This reflects the crucial role of personal relations and trust in funding biotechnology companies. Yet a small number of venture capital firms and investors might hinder the cluster's growth, particularly if entrepreneurs face a significant entrance barrier, which is to gain access to the social network of the sector.

In the Canadian case, venture capitalists also provided business planning, strategy formulation and coaching (Gertler and Vinodrai, 2009). This is also found in the Chilean biotech cluster. The number of entrepreneurs with academic training in science and business is limited in the Chilean biotech sector. In fact, from

interviews conducted with one university incubator and venture capital companies, the most common problem with scientists trying to obtain funds from private investors is the lack of a business strategy and vision. It is difficult for scientists to see their research as a product and to develop a business plan. This has reduced the financing provided by venture capitalists, hindering the number of start-ups created in the sector. There is a need for the development of these skills in the scientific world. Universities have recently included business courses in their biotechnology programmes; however, students on other programmes, such as biochemistry, biology, agriculture and engineering, might also benefit from these courses.

Additionally, the high risk and information asymmetries in the sector lead to venture capital firms favouring investment in firms that are physically close to them, so they can have closer collaboration and monitoring of the project. Access to venture capital during the first stages of a firm's formation is fundamental for the evolution of the cluster (Feldman et al., 2005). One of the venture capital managers interviewed pointed out that investors prefer to be geographically close to the firms and projects they finance. Monitoring of the project could be conducted at a lower cost when firms are geographically close (Hagedoorn et al., 2000), supporting a geographical concentration of firms.

All these features of the venture capital firms in Chile imply that firms located outside the Metropolitana region face higher difficulties accessing this type of capital. For example, in an interview with an entrepreneur in the Valparaíso region, the interviewee pointed out that a drawback of being located in a region outside the capital of the country is the lower access to financial capital. However, when this company had an offer of a new financial partner, they rejected it because it involved moving the company to the Metropolitana region – the personal costs of moving the

company were considered too high for the entrepreneurs. Venture capital companies have just started to invest in biotech firms that have part of their plant or research facilities located outside the Metropolitana region; however, most of them are consortia and the administrative area of the biotech firms are located in Santiago, close to the venture capital firms.

The importance of venture capital in the biotechnology sector is still in its early stages in Chile. The role that these companies might potentially have in the development of the sector is important. In particular, they can change the environment for entrepreneurship in the sector. However, the heavy reliance of investors on social capital and personal relations might become a problem for the development of the sector and regional clusters if this contributes to knowledge and business lock-in. In particular, the emergence of new start-ups in regions outside the country's capital is more difficult given the features noted here of venture capital investment.

In this respect, big client companies such as pharmaceutical, aquaculture and forestry firms might have a new role in the development of the regional clusters. In the Metropolitana region, two major national pharmaceutical laboratories are now acting as investors and partners of biotechnology companies. In the last six years, two large national pharmaceuticals have engaged in research projects or invested in biotech companies. One pharmaceutical company bought a DBF in the field of medical diagnostics. As mentioned before, in Bío-Bío the forestry companies have invested in consortia companies with a focus in biotech; however, they have not become investors in other new ventures. Aquaculture firms, on the other hand, have not been largely involved in the creation of new biotech firms in Los Lagos. Just one company participated in the creation of a consortium with other universities, which

is now established as an independent biotech firm. As discussed above, the entry of new investors might be crucial for the development of the cluster; therefore, the involvement of these big companies as investors could play an important role in the development of the sector, particularly in regions far from the capital with no venture capital firms physically present.

4.4.4 INDUSTRY ASSOCIATION

The original biomedicine entrepreneurs in the Metropolitana region have also played an important role in the development of the entire biotech sector in the country. In particular, they drove the creation of the sector's association, ASEMBIO, and pushed for the inclusion of biotechnology in the government development agenda in 2006. They are central to the creation of collective action in the sector, in the local and national realm, which is a signal of a new growth stage for the sector.

According to Gertler and Vinodrai (2009), industrial associations are important for the development of biotech sectors when they align the interests and resources of different stakeholders in the cluster. The cluster life cycle model of Menzel and Fornahl (2009) identifies the process of building institutions to promote collective actions and lobbying for the achievement of the needs of a cluster as a sign of growth. If industrial associations manage common resources, effectively promote collective actions and reduce the probability of free riding (Ostrom, 2000), firms can benefit from the positive externalities of agglomerations, which might reinforce the linkages and sustained growth of a cluster. ASEMBIO has an important role in promoting networking between biotech companies in Chile and in encouraging innovation policies towards the promotion of the sector. In the case of this cluster, ASEMBIO seems to be in early stages of promoting collective action.

The personal and business relations between entrepreneurs of the first firms established in Santiago were crucial for creating ASEMBIO. The association was founded in 2004 by a group of the early entrepreneurs in the sector. An entrepreneur from a small company that provides consultancy services for biotech firms attended the International Convention of the Biotechnology Industrial Organisation in 2001 and 2002, one of the most important international biotechnology fairs in the USA. This made him aware of the different perspectives and strong organisation that biotechnology companies had abroad. In 2003, at the National Biotechnology Congress, he met with the owners of the first two biomedicine companies in Chile, BiosChile and Biosonda. They decided to form ASEMBIO; the first office of the association was within the facilities of Biosonda.

During the first years of ASEMBIO, the focus was on establishing connections with international organisations and promoting the importance of biotechnology in Chilean governmental agencies. In 2010, a new administration proposed to change the activities undertaken by ASEMBIO. They have two projects financed and supported by CORFO and the Ministry of International Relations. The first aims to promote the Chilean biotechnology sector in the USA by promoting Chile as a country with high biotechnology potential. The second project aims to enhance relationships between 'bioentrepreneurs' and investors, and to generate a favourable environment for entrepreneurship in the biotechnology sector in Chile.

ASEMBIO brings together not only biotechnology companies from all areas, but also venture capital companies, research institutions, universities, government institutions and patent law firms. However, there is little participation by biotech firms outside the Metropolitana region. A couple of firms from Valparaíso are associated with ASEMBIO; however, many other firms think that participating in

ASEMBIO would not benefit them. Therefore, the association is an important actor but mainly in the Metropolitana region.

There are other industrial associations that could play an important role in the sector, but there is no interaction between these associations. In biomedicine, for example, there are two pharmaceutical laboratory associations. One brings together national laboratories and the other international laboratories. Nevertheless, the two largest national pharmaceutical laboratories were bought last year by international pharmaceutical firms. There might be scope for national laboratories to collaborate with local biotechnology companies. International laboratories could also collaborate with local biotech companies and public policies could promote such cooperation in the country. Only Pfizer has established (in 2015) a research centre in Santiago that collaborates with national universities in research projects. In other sub-sectors of biotechnology, such as biotechnology in marine biology, agriculture or bioprocesses, other associations could play an important role as well. An example could be the case of mining, where the main mining companies in the country are collaborating to create a network of suppliers in the sector. This programme and association could be highly important to promote the creation of bioprocess firms focused on mining-related areas. ASEMBIO could promote these new interactions in biotechnology and include other important actors and areas within biotech.

4.4.5 PUBLIC AGENCIES

As described in Section 3 of this chapter, there are two national public agencies, CORFO and CONICYT, that have been highly significant in the development of research and firms in the biotechnology sector. Also, in agriculture there are two additional public institutions that have an important role to play in the

biotechnology sector focused on agriculture; these are the Foundation for Agrarian Innovation (FIA in Spanish) and INIA.

It is important to note that, from the interviews and surveys, most collaborations between firms and universities were done under government programmes that promote collaborative research in CONICYT and CORFO. In this particular cluster, based on knowledge and research, collaborative research grants act as indirect research subsidies for biotech companies.

All these agencies have their headquarters in Santiago, the Metropolitana region, and have regional agencies. With respect to CORFO and CONICYT, the regional agencies' main efforts are concentrated on promoting the programmes that the agencies run, and on providing support to regional institutions in the application process. However, the regional agencies do not administrate regional budgets or develop regional programmes. All the programmes run and developed in CORFO and CONICYT are decided by headquarters.

Therefore, in the Metropolitana region these agencies have a greater role in the biotechnology sector than at the regional level. The regional agency of CORFO in Bío-Bío has attempted to gain more independence in generating activities to promote collaborative research projects between regional universities and firms. However, regional agencies do not play a major role in the development of biotech firms at the regional level.

With respect to the agencies oriented towards agriculture, FIA follows a similar organisational structure to CORFO; its four regional agencies are not that active in the generation of innovations, but rather bring together regional and national actors in the adaptation and generation of innovations. On the other hand, INIA is a public research centre with a regional presence in regions with a strong

agricultural sector. Its role has been important in the production of research with local universities, and also in technology adoption and diffusion in agricultural firms.

In other sub-sectors of biotechnology, there are no public agencies focused on promoting a particular sector, although public agencies in charge of regulations play a role defining institutions and development frameworks for biotech firms in different areas. These agencies, such as the Public Health Institute, the Fishing Institute or the National Patent Institute, do not collaborate with firms and do not provide public grants for research or innovation in firms. Therefore, their role is important for the framework conditions of biotech firms, but they are not considered actors in the cluster.

This section has described the different actors and their role in the biotechnology sector in four regions of Chile. The next section will present descriptive statistics on firms derived from the survey conducted as part of this thesis.

4.5 DESCRIPTION OF FIRMS IN THE BIOTECHNOLOGY SECTOR

This section presents descriptive and summary statistics for the biotechnology sector in Chile, obtained from the survey conducted. Table 4.4 shows the distribution of different types of firms in the sector and descriptive statistics from the firms interviewed for this study. Most of the surveyed firms are part of what I will call the 'core' of the sectors, i.e. DBFs, research centres using biotech, and laboratories that uses biotech processes. These firms are the core because they are based around biotechnologies and employ biotech research for their products and services.

Table 4.4 Firms' Characteristics by Type of Firm in the Biotechnology Sector

Type of Firm	Distribution		Year of Creation		Firms Age		Firms with Foreign Ownership	Percentage of Foreign Ownership *		Exporting Firms	Percentage of Sales Exported		Number of Employees		Number of Researchers		Number of PhDs	
	(N)	(%)	(Median)	(Mean)	(Median)	(Mean)	(%)	(Median)	(Mean)	(%)	(Median)	(Mean)	(Median)	(Mean)	(Median)	(Mean)	(Median)	(Mean)
Dedicated Biotech Firm	31	35.6	2001	1999	12	14.4	20.7	63.8	68.6	46.7	12.0	40.1	19.0	45.5	4.0	8.9	2.0	3.0
Lab Services using Biotech	10	11.5	2003	2001	10	12.0	0.0	0.0	0.0	75.0	4.5	7.7	13.0	14.5	3.0	2.8	1.0	1.4
Research Services using Biotech	8	9.2	1999	2001	14	12.0	16.7	100.0	100.0	16.7	5.0	10.0	18.5	48.1	3.0	43.4	1.5	6.4
Consortium	6	6.9	2007	2007	6	6.3	20.0	5.0	5.0	16.7	95.0	95.0	4.5	8.2	20.0	18.3	3.5	3.7
Firms using Biotech processes	9	10.3	1992	1987	21	26.0	11.1	40.0	40.0	33.3	21.0	33.7	14.0	81.9	2.5	3.0	0.0	0.9
Pharmaceuticals	7	8.0	1964	1965	49	47.7	66.7	90.8	74.5	50.0	20.6	20.6	40.0	417.3	3.0	3.4	0.0	0.7
Commercial Representative	3	3.4	1996	1995	17	18.3	33.3	100.0	100.0	66.7	32.5	32.5	90.0	213.3	4.0	4.0	0.0	8.3
Services to Biotech Firms	13	14.9	2007	2004	6	9.5	7.7	100.0	100.0	30.8	20.0	23.7	5.0	7.5	3.5	3.5	1.0	0.9
Total	87	100.0	2001	1996	12	16.9	19.0	81.6	70.3	42.0	14.6	30.9	14.0	73.4	3.0	11.3	1.0	2.7

Note: * Median of the % of capital foreignly owned in Chilean firms with at least 1% of foreign ownership

Another important group are firms that provide services to biotech firms. They are mainly consultants, investors, venture capital companies and legal firms. Potential clients in the sector, such as pharmaceuticals and firms using biotechnologies in their processes, are the oldest firms. The core firms and service firms are the youngest, an indication that the sector is still relatively new in the country. Table 4.4 shows that 21% of DBFs have part of their property owned by foreign companies; the average foreign share percentage is 69%. Private foreign research institutions account for 17% of these type of firms, while there are no foreign-owned laboratories. Most pharmaceutical firms (67%) have a large percentage of foreign ownership (75%). Overall, 33% of commercial representatives of international firms and 8% of companies are providing services to biotech firms that are completely foreign owned.

With regards to exports, 47% of DBFs sell products abroad. On average, 40% of their sales are exports. A larger proportion of laboratories export their products and services (75%); however, their exports account for only 8% of their sales. The Latin American market is the main recipient of exports from Chilean firms in the biotech sector, followed by the USA and European countries (Table 4.5).

Table 4.5 Average Share of Exports Distributed by International Markets of Exports

International Markets	Type of Firm								
	Dedicated Biotech Firm	Lab Services using Biotech	Research Services using Biotech	Consortium	Firms using Biotech processes	Pharma-ceuticals	Commercial Representa-tive	Services to Biotech Firms	Total
Number of observations	14	6	1	1	3	3	2	4	34
USA	24.6%	0.0%	0.0%	100.0%	11.7%	0.0%	0.0%	25.0%	15.2%
Latin America	45.0%	60.7%	33.3%	0.0%	86.7%	71.6%	100.0%	32.5%	53.5%
Europe	22.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.0%	9.9%
Asia	0.7%	0.0%	0.0%	0.0%	1.7%	2.6%	0.0%	2.5%	0.9%
Other	0.0%	1.1%	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.3%

Note: Percentages over firms exporting

The average number of employees in total shown in Table 4.4 (74 employees) is biased by big pharmaceutical companies, commercial representatives and large firms that use biotechnology in the sector. DBFs usually have fewer than 50 employees – categorising them as small firms – while pharmaceuticals are large companies both in terms of sales and the number of employees, as shown in Table 4.6. In terms of the number of researchers, research centres have the highest number of researchers (43.4 on average), followed by consortia that include universities (18.3 on average) and then DBFs (8.9 on average). However, the number of employees with PhDs is relatively low in comparison with the number of researchers with PhDs. Commercial representatives of machines and reagents have a higher number of PhDs; however, they do not perform research activities but work as salesmen for high-tech products.

Table 4.6 Size of Firms by Sales and Number of Employees

	Type of Firm								
	Dedicated Biotech Firm	Lab Services using Biotech	Research Services using Biotech	Consortium	Firms using Biotech processes	Pharma-ceuticals	Commercial Representa-tive	Services to Biotech Firms	Total
Number of observations	31	10	8	6	9	7	3	13	87
Size by Sales									
Small (less than 115,000 dollars)	8	0	2	3	2	0	0	1	16
Medium (between 115,000 and 4,7 million dollars)	11	6	2	0	3	0	0	5	27
Large (more than 4,7 million dollars)	12	4	4	3	4	7	3	7	44
Size by Number of Employees									
Small (less than 50 workers)	25	10	6	6	6	4	0	13	70
Medium (between 50 and 200 workers)	4	0	2	0	2	0	2	0	10
Large (more than 200 workers)	2	0	0	0	1	3	1	0	7

Sales and number of employees are usually used to classify organisations by size (Table 4.6). Most firms in the core of the sector are small in terms of number of employees; however, since this is a knowledge-based sector, it is possible to observe that firms with a small number of employees obtain higher sales. For example, as Table 4.6 shows, 81% of DBFs have fewer than 50 workers, yet only 26% of them are small in terms of sales (i.e. with sales lower than US$115,000 dollars).

Table 4.7 Markets by Type of Firm

Market	Type of Firm								
	Dedicated Biotech Firm	Lab Services using Biotech	Research Services using Biotech	Consortium	Firms using Biotech processes	Pharma-ceuticals	Commercial Representa-tive	Services to Biotech Firms	Total
Number of observations	31	10	8	6	9	7	3	13	87
National Market									
Final consumer	12	6	2	1	6	5	1	3	36
Company in the biotechnology sector	7	3	2	1	1	1	0	7	22
A trade or distribution company	6	1	2	1	3	1	1	3	18
Hospitals or Health Centres	4	5	3	1	1	2	2	3	21
Universities	3	4	2	2	0	0	1	7	19
Production Firm in Other Economic Sector (e.g. Mining)	4	1	2	3	0	2	0	2	14
Public Sector	14	5	4	2	3	2	1	7	38
International Market									
Final consumer	8	2	1	1	2	2	0	1	17
Company in the biotechnology sector	5	1	1	0	1	0	0	6	14
A trade or distribution company	1	0	0	0	2	0	1	2	6
Hospitals or Health Centres	2	2	1	1	0	1	1	2	10
Universities	1	0	1	0	0	0	0	2	4
Production Firm in Other Economic Sector (e.g. Mining)	4	0	1	1	0	1	0	3	10
Public Sector	11	1	2	1	1	0	1	3	20

Note: Multiple responses allowed

Table 4.7 shows the markets targeted by the firms in the biotech sector. It is possible to observe the value chain of the sector, but also the multiple roles and

markets of the firms, as represented in Figure 4.3. Laboratories focus mainly on the national market, particularly on the final consumer, health and public sector, and on universities. DBFs and research centres also have a focus on the national market, although with higher level of diversification.

Finally, the large majority of firms are private companies (Table 4.8), although a small proportion (8%–22%) are considered family companies since the owners and partners are all from the same family. Within the classification of other types of organisations, it is possible to find non-profit firms or research institutes.

Regarding areas of research within biotechnology, the most important area is 'Health and Medical Diagnosis', with most DBFs (33%) and laboratories (75%) indicating it as their main biotechnology area. These facts might stress the importance of path-dependence processes in the formation of this sector, since this area was the main focus of the initial biotech firms in the country. Other important biotech areas are: agriculture, aquaculture, and food and nutrition.

Table 4.8 Type of Organisation and Main Biotechnology Area

	Type of Firm								
	Dedicated Biotech Firm	Lab Services using Biotech	Research Services using Biotech	Consortium	Firms using Biotech processes	Pharma-ceuticals	Commercial Representa-tive	Services to Biotech Firms	Total
Number of observations in Survey	31	10	8	6	9	7	3	13	87
Company Organization									
Family Company	2	1	0	0	2	1	0	2	8
Private Company	27	7	6	6	7	5	3	11	72
Other type of company	1	0	1	0	0	0	0	0	2
Total	30	8	7	6	9	6	3	13	82
Main Biotechnology Area of Research and Production									
Health and Medical Diagnosis	10	6	0	2	1	4	n.a.	n.a.	23
Food and Nutrition	3	0	0	0	2	0	n.a.	n.a.	5
Aquaculture and Marine Biology	4	0	2	0	0	1	n.a.	n.a.	7
Agriculture	9	2	1	0	1	0	n.a.	n.a.	13
Patents, Publications, Inventions	1	0	1	1	0	0	n.a.	n.a.	3
Bioindustry with Genetic Tech	1	0	3	3	0	0	n.a.	n.a.	7
Bioprocess and Clasic Fermentation	2	0	0	0	0	0	n.a.	n.a.	2
Total	30	8	7	6	4	5	n.a.	n.a.	60

Note: The number of observations is lower since not all surveyed firms answer these questions

4.6 CONCLUSION

This chapter has presented descriptive evidence from secondary sources and from the survey and interviews conducted in this research. From the information, it is clear that the biotechnology sector in Chile has similar characteristics to those in countries such as in Canada (Gertler and Vinodrai, 2009), though the size of the sector in Chile is much smaller. Nevertheless, the sector is relatively efficient in scientific publications, showing a potential for growth in certain niches of biotechnology research that are not being studied in other countries, such as in aquaculture forestry and health, which are more important to the Chilean national context (CORFO, 2007; Santibáñez, 2010a, 2010b).

The four regions studied in this case show different levels of development of biotech clusters. From a cluster life cycle perspective, following Menzel and Fornahl (2009), the biotechnology clusters in Chile are still in a formative stage. The biotechnology cluster in the Metropolitana region shows higher levels of development and cohesion than in other regions. For the last ten years, there have been important changes in the sector, but these have been mainly concentrated in the Metropolitana region. The creation of the industrial association, the creation of venture capital funds investing in biotechnology and the foundation of new start-ups and spin-offs might be seen as major changes in the cluster evolution. The cluster seems to be in an early phase of growth, as defined by Feldman, Francis and Bercovitz (2005), with new players and relations among them. How the cluster will develop from this stage may depend on how institutions evolve.

There are a series of events that show the path-dependent growth of the sector in line with analysis from other biotech clusters in the USA and Canada (Feldman, 2003; Gertler and Vinodrai, 2009). In the Metropolitana region there is a clear

anchor firm and leader entrepreneurs promoting the development of the sector. The importance of an anchor firm or institution in the development of biotechnology clusters has been studied in the case of biotechnology clusters in the USA and Canada (Feldman, 2003; Gertler and Vinodrai, 2009). The lack of such a leader or anchor institution in other regions might hinder the development of biotechnology clusters in other geographical areas in the country outside the Metropolitana region. As discussed above, in the Bío-Bío region it was a leader scientist that promoted the creation of the Biotechnology Centre in the region's main university. It may be that this centre will become an anchor institution in the development of the local biotech cluster; however, other regions do not appear to have an actor with such leadership potential.

There are benefits and potential disadvantages in the existence of a few anchor firms or highly important actors in the sector. The main benefit is that linkages between an anchor firm and its owners have been crucial for the development of the biotech cluster in the Metropolitana region. In particular, the successful example of BiosChile in the Metropolitana region might mean that it can act as a leading firm in the cluster, attracting other entrepreneurs and firms to locate their firms in the region. Another important benefit is the creation of relations among entrepreneurs, academics and venture capital firms, advancing the development of the sector in Chile, particularly through promoting the potential of the sector in terms of the country's economic growth among politicians. The competitive features of the sector, however, promote collaborations with research institutions but discourage collaboration with potential competitors (Hagedoorn et al., 2000; Hernández-Cuevas, 2007). This feature of the sector could be taken into consideration in the policies oriented towards developing the biotechnology sector, and towards

promoting international collaborations and internationalisation of companies, increasing their growth and potentially their exports.

Some drawbacks of this leadership can emerge, especially if there is only one important firm in a small cluster, as for those observed in Chile. As Christopherson and Clark (2007) have shown, the power of multinationals in a network of firms could hamper the growth of local companies if they exert that power to promote their interests alone, which could be unaligned with the interests of national companies. A similar situation might occur in a cluster if there is only one important firm which has relatively more power than others, and also if its interests are different from those of other firms. Another potential downside of having only one major leading firm is the possibility of generating a lock-in of knowledge in the cluster (Gertler and Vinodrai, 2009; Menzel and Fornahl, 2009; Uzzi, 1996). External linkages and relations are crucial to reducing this risk, particularly to attracting other investors and entrepreneurs to the sector. In this respect, social relations between venture capital firms and biotech entrepreneurs may be crucial to obtaining financing for new ventures, which in turn could potentially reduce the sector growth if new entrepreneurs do not have the necessary relations with venture capital firms. The sector might need a successful case of a new biotech product developed in Chile to attract foreign investors, but public institutions could also promote international exposure of new ventures to seek financing support from foreign venture capital firms.

The importance of personal and business relations in the Chilean biotech sector for the emergence of biotech firms, the development of new business collaborations and the creation of new knowledge will be studied in detail in the following chapters.

5 SOCIAL NETWORKS, CO-LOCATION OF FIRMS AND CLUSTER EMERGENCE

5.1 INTRODUCTION

As mentioned in Chapter 1, the concept of cluster followed in this thesis has two main elements: geographic agglomeration of firms and actors, and interactions between those actors (Porter, 1998a). In this chapter, I will study cluster emergence by focusing on location decision at the firm level, since this process sparks the geographic agglomeration of firms.

This decision for the firm can be studied from the traditional transaction costs point of view or in terms of the individual decisions taken by the entrepreneurs. On the one hand, under the transaction costs literature, the optimal location of firms is based on a reduction of transport costs and close physical proximity to suppliers and clients. Some of the costs to consider when choosing a location are tax reductions, input costs, and transport and search costs with clients and suppliers. Other considerations are employment and the presence of a skilled labour force (Feldman and Braunerhjelm, 2006; Karlsson, 2008a, 2008c; Lawton Smith, 2008). But the co-location of companies does not necessarily imply an increase in firm productivity. Co-location of firms by itself will not cause knowledge spillovers or agglomeration economies (Boschma, 2005). Companies in a cluster co-locate in a geographical area, but they may or may not have business relations. Formal and informal networks and connections between companies are fundamental for knowledge spillovers and to exploit the advantages of co-location (Boschma, 2005; Giuliani, 2007; Giuliani and Bell, 2005).

On the other hand, the entrepreneurship literature has included social networks and the social capital of entrepreneurs as crucial for entrepreneurial action (Audretsch and Aldridge, 2008; Bercovitz and Feldman, 2008). Social networks affect the identification of opportunities and access to key resources, such as financial capital and knowledge, in the establishment of start-ups (Audretsch and Aldridge, 2008; Hsu, 2007; Uzzi, 1999). However, the role of entrepreneurs' social capital and social networks in the formation of clusters has not been extensively studied in cluster literature, despite the recognition of their impact in decisions at the level of the entrepreneur. In this chapter, I will combine entrepreneurship and cluster literature to examine the importance of social networks in the early stages of cluster formation.

Location decisions are so intertwined with the decision to set up a firm that they have not been studied on their own terms. It is assumed that location is determined and subordinated to creation decisions, and it is often considered location inertia when entrepreneurs maintain their previous location because 'they had strong personal ties to the region' (Feldman, 2001). Location decisions, and particularly co-location, are fundamental for the emergence of a cluster, yet it is surprising that the cluster literature has not focused on this issue. The location decisions of clustered firms are assumed to follow the benefits of the cluster location. However, for the first companies establishing themselves in a cluster there are no obvious co-location benefits. Pitelis (2012) has developed a theory of cluster emergence by introducing entrepreneurial action as central to the co-creation and co-evolution of firms, markets and clusters. In Pitelis's argument, the location decision of first entrepreneurs is based on the OLI model developed by Dunning and on the advantages of a location to increase the 'productivity opportunities', as

developed by Penrose (1995), perceived by the entrepreneurs. The OLI model was developed by Dunning to explain location decisions taken by multinationals outside their home countries; it is questionable whether the assumptions would be the same for emerging firms, as proposed by Pitelis (2012), particularly when sectors and markets do not yet exist. The importance of studying the location decisions of the initial firms in the emergence of a cluster is therefore significant for the advancement of cluster literature.

This chapter will explore the importance of social relations – personal and business – for the location decisions of new firms of the biotechnology sector in Chile. The central proposition of this study is that personal and business relations, as a proxy for social capital, affect the creation and location of start-ups, since social capital improves access to resources, enhances opportunity recognition and helps to overcome obstacles faced in the establishment of a new firm. New firms in sectors with significant capital and technological knowledge requirements, a high level of risk, uncertainty about return on investment and information asymmetries, such as biotechnology, face greater obstacles to being established. Entrepreneurs' social capital might help to overcome these market imperfections, allowing them to access different networks of support and affecting the location decisions taken for new companies. This study also proposes that the location decisions of firms will depend on the entrepreneur's benefits or the strategic use of their social networks (Lin et al., 2001), in the sense that social capital is mobilised to access key resources and to identify new opportunities when establishing a firm in a particular sector.

This study aims to provide some insights into the importance of social relations for high-tech firms and cluster formation in emerging economies. The main results suggest that social capital plays an important role in overcoming difficulties

accessing resources such as qualified staff and knowledge, and financial capital from the financial sector and venture capital firms. It is also important for accessing suppliers and clients. Business relations, in particular, are highly significant for the location and creation of firms.

The chapter is structured as follows. Section 5.2 summarises the relevant literature and draws out the main hypothesis of the paper. Section 5.3 describes the methodology employed to collect the data and the representativeness of it. Section 5.4 presents the results of the content analysis of open-ended questions and in-depth interviews and the statistical analysis of quantitative data. Section 5.5 proposes a framework for cluster emergence that links the results at the firm level to the process of co-location and the emergence of a cluster. Finally, Section 5.6 concludes.

5.2 LITERATURE AND THEORETICAL FRAMEWORK

There are two separate streams of literature that are not usually combined to understand the phenomenon of cluster emergence: cluster literature and entrepreneurship literature. Literature on clusters, mainly from economic geography, has traditionally emphasised the role of local factors in the emergence of agglomerations of firms. The main argument is that local factors such as local knowledge, natural resources and cost reductions are sufficient to attract new firms to the same area (Feldman and Braunerhjelm, 2006; Karlsson, 2008a, 2008c). Later, economies of agglomeration will attract new entrants until there is equilibrium between the benefits and costs of agglomerations (Maggioni, 2006). This literature has implicitly assumed that there is a point at which a certain number of firms will gain agglomeration economies and will then attract others. However, this critical

mass, or number of first entrants, cannot be empirically determined and is assumed to be dependent on local factors, type of industry and public policies (Maggioni, 2006).

Cluster literature has not widely included entrepreneurs' agency in the development of clusters, nor has it taken into account the factors that shape the first entrants' creation and location decisions, leaving an important research question unanswered (Feldman, 2008; Pitelis, 2012). The literature on entrepreneurship, in contrast, emphasises the role and agency of entrepreneurs in founding new companies that will later form a cluster, recognising the importance of networks of entrepreneurs (Feldman et al., 2005; Feldman, 2008). Also, social network literature highlights the importance of social capital in creating links between actors in a network (Owen-Smith and Powell, 2004; Powell et al., 1996). So far, less attention has been paid to the role of entrepreneurship and social networks in the formation of clusters; therefore, there is scope to study further the role of social networks and relations in cluster emergence.

The structure of networks of firms can influence the business relations that a firm creates, affecting the formation of companies, and later the emergence and development of a cluster (Hite, 2005; Perez-Aleman, 2005; Whittington et al., 2009). However, the role of social structures and entrepreneurs in cluster formation is still not clear (Feldman and Braunerhjelm, 2006; Pitelis, 2012; Ter Wal and Boschma, 2009a). In this study, I explore the relation between entrepreneurial location decisions and the emergence of biotechnology sectors in four regions of Chile. I also bring together entrepreneurship and cluster literature in order to deepen our understanding of the processes behind cluster creation.

5.2.1 LOCAL FACTORS IN CLUSTER EMERGENCE

The environment plays an important role in the decision to establish a new company in a particular sector and location (Feldman et al., 2005; Feldman, 2008; Karlsson, 2008b). Policies and regional factors shape the environment. Therefore, policies, institutions and local factors are important for cluster formation, the decision to start a new company and its location (Feldman et al., 2005; Feldman and Braunerhjelm, 2006; Feldman, 2008; Karlsson, 2008b).

Feldman, Francis and Bercovitz (2005) suggest three phases in the development of a cluster. First, individual entrepreneurs establish the first start-ups, which may be supported by external factors, such as a change in policy. The second phase is characterised by linkages formation, self-organisation between the start-ups and the emergence of venture capitalists. In this phase, social capital between early entrepreneurs and other organisations is very important. The third phase is the maturation of the cluster with public and private financing, and the deepening of social ties. These phases are consistent with the proposition of Pitelis (2012) that clusters emerge because firms and entrepreneurs want to appropriate the value of co-created resources. The location decisions of entrepreneurs could help to develop an entrepreneurial ecosystem that might create a cluster endogenously. Yet location decisions in Pitelis's (2012) model are based on Dunning's OLI model, which does not necessarily hold for small start-ups.

Local factors, such as a reduction of transport and transaction costs, a pool of labour with the necessary skills to work in the sector or reduced taxes, can influence the location or co-location of companies (Karlsson, 2008b). The possibility of benefiting from knowledge spillovers is also important for location decisions (Audretsch and Aldridge, 2008). Knowledge has been defined as being explicit or

tacit, and its diffusion occurs through formal and informal interactions between agents in a cluster (Lawton Smith, 2008). Tacit knowledge refers to the non-codified knowledge, while explicit knowledge refers to the formal and codifiable knowledge (Audretsch and Feldman, 2004). It has been argued that the tacit knowledge makes geographic proximity an important element in firms' agglomerations (Audretsch and Aldridge, 2008; Boschma, 2005). Tacit knowledge is more commonly diffused by informal interactions, particularly in high-tech clusters (Lawton Smith, 2008). Informal interactions are usually based on personal relations and social capital, which may influence the location decisions of new firms, spurring firm agglomeration (Lawton Smith, 2008). Given this discussion in cluster literature, it seems important to analyse how the entrepreneurs' relations and social capital could influence the emergence and location decisions of firms in the first stages of a cluster and shed light on the social structures behind this process.

5.2.2 NETWORKS AND ENTREPRENEURSHIP

Entrepreneurs are catalysts for cluster emergence (Karlsson, 2008b). Opportunity recognition and access to resources are two key aspects for entrepreneurs in the decision to establish a new venture (Audretsch and Aldridge, 2008).

Uzzi (1997, 1996) shows that entrepreneurs and start-ups are embedded in a social structure that affects their economic outcomes. The embeddedness of firms allows them to manage their resources efficiently and to adapt to complex environments. Nevertheless, Uzzi identifies an inverted U of benefits. After a certain level of embeddedness – or over-embeddedness – there are negative effects, making firms vulnerable to external shocks and reducing sources of external information

and knowledge. Thus, the negative effects of networks should be borne in mind when analysing networks of firms.

In relation to funding for entrepreneurs, results from Hsu (2007), on the information and communications technologies industry in the USA, identify the importance of previous ties with venture capitalists to increase the likelihood of gaining funding. These results are in line with results from Uzzi (1999), who identifies lower interest rates in credit extended to firms with social ties with their lenders. Therefore, it is possible to identify the importance of entrepreneurs' social capital and networks in financing start-ups.

Regarding location, Carlton (1983) assesses the location of new firms in the USA between 1967 and 1971. He finds that energy costs have an important effect on location decision, in line with cluster literature. However, taxes or state programmes to attract new firms do not seem to have a significant effect on location. Concentration of employment and skilled labour is important to location, particularly for industries with a small average plant size and high-tech sectors. Nevertheless, Carlton did not study the location decision process, but the actual location of firms, which is the result of the decision process.

This stream of literature has not focused on entrepreneurs in clusters or their role in cluster genesis. It has been suggested that clusters, or firm agglomerations, increase the creation of new firms in the same location (Bercovitz and Feldman, 2008; Pitelis, 2012; Porter, 2000). However, Walker et al. (1997), in analysing the new relations of start-ups in the US biotechnology sector between 1984 and 1988, find that there is evidence that social capital tends to reproduce network structures over time. Thus, the persistence of firms' roles within a network could restrict entrepreneurship in certain networks. Feldman (2008) studies the emergence of

the biotechnology and information and communication technology clusters in the Capital Region in the USA, identifying those exogenous factors, such the reduction of state control in the 1970s and the introduction of policies promoting technological patents and licensing by public research centres and universities, which prompted former governmental researchers and employees to decide to start their own companies. Feldman (2008) also determines that the social structure of the region, particularly relations between previous entrepreneurs, professional networks and firms' associations, acted as supportive organisations for the creation of a dynamic entrepreneurial region.

These results are in line with what Audretsch and Aldridge (2008) propose regarding the knowledge spillover theory of entrepreneurship and the geographic clustering of firms. The authors argue that in regions where there is a higher rate of knowledge creation in private or public organisations, there is a gap between total knowledge and 'economically valuable knowledge', or the knowledge that is already being commercialised in the market (Audretsch and Aldridge, 2008, p. 68). This gap gives employees, academics or researchers an opportunity to decide to establish a company if their personal evaluation of the risk and costs of creating a new firm is sufficiently favourable. The appreciation of risk and costs by individual; according to Audretsch and Aldridge (2008, p. 69), the origin of these differences are in part due to differences in access to information, personal skills, and financial and social capital.

5.2.3 THEORETICAL FRAMEWORK

From the discussion presented above, it is possible to conclude that the social networks of entrepreneurs might facilitate or restrict the linkages that a start-up

creates, affecting the establishment of the firm. This in turn will impact the emergence and evolution of a cluster. In emerging economies, social networks might be even more important for the creation of high-tech firms and knowledge-based cluster formation since it may be more difficult to gain access to key resources to create a firm than in developed economies. For example, there are only two venture capital firms in Chile that invest in biotechnology firms, and therefore access to this type of capital might be more difficult.

The creation and initial location decisions of a start-up are intertwined. I will assume that the decision to establish a firm depends on two main factors: the local factors relating to a specific territory; and access to resources and opportunity recognition in that territory. Personal networks, however, facilitate access to the necessary resources and shape opportunity recognition (Arenius and Clercq, 2005). Therefore, location decisions will also take into account the social capital and networks of entrepreneurs. Social capital and social networks may influence firms' location decisions, shaping the formation of a cluster. Social capital will be considered, following Lin's (2001) definition, as 'resources embedded in a social structure which are accessed and/or mobilised in purposive actions' (Lin, 2001, p. 12). Previous studies allow me to conclude that social capital and networks of firms in earlier phases of a cluster's emergence are important to its development.

Assume that there is a distribution of resources important to creating firms across different regions of a country, and that there are no information asymmetries for all entrepreneurs. However, opportunity recognition is influenced by an entrepreneur's social capital (Audretsch and Aldridge, 2008), affecting the decision on whether or not to start a company. The entrepreneur's relations determine his or her social capital. All an entrepreneur's relations will form social networks, which

are created through social interactions determined by location and the path-dependent processes of an entrepreneur's life. This aspect of personal social network creation and evolution implies that social capital and social networks differ between entrepreneurs and are unevenly distributed among entrepreneurs and regions. Given that the ability of entrepreneurs to identify opportunities and access key resources for firm creation is shaped by their social networks, and that this is unevenly distributed across persons and regions, entrepreneurs' capacity to start a new venture (and bear the costs involved) will be different in each region and for each entrepreneur.

For example, if an entrepreneur wants to access resources in a region where he or she has only a few linkages and low social capital, the cost will be higher than for accessing the same resources in a region where he or she has strong and multiple linkages in his or her network, i.e. higher social capital. Thus, creation and location decisions will be chosen to maximise access to resources and the identification of opportunities that an entrepreneur could gain from his or her social network, which should minimise the creation costs of a new firm.

In high-tech sectors, such as biotechnology, the main resources for starting a company are: financial capital, high-skilled labour, and scientific and technological knowledge (Kolympiris et al., 2015; Lawton Smith, 2008; Zhang and Wong, 2008). The social networks of entrepreneurs facilitate access to these key resources. Zhang et al. (2011) studied the importance of personal ties for reducing information asymmetries between investors and entrepreneurs in high-tech start-ups in China and Singapore. Their results show that personal connections effectively reduced information asymmetries and increased the likelihood for entrepreneurs of

obtaining financial resources from investors with no prior knowledge of the technologies and the start-up sector.

Social networks also enable entrepreneurs to recognise opportunities (Arenius and Clercq, 2005; Bhagavatula et al., 2010; Crawford et al., 2015; Ma et al., 2011). In particular, it is necessary to have information on, for example, the structure of the market, potential clients, legal and services firms, the economic activities in the same region, intellectual property rights, and regulatory processes. Knowledge about the market is also valuable, although is not considered a knowledge resource; it can be considered knowledge that affects opportunity recognition. Knowledge concerning actors in the sector (other agents such as universities, anchor firms, governmental agencies, etc.) affects both opportunity recognition and access to key resources. The social networks of entrepreneurs could also shape access to knowledge and information on these aspects (Audretsch and Aldridge, 2008). In addition, access and closeness to key actors in the system could increase credibility or reputation, facilitating access to other resources such as financial capital or clients. Reputation could be highly important in a sector with information asymmetries, where reputation in other areas, such as in science or academia, could stand as a proxy for the quality of scientific and technological knowledge, which is important for starting a biotechnology company. Knowledge about these aspects is also a valuable resource for the entrepreneur. Therefore, as noted in Chapter 1, the first two hypotheses of this study are:

> *Hypothesis 1a: Entrepreneurs' social networks will reduce the transaction costs and the costs to access resources to establish a company. Therefore, it is more likely that a firm will be located where entrepreneurs' social*

networks minimise the costs to access required resources or, equivalently, where entrepreneurs maximise access to resources.

Hypothesis 1.b: The entrepreneurs' social networks will shape and determine opportunity recognition identified by entrepreneurs. Therefore, it is more likely that a firm will be located where the entrepreneurs' social networks facilitate the identification of a profitable opportunity.

These two aspects, access to resources and opportunity recognition, will in turn affect location and creation decisions, and will later affect the growth of the companies and the development of a cluster in a particular location. Thus, social networks affect process of creation and location indirectly through access to resources and opportunity recognition. These relations lead to a set of corollaries:

Corollary 1: A firm will be more likely to be located where the entrepreneur's social network is more important for access to resources and opportunity recognition simultaneously.

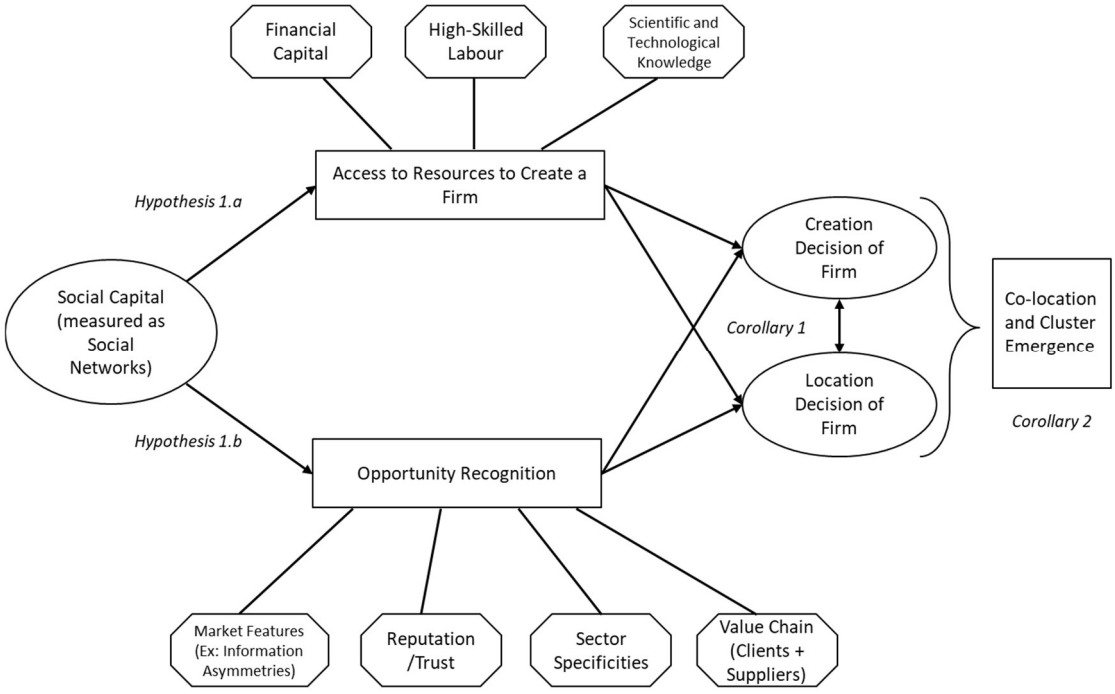
Corollary 2: Firms will co-locate if the benefits of their owners' social networks are higher in the same locality than in another.

A conceptual model of the theoretical framework is presented in Figure 5.1. The model shows the hypotheses discussed above. Social capital measured by social networks, particularly business and personal connections, which affect access to resources to create a firm (Hypothesis 1a) and opportunity recognition (Hypothesis 1b). In turn, access to resources and opportunity recognition will affect the decisions to create a firm and locate it in a particular area (Corollary 1).

If this model has empirical support, it would be possible to establish that entrepreneurs will in fact decide to create and locate a firm where their social

networks reduce the cost of creation, by giving them access to resources and by increasing the possibilities for opportunity recognition. Therefore, entrepreneurs will usually establish their firms where they can maximise the benefits of their social networks, whether these be personal or professional. This is usually the same place where the entrepreneur lives, studies or works at the moment of the decision to establish a firm. Given this argument, the co-location of firms in the first stages of a cluster will usually be generated more organically, until the cluster reaches relative growth and new entrants are attracted from other locations (Corollary 2). At this point, the benefits of agglomerations are already in place and are higher than the entrepreneur's benefits from their own local networks.

Figure 5.1 Conceptual Model



Source: Author's model

Each of these aspects will be analysed in Section 5.4, while the data and methodologies of analysis will be discussed next.

5.3 DATA AND METHODOLOGY

5.3.1 DATA

A total of 45 in-depth interviews and 87 surveys collected in four regions of Chile were used in the analysis of this chapter. The distribution of the observations by region and type of firm is presented in Chapter 3 (Section 3.4). The data used is representative of the biotech sector in each of the four regions studied.

5.3.2 METHODS OF ANALYSIS

Mixed methods of analysis are used in this chapter to identify the main trends and the underlying processes of firm emergence in the initial stages of a high-tech cluster. The problem of interaction between the factors affecting the access to resources and the recognition of opportunities is inevitable; therefore, the use of mixed methods, particularly qualitative analysis, is the best option for studying these issues. In-depth interviews were transcribed and coded using NVivo.[11] The codes used[12] follow the concepts and aspects presented in Figure 5.1.

There are two questions assessing factors determining location decision and one question about obstacles to the creation of the firm.[13] The first question about location asks interviewees to rank in order of importance the factors that influenced their location decisions. These factors were obtained from the first round of interviews in 2011, and were then asked again in the 2013 survey. The second location question asks interviewees to determine, using a four-point Likert scale, how important different factors were in their selection of a region of the country as the base for the new firm.

[11] NVivo 10 for Windows was used in the analysis.
[12] A list and description of the codes used is presented in Appendix 1.
[13] See questionnaire in appendix.

Also, at the end of the survey interviewees were asked open-ended questions. These questions enquire about the respondent's opinion of the importance of personal relations in the creation of firms in Chile, and ask them to compare this general opinion with the particular case of biotechnology. These questions are:

1. *In your opinion, how important are social/personal relations to starting a company in Chile?*
2. *In your opinion, how important are social/personal relations to starting a company in the field of biotechnology in Chile?*

Answers to these open-ended questions were coded in NVivo. Later, variables indicating the number of times a coding concept was mentioned were created. These variables were cross-tabulated and presented in tables to identify overlaps between the concepts, i.e. how many times a concept was mentioned together with another.

Overall, four methods of analysis were used for this chapter. First, the relationship between social relations[14] and access to resources or opportunity recognition was studied by content analysis of the interviews and open-ended questions in the survey. Tables relating attitudes to social networks mentioned together with access to resources or opportunity recognition aspects were created. Secondly, a relation between attitudes towards social connections and the creation and growth processes of firms was analysed. This analysis was also conducted using content analysis of the same questions and data used in the first part. Tables relating attitudes to social networks and creation of firms were also produced. Thirdly, descriptive statistics for the survey questions related to location factors, and obstacles to firm creation and to firm growth are presented. These questions were

[14] Social relations are understood as personal and business relations between organisations.

asked on a four-point Likert scale running from 'not important' to 'highly important'. Finally, several Kruskal-Wallis non-parametric tests were conducted on the variables of location factors, obstacles to firm creation and to firm growth, and three-scale variables of business and personal networks. The variables of business and personal networks were categorised on three levels: firms without connections (0); firms with a number of connections lower than the average (1); and firms with a number of connections above the average (2).

To study this relationship, the answers of firms to Likert-scaled questions in the survey in the biotechnology sector are analysed. The analysis is divided into three groups of firms: DBFs; DBFs, laboratories and research centres using biotech processes; and total firms including the previous groups and services companies, venture capital organisations, pharmaceutical companies, and clients of DBFs. The first two groups can be considered the core of the biotech sector since they do research and develop services and products based on biotechnology. The third group gives a better idea of the sector as a whole.

This section presents descriptive statistics of the key questions mentioned above. Additionally, Kruskal-Wallis tests were conducted to identify the correlation between social capital and the variables of interest: location factors, creation obstacles and growth obstacles. A Kruskal-Wallis test is used to determine the differences on an ordinal dependent variable between the groups of an independent variable. The dependent variables in this exercise are the answers about the importance of location factors, creation obstacles and growth obstacles, measured on a four-point Likert scale, while the independent variable represents firms' social capital. The variable to measure social capital was identified by asking the interviewees to list all the business relations of the firm and all the personal

relations of their owners or CEOs in the biotechnology sector. Business connections create the business network of the sector, while personal connections form the personal network. Later, each firm was classified using a categorical variable identifying the number of connections. These categorical variables of networks had the value 0 for firms with no connections, 1 for firms with a number of connections lower than the mean, and 2 for firms with a number of connections above the mean. The networks were identified for national and international connections, but only national connections will be used in this test, since this is a better proxy of social capital that could influence the process of location, creation and growth.

5.3.3 LIMITATIONS OF THE ANALYSIS

The type of information collected could present a problem, given that most of the questions ask participants to recall past events, such as obstacles to creation or location factors considered at the time of creation. This bias, called 'recall bias', could affect older firms disproportionately more, given the time that has passed between the creation process and the survey. Unfortunately, it is not possible to determine ex ante the direction of this bias. But it will be considered in the analysis of the results.

Also, recall bias could emerge when subjects are asked about their business and personal relations. This type of bias often translates into under-reporting of the number of their connections and acquaintances (McCormick et al., 2010). In this case, however, it is possible that the bias will reduce the significance of social connections in the location and creation of companies, because of the under-reporting.

The analyses of the data are presented in the following sections. In Section 5.4.1, the first two analyses, relating to the coding of interviews and the open-ended questions, are presented. This analysis focuses on the relation between social networks and access to resources and opportunity recognition. In Section 5.4.2, the analysis of firms' determinants of location are studied, differentiating between determinants related to resources and opportunity recognition. Later, the same analysis is presented but in this case for the obstacles to the creation of firms. Descriptive statistics and non-parametric tests are presented to assess the relation between social networks and firms' formation.

5.4 RESULTS

5.4.1 EVIDENCE FROM QUALITATIVE DATA

This section presents the content analysis conducted to establish the relation between social connections and access to resources and opportunity recognition. The focus is on analysing the interviews and open-ended questions in the survey (described above) using content analysis in NVivo.[15]

ACCESS TO RESOURCES

Traditionally, there are at least three main resources needed to start a company: capital (physical and monetary); labour; and natural resources. In the case of biotechnology or high-tech sectors, the main factors are capital, high-skilled labour, and scientific and technological knowledge (Lawton Smith, 2008). In this study, I

[15] The quotations presented in this chapter are my translations of the original interviews, which were conducted in Spanish. The translations were made with the utmost care and reviewed by a native English speaker to make sure that there was no distortion of what was said by the interviewee.

will consider capital as financial capital in the analysis of the location, creation and growth processes of firms.

Table 5.1 presents the count of the number of times that social networks or social capital were mentioned in relation to the resources needed to create a company. Most of these relate to a positive impact or attitude of social networks in relation to resources in general terms. In particular, when asked about the biotechnology sector in Chile, most respondents identified that social relations are more important in this sector than in others.

Scientific and technological knowledge is the resource accorded most importance in relation to the creation of a company and as the most important resource in the biotechnology sector. After scientific knowledge, financial capital is the second most mentioned resource with respect to having a positive impact on firm creation. In contrast, high-skilled labour is a resource that is not often mentioned in relation to social capital and the creation process for a firm.

Although the open-ended questions in the survey focused on the creation process of companies, spontaneous responses were given for the growth process. This is because, in some cases, interviewees mentioned that social networks were not that important for the creation process, but they were important for the growth of a company. For example, the owner of a biotechnology company in the Metropolitana region stated:

> *To start a company, social relations are not important. However, to make the company grow, get clients, attract attention and financial capital, the social network of its* [the firm's] *members is important. Many things can be obtained with a good introduction in the environment, particularly information, collaboration and partners*.

Table 5.1 Count of Number of Times Social Network/Social Capital were Mentioned in Relation to Resources to Create a Company

	Resources for Creation of Company			
	Financial Capital	**High Skilled Labour**	**Scientific and Technological Knowledge**	**Total Mentions**
Social Capital Impact	**27**	**4**	**36**	**63**
Positive	24	3	31	54
No impact - Neutral	2	1	4	8
Negative	1	0	0	1
Social Capital in Biotech	**27**	**5**	**37**	**61**
More relevant	20	3	23	42
Same relevance	5	0	6	10
Less relevant	2	2	8	9

Note: Table from Nvivo coding of open ended questions in the survey

Table 5.2 and Table 5.3 present the number of times that social capital and resources were related to the formation of companies. Table 5.2 focuses on the general perception of the importance of social capital, while Table 5.3 focuses on the biotechnology sector in particular. Again, scientific and technological knowledge seems to be the most important resource for the creation and growth of firms, followed by financial capital. These are strongly associated with a positive impact of social networks on the formation and growth of companies.

Table 5.2 Number of Times Social Network/Social Capital were Mentioned in Relation to Resources to Create a Company for the Process of Formation of Firms

	Firm Formation and Impact of Social Networks		
Resources for Creation of Company	**Positive Impact of Social Networks**	**Negative or Neutral Impact of Social Networks**	**Total Mentions**
Total	**52**	**11**	**65**
Financial Capital	21	3	28
High Skilled Labour	3	2	6
Scientific and Technological Knowledge	27	5	40

Note: Table from Nvivo coding of open ended questions in the survey

Negative or neutral impact of social networks is identified only with respect to the creation of firms. As the owner of a DBF in the Bío-Bío region said, 'Most

important is the information and the trust between companies.' The most extreme was the position of the owner of a private research centre in the Metropolitana region, who said:

> *For me,* [social relations] *are absolutely irrelevant. We were not from the environment* [or circles] *and this type of relation did not happen when we needed them and now we do not need them.*

This quotation identifies that there is an 'environment' or group of people and firms that created this particular 'environment' within the biotechnology sector. Belonging to this 'environment' gives a firm the access to 'this type of relation'. The quotation also highlights that there might be a stage when social relations are relevant for the creation of a firm, even if this firm did not have them. However, this firm was created and grew without social relations, and the quotation indicates that the firm is at a stage where social relations are no longer needed.

Table 5.3 Number of Times Social Network/Social Capital were Mentioned in Biotechnology in Relation to Resources to Create a Company for the Process of Formation of Firms

	Firm Formation and Impact of Social Networks			
Resources for Creation of Company	**More Relevance of Social Networks in Biotech**	**Same Relevance of Social Networks in Biotech**	**Less Relevance of Social Networks in Biotech**	**Total Mentions**
Total	**45**	**12**	**12**	**65**
Financial Capital	19	5	2	28
High Skilled Labour	3	0	2	6
Scientific and Technological Knowledge	22	6	8	40

Note: Table from Nvivo coding of open ended questions in the survey

In Table 5.3, the number of times resources and firms' processes are mentioned are divided between the different perceptions of the importance of social relations in the biotechnology sector. Most of the mentions are related to the higher importance of social networks in the biotechnology sector for the formation and

growth of firms. Once again, scientific knowledge and financial capital are the most important resources mentioned.

From the content analysis of interviews and survey responses presented in this section, it is possible to state that Hypothesis 1a seems to be supported by the data collected.

OPPORTUNITY RECOGNITION

Another important aspect for entrepreneurs is the recognition of opportunities in the environment. To identify a business opportunity, information about the structure of the market and the sector, potential clients and suppliers, intellectual property rights, and regulatory processes, among others, is required. Additionally, other resources of the entrepreneur, such as reputation and trust, are important to generate business relations in the sector.

As stated in the theoretical framework, the social networks of entrepreneurs can shape the access to the types of knowledge that are important to identifying new opportunities in the market. To study this relation, I grouped different aspects that can be related to opportunity recognition. The first group, which I named the 'value chain', includes all the mentions related to the identification and connections to suppliers and clients that are associated with the structure of the market. The second group comprises mentions related to information asymmetries between agents, which are also related to the structure of the biotechnology sector. The third group is related to other aspects specific to biotechnology – most of these mentions are related to the high-tech and knowledge specificities of the sector. The fourth group are mentions related to reputation and the importance of the reputation of the entrepreneur and the company.

The results from Table 5.4 indicate that a higher proportion of respondents mentioned aspects of opportunity recognition together with a positive evaluation of the impact of social relations. Within this group, most mentions are in relation to the positive impact of social networks on acquiring clients and suppliers. The second most important aspects are related to the specificities of the biotech sector, such as the high-tech and knowledge base of the products. The third most important aspect where social relations have a positive impact is on reputation.

Table 5.4 Number of Times Social Network/Social Capital Mentioned in Relation to Opportunity Recognition in Open-Ended Questions of Survey

	Opportunity Recognition				
	Value Chain (Clients, Suppliers)	**Reputation**	**Information Asymmetries**	**Biotech Specifics (Based on Knowledge)**	**Total Mentions**
Social Capital Impact	**33**	**18**	**6**	**26**	**69**
Positive	31	16	4	22	60
No impact - Neutral	4	2	2	3	10
Negative	0	0	0	0	0
Social Capital in Biotech	**29**	**17**	**7**	**26**	**63**
More relevant	9	6	1	5	18
Same relevance	21	7	5	15	37
Less relevant	0	4	1	6	9

Note: Table from Nvivo coding of open ended questions in the survey

When asked about the importance of social relations on the biotechnology sector, most respondents stated that, in terms of the aspects considered as affecting opportunity recognition, there was not a difference in biotechnology as compared to other sectors in the country. The importance of the aspects related to opportunity recognition were the same as in the general question; the most important were the aspects related to clients and suppliers, followed by the specificities of the knowledge-based features of biotech. Reputation seems to be important as well, and several interviewees related the importance of reputation to the validation in the

market of the technical knowledge of the entrepreneur and the new start-up. For example, a CEO of a biotech company in the Valparaíso region said:

> *It is more important to generate the conditions of validation among peers* [reputation]. *Secondly, to have the knowledge* [of the science behind the product or service]*. Thirdly, to have a product or service that attracts the financial networks. This is the most important.*

Therefore, reputation and technical knowledge are closely related for entrepreneurs. Additionally, reputation is related to access to other resources, particularly financial capital, as mentioned by the owner of a biotech company in the Metropolitana region:

> *It is difficult to start any company in Chile, even more so in the biotechnology sector, because it is a very small sector in the country … Today, if there is not a renowned institution or university behind the entrepreneurship, it is very difficult to position the company in the sector and to obtain all the types of resources. The last part is particularly important in getting public resources, because the names of the people behind the inventions have a lot of importance and weight.*

For the processes of the creation of companies, presented in Table 5.5, it appears that factors of opportunity recognition are more related to the process of the formation of companies. Most mentions associate a positive impact of social relations with aspects of opportunity recognition in the processes of the formation of firms. For both processes, the most important factor is the knowledge-based aspect of the sector and the specificities of the sector, followed by the access to clients and suppliers. In third place is the factor of reputation.

Table 5.5 Number of Times Social Network/Social Capital Mentioned in Relation to Opportunity Recognition for the Process of Formation of Firms

	Firms' Creation and Impact of Social Networks		
Opportunity Recognition	**Positive Impact of Social Networks**	**Negative or Neutral Impact of Social Networks**	**Total Mentions**
Total	**63**	**12**	**68**
Value Chain (Clients, Suppliers)	19	4	28
Information Asymmetries	4	2	7
Reputation	13	2	18
Biotech Specifics (Based on Knowledge)	25	4	31

Note: Table from Nvivo coding of open ended questions in the survey

When we compare the biotech sector with other sectors of the country, as shown in Table 5.6, most mentions indicate that social relations are more important in biotech than in other sectors for the formation and growth of companies. Once again, the specificities of the sector, such as the knowledge-intensive characteristic of biotech, are the most important aspect, followed by connections in the value chain. Reputation appears more important in the formation stage of firms, indicating that this aspect is highly important for knowledge-intensive sectors in particular. The data presented in this section gives support to Hypothesis 1b.

Table 5.6 Number of Times Social Network/Social Capital Mentioned in Biotechnology in Relation to Opportunity Recognition for the Process of Formation of Firms

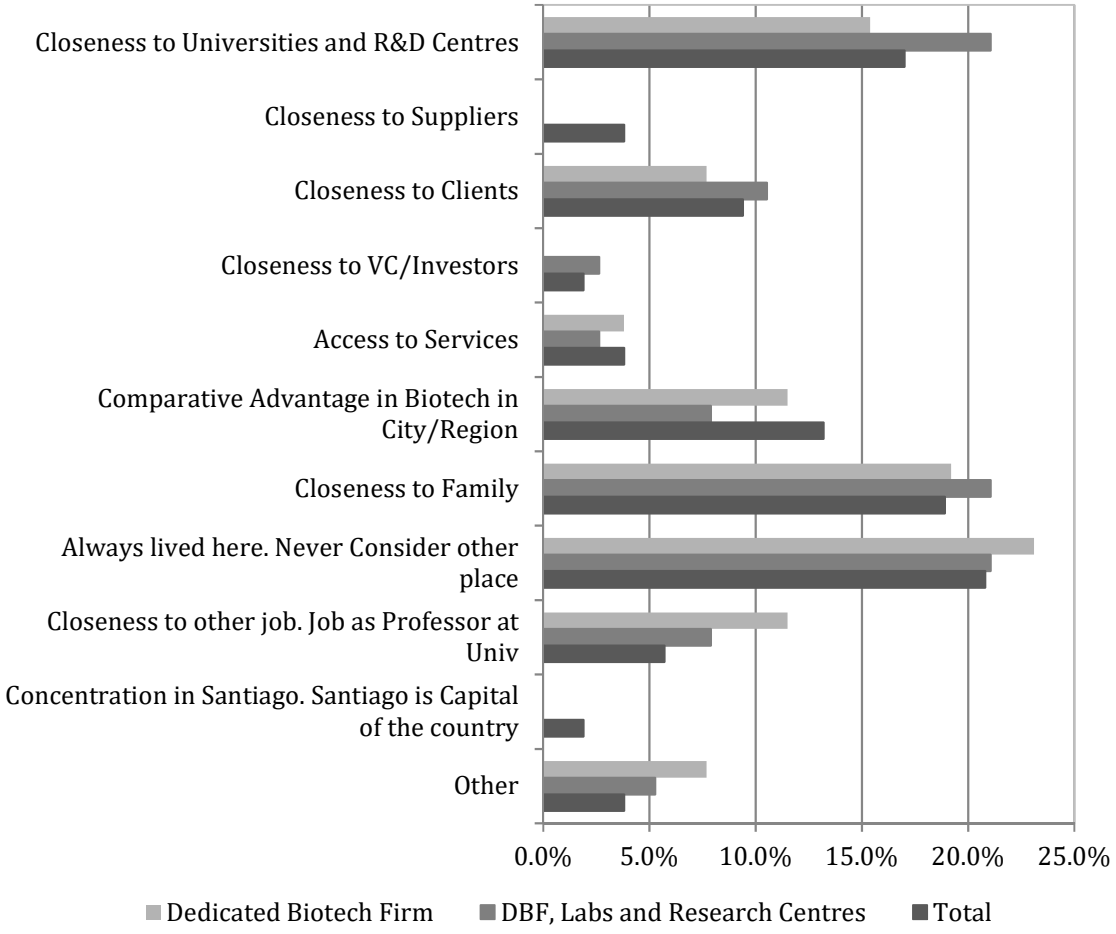
	Firms' Creation and Impact of Social Networks			
Opportunity Recognition	**More Relevance of Social Networks in Biotech**	**Same Relevance of Social Networks in Biotech**	**Less Relevance of Social Networks in Biotech**	**Total Mentions**
Total	**47**	**21**	**11**	**68**
Value Chain (Clients, Suppliers)	14	5	6	28
Information Asymmetries	5	1	1	7
Reputation	7	6	4	18
Biotech Specifics (Based on Knowledge)	20	9	0	31

Note: Table from Nvivo coding of open ended questions in the survey

5.4.2 EVIDENCE FROM QUANTITATIVE DATA

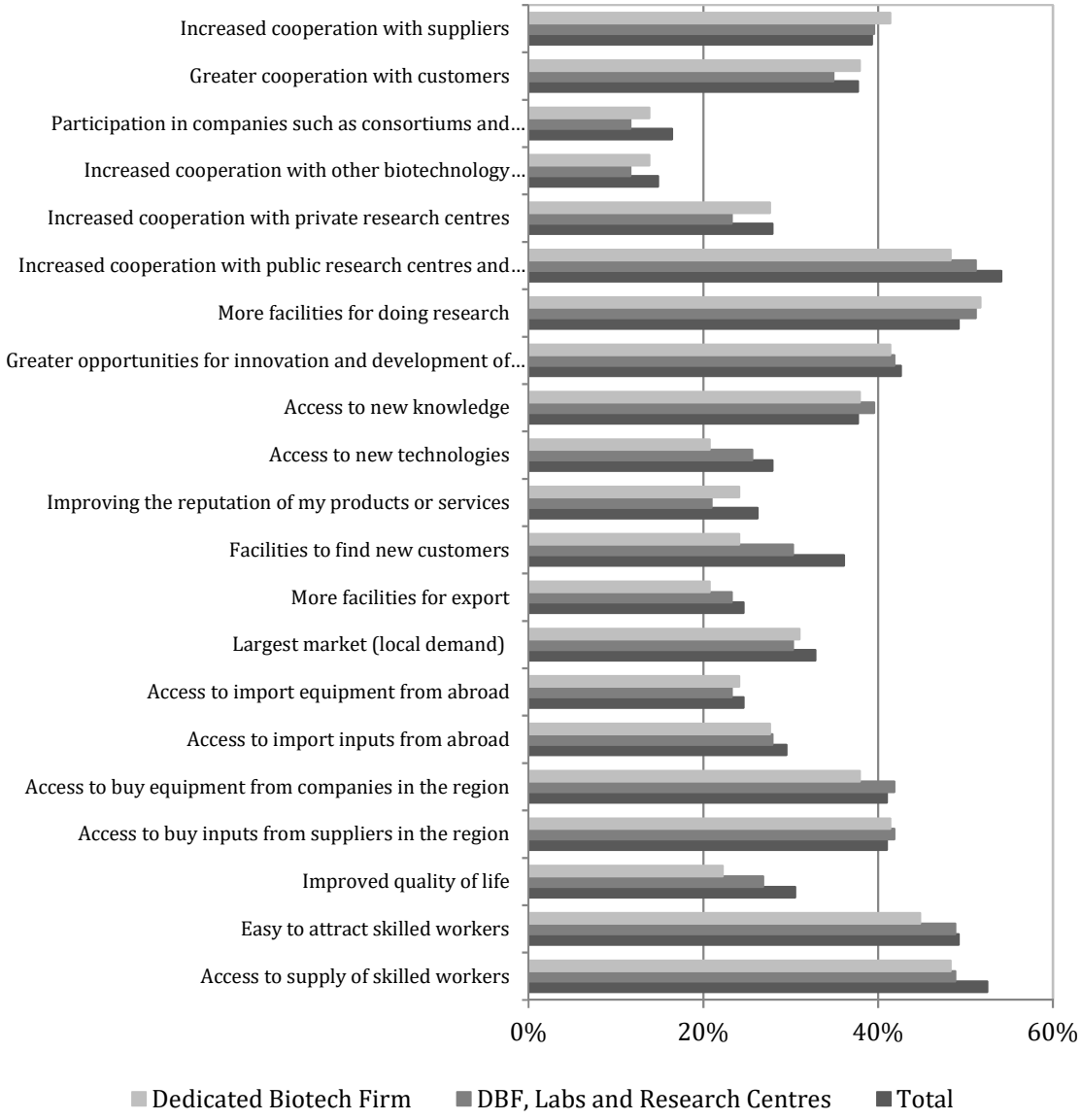
To analyse location decisions, two questions were included in the survey. The first asked for a ranking of the three most important factors for such decisions. These factors were obtained from the in-depth interviews in 2011 and were asked as a multiple response and ranking question in 2013. Results for the most important location factor are presented in Figure 5.2. The most important factors are: 'Always lived here, never considered other place'; 'Closeness to family'; and 'Closeness to universities and research centres'. The first two factors are related to the entrepreneurs' social networks, and highlight the importance of social factors, ones not directly related to resources or opportunity recognition, as most important for the location decision.

Figure 5.2 Most Important Reason for Location Decision



The second question asked the interviewee to determine, on a four-point Likert scale, how important different factors were in the decision to locate the firm in the region where they are established, in comparison to other regions in the country. The percentage of firms that consider each factor to be highly important is presented in Figure 5.3. Results will be analysed by factors connected to 'Access to Resources' and 'Opportunity Recognition' separately.

Figure 5.3 Percentage of Responses that Consider Each Factor as Highly Important for Location Decision



ACCESS TO RESOURCES AND LOCATION

The most important factors for location decision from Figure 5.2 that could be related to access to resources are: 'Closeness to universities and research centres', which is a proxy for access to knowledge and closeness to a pool of high-skilled workers; 'Closeness to venture capital firms and investors', which is a proxy for access to financial capital; and 'Closeness to other job/Job as a professor at a university', which could also be considered access to other financial capital and knowledge. This group of factors seems to be the second most important, and is more important for DBFs, laboratories and research centres than for other types of firms.

When asked to compare factors for location between the region of location for the interviewed firm and the rest of the regions in the country, as presented in Figure 5.3, it seems that access to resources is relatively more important than factors of opportunity recognition. The most important factors for location decisions are related to knowledge and access to high-skilled workers.

OPPORTUNITY RECOGNITION AND LOCATION

Factors related to opportunity recognition in Figure 5.2, following the description given in the previous section, are: 'Closeness to clients'; 'Closeness to suppliers'; 'Access to services'; and 'Comparative advantage in biotech (in the area of the company) that exists in my city/region'. This group of factors seems to be third in importance and is more important for firms in general in the sector than for DBF firms specifically. The most important factors of opportunity recognition for DBF are comparative advantage in the biotech sector in the region, and closeness to clients.

With respect to factors related to opportunity recognition in Figure 5.3, this is the second most important group of factors for location. They are related to access to equipment and input from suppliers in the region, and cooperation with clients and suppliers.

Social Capital and Location

As mentioned at the previous section, several Kruskal-Wallis tests were conducted to identify the correlation between social capital and the location factors presented in Figure 5.3. This test is a non-parametric test similar to ANOVA, but is preferred when the distribution of the variables is skewed and non-normal. In essence, it estimates the mean difference of the dependent variable between the groups in the independent variable. A summary of the test results for the total sample of firms is presented in Table 5.7, together with the average importance of each locational factor for different levels of the connections of firms. This summary is useful to reveal the differences between the effects of business and personal networks.

The Kruskal-Wallis tests were run to determine if there were differences in the scores for the importance of location factors between three groups of firms with different levels of business and personal connections: 'No connections'; 'Number of connections below average'; and 'Number of connections above average'. The mean ranks of importance in location factors are not similar between groups of firms with different levels of connections when the p-value of the Kruskal-Wallis test is lower than 0.10, 0.05 or 0.01. This means that the distribution is not the same for firms with no connection, a low number of connections or a high number of connections.

For example, the results of the Kruskal-Wallis test in Table 5.7 tell us that the mean rank of the scores for 'Easy to attract skilled workers' is not similar for all groups of business connections. The distributions of the 'Easy to attract skilled

workers' scores were statistically significantly different between groups, with values of $\chi 2(1) = 6.53$, and a p-value lower than 0.05. Therefore, it is possible to say, with a significance level of 0.05, that the importance of the factor 'Easy to attract skilled workers' is statistically different for firms with dissimilar levels of connections. The results suggest that there is a significant difference in the importance of location factors related to access to high-skilled workers between firms that differ in their level of connections in the business network. Firms with more connections found that access to high-skilled workers was more important for their location decisions. These results do not hold when we look at differences in personal networks.

With respect to the factor that is related to personal reasons for location – improved quality of life – there are no significant differences in firms with diverse levels of business relations; however, there is a low significance in the case of personal networks. Firms with more personal connections tend to consider this factor more important for their location decisions.

The four factors related to access to suppliers present highly significant results of the Kruskal-Wallis tests. The ability to buy inputs and equipment locally and to import inputs and equipment are significantly different between groups of firms with a different number of business connections. Firms with above-average connections have a higher mean for the importance of these factors, implying the higher importance of these factors for location decisions. This result holds partially when considering personal networks. A highly significant difference in the importance of access to equipment from regional suppliers among groups with different levels of personal relations was found. Yet the significance of the Kruskal-Wallis test is not that high for the other factors of access to suppliers.

Table 5.7 Mean Importance of Location Factors by Groups of Business and Personal Networks for the Total Sample, with Results of Kruskal-Wallis Tests

Mean Relevance of Location Factors by Type of Network and Number of Connections								
Location Factors	**National Business Network**				**National Personal Network**			
	No Connections	Connections below Average	Connections Above Average	Kruskal-Wallis Test Chi2 (2DF)	No Connections	Connections below Average	Connections Above Average	Kruskal-Wallis Test Chi2 (2DF)
Access to supply of skilled workers	2.3	3.1	3.4	5.31*	3.0	3.1	3.3	1.53
Easy to attract skilled workers	2.5	2.9	3.5	6.53**	3.1	3.1	3.3	0.53
Improved quality of life	2.8	2.6	3.0	2.47	2.7	2.4	3.0	5.44*
Access to buy inputs from suppliers in the region	1.8	2.7	3.2	8.91**	2.9	2.5	3.2	4.35
Access to buy equipment from companies in the region	1.8	2.5	3.3	12.28***	2.7	2.3	3.3	9.77***
Access to import inputs from abroad	2.3	2.3	3.0	6.70**	2.8	2.3	2.9	4.92*
Access to import equipment from abroad	2.3	2.3	2.9	6.15**	2.4	2.2	2.9	5.83*
Largest market (local demand)	2.3	2.6	2.7	0.65	3.0	2.3	2.7	3.62
More facilities for export	3.0	2.2	2.2	1.41	3.2	2.0	2.2	8.27**
Facilities to find new customers	2.5	2.6	2.9	1.14	2.7	2.4	3.0	4.89*
Improving the reputation of my products or services	2.8	2.7	2.4	2.35	2.8	2.3	2.7	3.37
Access to new technologies	2.5	2.7	2.8	0.37	2.3	2.8	2.9	2.897
Access to new knowledge	2.8	2.8	3.0	1.04	2.5	2.9	3.1	1.95
Greater opportunities for innovation and development of new products and	2.8	2.9	3.1	0.54	2.8	2.9	3.1	0.90
More facilities for doing research	2.8	3.0	3.3	1.57	2.9	2.9	3.4	2.80
Increased cooperation with public research centres and universities	2.8	3.1	3.3	1.99	2.6	2.9	3.6	11.44***
Increased cooperation with private research centres	2.8	2.7	2.4	0.88	2.3	2.1	2.9	7.73**
Increased cooperation with other biotechnology companies in the region	2.5	2.2	2.3	0.24	2.0	1.9	2.6	8.98**
Participation in companies such as consortiums and trade/industry associations	3.3	2.4	2.2	4.42	2.7	2.3	2.3	2.46
Greater cooperation with customers	2.3	2.8	2.8	1.04	2.5	2.7	3.0	1.90
Increased cooperation with suppliers	2.8	2.7	3.0	1.83	2.8	2.6	3.0	1.83

Note: Source Author's Survey. Answers to a 4-point Likert scale with 1=No Relevant, 2=Low Relevance, 3=Medium Relevance, 4=High Relevance. Asymptotic significances are displayed with * for the tests with significance level 0.10, ** for the tests with significance level 0.05 and *** for the tests with significance level 0.01

In the case of factors related to access to clients, an interesting result is found: personal relations are the only networks important in this case. For the factor that identifies ease of exporting (and therefore access to foreign clients), firms with no personal national connections in the biotechnology sector consider it more important for their location decisions for them to have facilities to export. Also, there

is a low significance of the Kruskal-Wallis test for the factor 'Facilities to find new customers' with respect to different firms' groups of personal connections. In this case, firms with above-average personal connections tend to find this factor affecting location more important. Therefore, it could be argued that personal connections give access to more national clients; firms with a low level of national connections aim to find their clients abroad.

More notably, personal connections are highly important for cooperation with public research centres and universities as a location factor, as well as with private research centres and biotechnology firms. These factors are related to access to scientific and technical knowledge. Firms with above-average personal connections find these factors more important in their location decisions than firms with below-average connections and firms without personal connections.

From this exercise, it is possible to determine that social capital, measured by social networks as business and personal connections, are important for access to resources and that this impacts the location decision of the firm. In particular, social networks (business and personal) are important for access to high-skilled labour, access to suppliers, access to foreign clients, and access to knowledge through collaboration with universities, research centres and biotech firms.

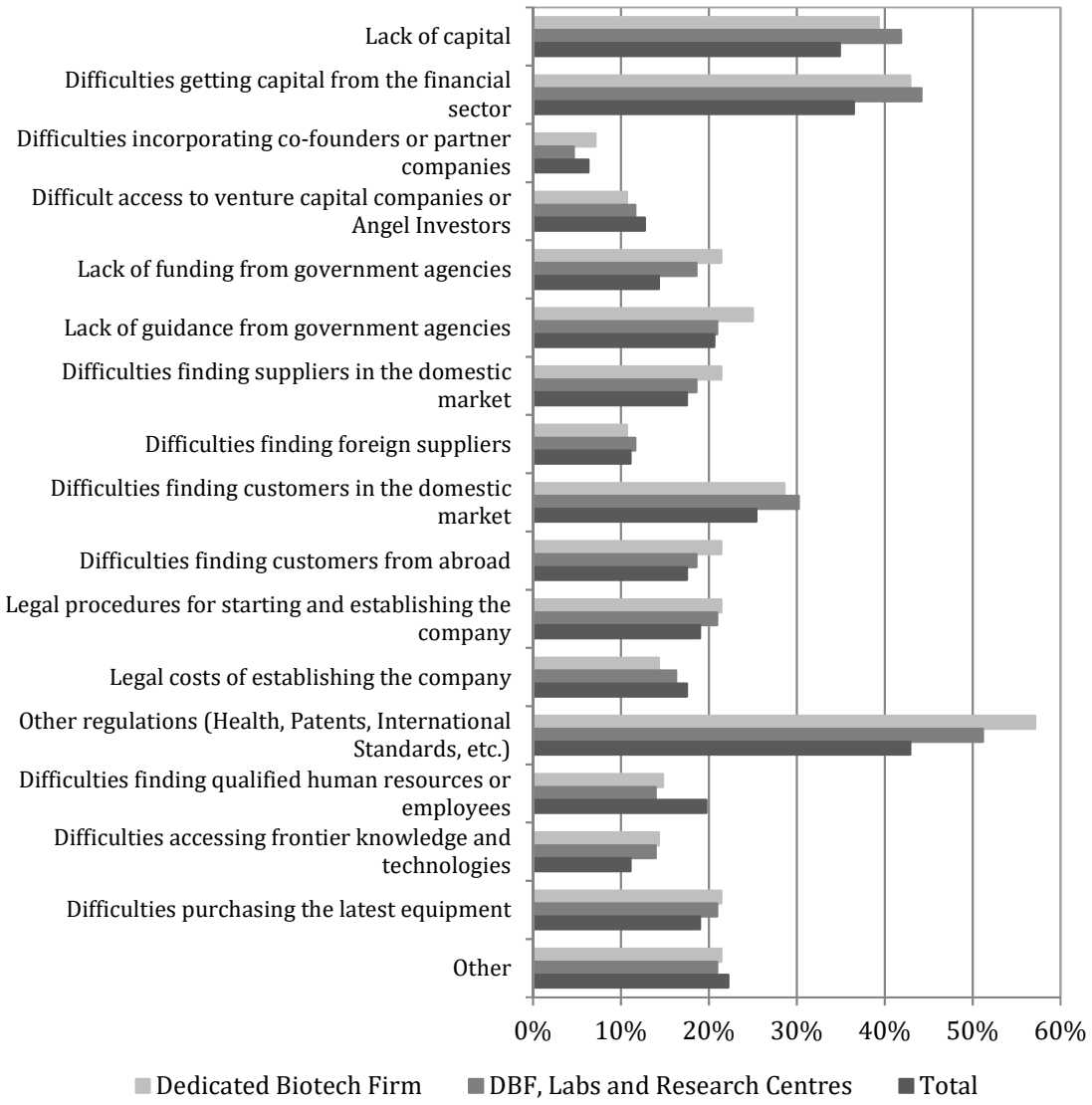
As a conclusion to this section, the reasons for locating a firm, in order of importance, is: social factors; resources; and opportunity recognition. These results, together with the importance of social networks for access to resources and opportunity recognition as location factors, give support to Hypotheses 1a and 1b, and argue in favour of Corollary 1. Therefore, social relations are important for access to resources and opportunity recognition, affecting the location decisions of start-ups.

SOCIAL NETWORKS AND CREATION OF FIRMS

As mentioned earlier, creation and location decisions are inextricably intertwined. This section analyses the answers to obstacles to the creation of firms in the Chilean biotech sector, as shown in Figure 5.4. When asked about the importance of obstacles to the creation of firms, the most important factor for more than 40% of firms is compliance with the regulations, such as health regulation, patents, and international quality standards, among others. This obstacle is even more important for DBFs and research-based firms (laboratories and research centres), indicating that the legal specificities of biotechnology at the international level are an important factor to consider when establishing a firm. This factor could be considered to be related to opportunity recognition, since these regulations might generate the possibility of competing in the market or making the possibility of worldwide revenues more likely if a biotech product is successfully introduced onto the international market.

The second group of obstacles in importance are 'Lack of capital' and 'Difficulties obtaining capital from the financial sector'. These factors are highly important for 35% and 37% of firms respectively. In this case, financial capital is perceived as a highly important resource and the difficulty accessing it is one of the main obstacles to firm formation, particularly for DBFs and research-oriented firms that consider these factors as highly relevant (42% and 44% respectively). A third obstacle for 25% to 30% of firms, although of far less relative importance compared with the other obstacles, is finding clients in the local market. This obstacle is also related to opportunity recognition, since firms need to identify an unsatisfied need of clients (demand) that could be meet with the new product offered by the firm.

Figure 5.4 Percentage of Responses that Consider Each Obstacle as Highly Important for the Creation of the Firm



Other obstacles to firm formation have a higher importance for about 20% (or less) of the surveyed firms. Lack of guidance from governmental agencies is a highly important obstacle for only 20% of total firms; however, for DBFs it is more important, with 25% of this group finding this obstacle to be highly important for the formation of firms.

When conducting Kruskal-Wallis tests to determine if there are differences in obstacles to formation for different groups of social relations (presented in Table

5.8), it is possible to observe that the same obstacles show a significant difference between firms with different levels of connections.

Table 5.8 Mean Importance of Obstacles to Creation by Groups of Business and Personal Networks for the Total Sample, with Results of Kruskal-Wallis Tests

Mean Relevance of Obstacles for Creation by Type of Network and Number of Connections								
Location Factors	**National Business Network**				**National Personal Network**			
	No Connections	Connections below Average	Connections Above Average	Kruskal-Wallis Test Chi2 (2DF)	No Connections	Connections below Average	Connections Above Average	Kruskal-Wallis Test Chi2 (2DF)
Lack of capital	1.3	3.0	2.6	8.39**	3.3	2.5	2.7	3.24
Difficulties getting capital from the financial sector	1.0	2.8	2.7	7.43**	3.2	2.6	2.5	2.56
Difficulties incorporating co-founders or partner companies	1.3	2.0	1.9	2.59	2.2	2.0	1.7	2.11
Difficult access to venture capital companies or Angel Investors	1.0	2.0	1.6	3.38	2.1	1.6	1.6	0.86
Lack of funding from government agencies	1.0	2.2	1.9	5.57*	2.0	2.0	2.0	0.04
Lack of guidance from government agencies	1.0	2.6	1.9	10.08***	2.5	2.0	2.3	1.57
Difficulties finding suppliers in the domestic market	1.5	2.4	2.4	3.12	2.5	2.1	2.5	2.41
Difficulties finding foreign suppliers	1.3	2.2	2.2	3.97	2.4	1.9	2.3	3.29
Difficulties finding customers in the domestic market	2.0	2.7	2.4	2.12	3.3	2.4	2.3	6.26**
Difficulties finding customers from abroad	1.5	2.1	2.1	0.80	2.2	1.9	2.2	0.91
Legal procedures for starting and establishing the company	2.3	2.4	2.5	0.41	2.4	2.3	2.5	0.48
Legal costs of establishing the company	2.0	2.3	2.5	1.13	2.4	2.3	2.5	0.39
Other regulations (Health, Patents, International Standards, etc.)	1.8	2.9	3.0	3.38	3.6	2.6	2.9	5.25*
Difficulties finding qualified human resources or employees	2.8	2.4	2.8	2.51	2.7	2.5	2.7	0.47
Difficulties accessing frontier knowledge and technologies	1.8	2.3	2.2	1.27	2.5	2.0	2.3	1.97
Difficulties purchasing the latest equipment	2.0	2.3	2.5	1.24	2.4	2.2	2.5	0.55
Other	3.0	1.8	1.5	5.69*	1.5	1.7	1.8	0.54

Note: Source Author's Survey. Answers to a 4-point Likert scale with 1=No Relevant, 2=Low Relevance, 3=Medium Relevance, 4=High Relevance. Asymptotic significances are displayed with * for the tests with significance level 0.10, ** for the tests with significance level 0.05 and *** for the tests with significance level 0.01

Lack of capital and difficulties obtaining capital from the financial sector differ significantly for firms with a different number of business connections. In this case, firms with a below-average number of business connections consider this obstacle to be more important than firms with above-average business connections. This result highlights the importance of social networks, particularly business relations,

for access to financial capital in the creation of a firm. The same result is seen for government funding, although with a lower Kruskal-Wallis test significance.

Firms with no national business linkages (although there are only four of these) find a lack of capital and access to the financial sector to be important. Three of these firms are consortia that do research and do not yet sell products; they have been created through substantial grants from the government. The last firm is owned completely by a foreign firm and exports all its products. The particular features of these firms explain why, for them, lack of capital is not a major concern in the creation process.

A lack of guidance from governmental agencies is significantly different between groups that differ in their level of national business networks. In this case, firms with below-average national business connections identify this factor as more important than firms with an above-average number of connections. This result is consistent with results from Figure 5.4, indicating that firms with low social capital in the national business network, and particularly DBFs, want governmental agencies to play a more active role in the sector.

Finally, for all firms, national personal connections are important for finding customers in the local market. Firms without national personal connections in the biotech sector consider this highly important in terms of their difficulties finding local clients, while firms with national personal connections consider this aspect to be less important. There are no large differences between firms with low and high levels of national personal connections.

The results presented in this section show that access to financial capital and some factors related to opportunity recognition, such as compliance with regulations, patents, etc. and finding local customers, are considered important

obstacles to firm creation. Furthermore, national business connections are important for considering access to financial capital as an important obstacle. Firms with higher levels of national business connections find access to financial capital a less important obstacle, supporting Hypothesis 1a once more. Overall, these results indicate that access to resources and opportunity recognition are important for the creation process of a firm, supporting Corollary 1.

5.4.3 SUMMARY OF FINDINGS

From the results presented in previous sections, it is possible to summarise the findings in diagrams 5.5 to 5.8. Figure 5.5 and Figure 5.6 present the results with respect to access to resources from the content analysis and the analysis of the survey results respectively.

From the open-ended questions (Figure 5.5), it is possible to see that social connections are highly important for accessing financial capital and scientific knowledge, and, to a lesser extent, for accessing high-skilled labour. This result is confirmed by the findings from the survey (in Figure 5.6). Note that Figure 5.6 shows a negative relation between social capital and financial capital. This is because firms with more connections consider this factor to be less important, which is consistent with the idea that firms and entrepreneurs with more social capital have better access to financial capital and so find this factor to be less important for their creation process.

Figure 5.5 Summary of Results for Access to Resources from Content Analysis

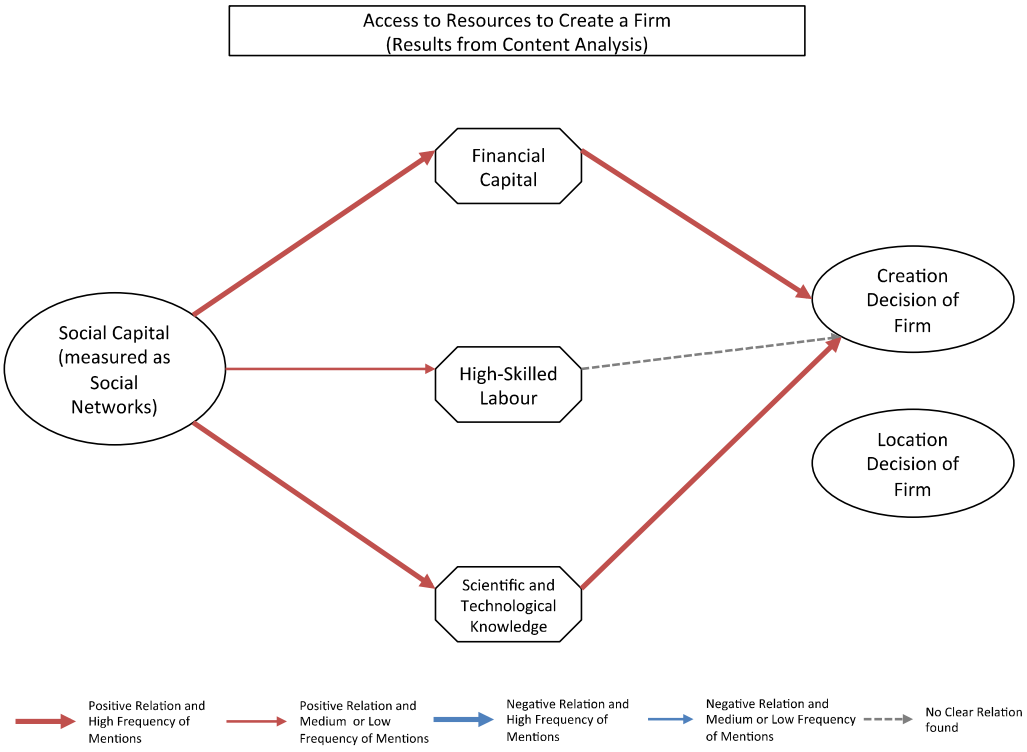


Figure 5.6 Summary of Results for Access to Resources from Analysis of Survey

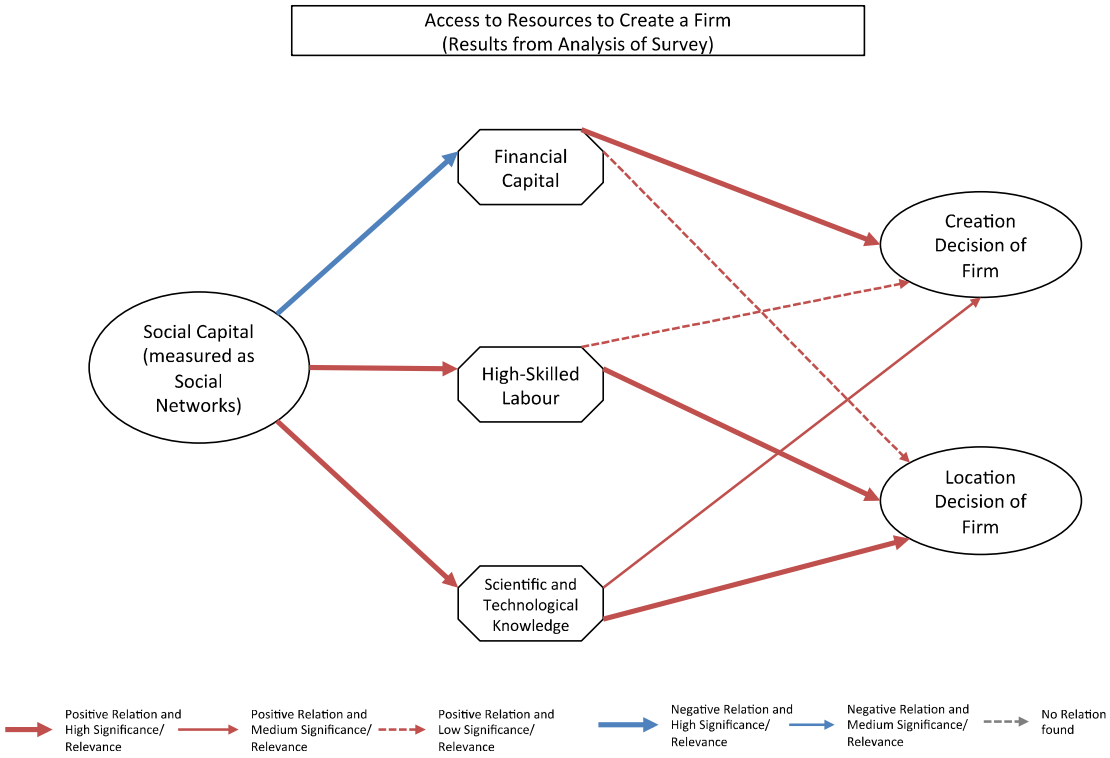


Figure 5.7 Summary of Results for Opportunity Recognition from Content Analysis

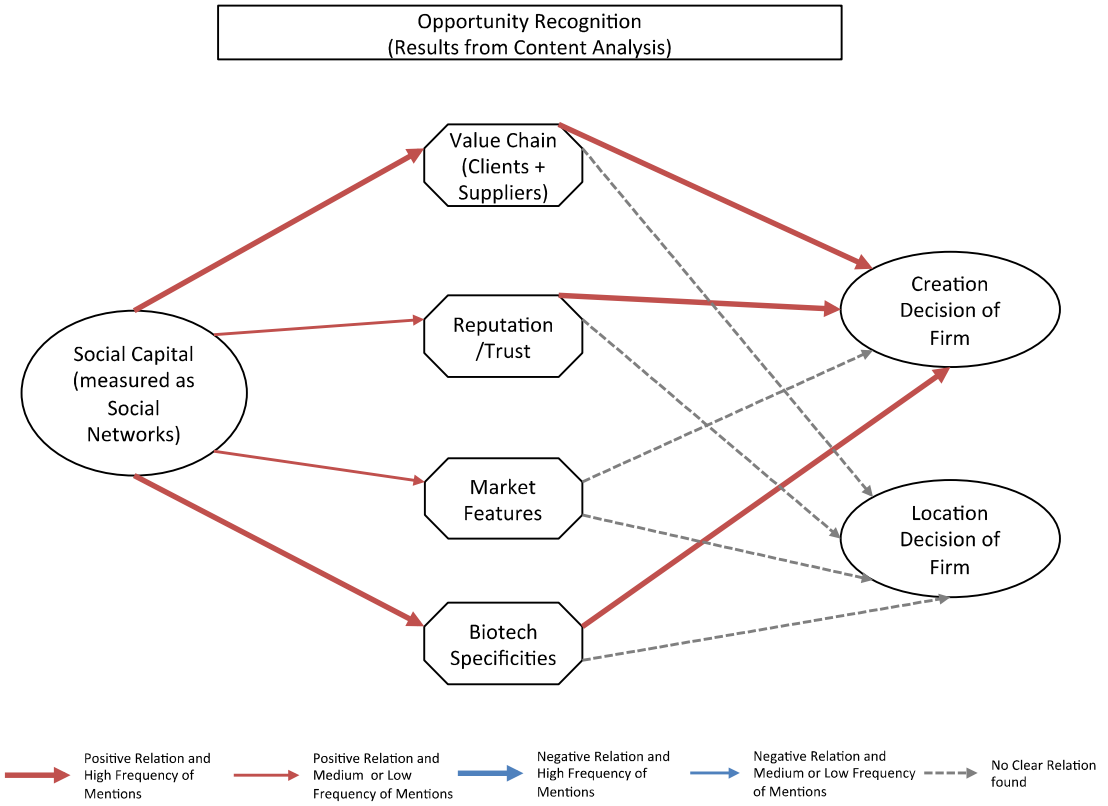
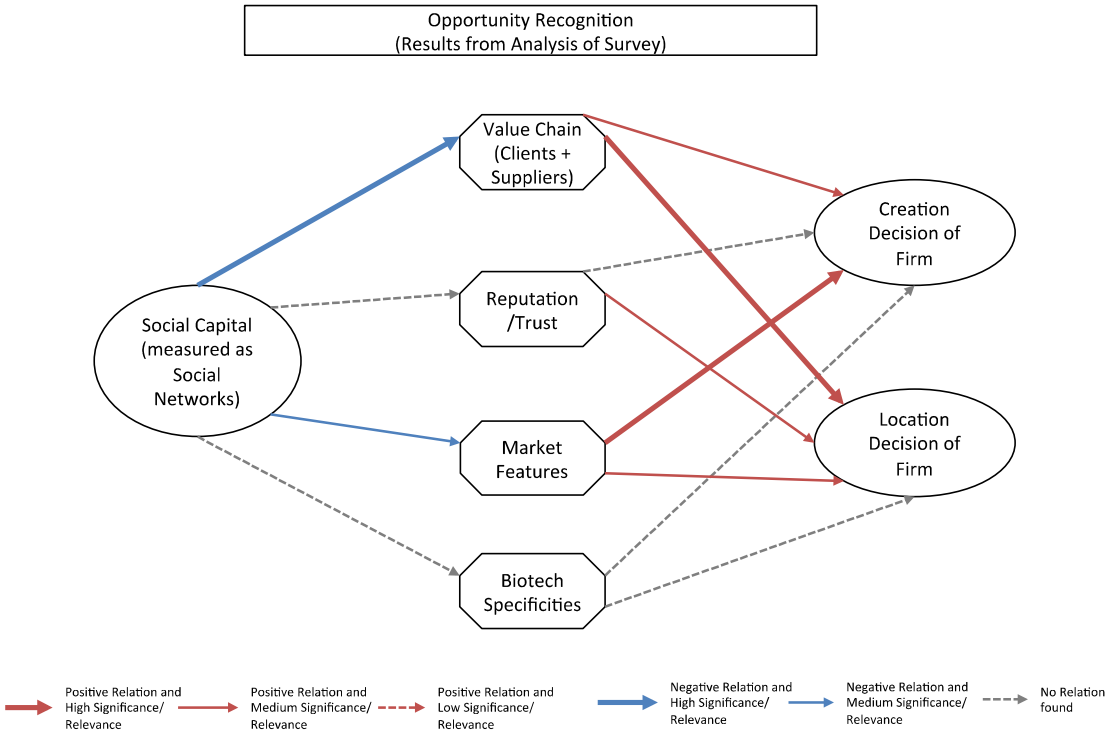


Figure 5.8 Summary of Results for Opportunity Recognition from Analysis of the Survey



The importance of high-skilled labour is revealed in the survey (in Figure 5.6) when it asks about this factor for the different processes analysed in this chapter. Access to high-skilled labour is very important, particularly for the location of firms. Also, from the results in this chapter, financial capital is most important in the creation process. Overall, these results support Hypothesis 1a.

A summary of the results for the aspects of opportunity recognition are presented in Figure 5.7 and Figure 5.8. It is possible to observe from them that social capital is related to the factors of opportunity recognition. Once more, from the open-ended questions the respondents identified that social capital was important for access to clients and suppliers, and the survey identifies that firms with more connections consider access to clients and suppliers as less important for creation, precisely because they already have access to these factors. These results support Hypothesis 1b. From all the results combined, it is possible to assert that entrepreneurs' social capital plays an important role in the entrepreneurial process, shaping location and creation decisions.

With respect to co-location and the emergence of clusters, this research could help explain the process. In the early stages, when the sector or the cluster does not exist in a country, entrepreneurs might rely more heavily on their own connections and therefore will locate their firms in the physical space where they can benefit from their connections to gain access to resources and opportunity recognition. As a result, the early entrepreneurs will locate their firms where they have been living and developing their professional careers. The personal realm of the entrepreneur is then inexorably related to the business project. In this sense, these results support the proposition of Pitelis (2012) that the emergence of clusters is a process co-created by entrepreneurs; however, in contrast to Pitelis's argument, local

conditions are necessary alone to start a company – a social structure is required that supports entrepreneurs in their endeavours to make use of the local conditions necessary for the creation of firms.

5.5 CO-LOCATION AND CLUSTER EMERGENCE

The results presented in previous sections support the argument that social networks facilitate access to resources and opportunity identification for entrepreneurs, in line with the entrepreneurship literature (Zhang et al., 2011). Therefore, it is through these two factors that social networks indirectly affect the creation and location decisions of new firms. This dynamic drives the development of clusters in their early stages. To move the analysis forward, from the individual level to the collective level, in other words to draw conclusions about cluster emergence, it is necessary to analyse the issue at higher levels of abstraction and present the argument theoretically. This is required given that the data does not account for mobile entrepreneurs in the start-up phase.

In this section, I provide a formal analysis of the relation between social networks and traditional agglomeration economies to explain the emergence of a cluster. It could be surmised that since Hypotheses 1a and 1b are supported by the data, and that the data also supports Corollary 1, then Corollary 2 must follow. I will show why this is the case.

Considering the model of life cycle of clusters developed by Maggioni (2006), it is only when agglomeration benefits are greater than agglomeration costs, i.e. when agglomeration net benefits are positive, that it is possible to observe the spontaneous emergence and development of a cluster. This point is achieved with a minimum number of firms in the cluster, marked A in Figure 5.9 (following

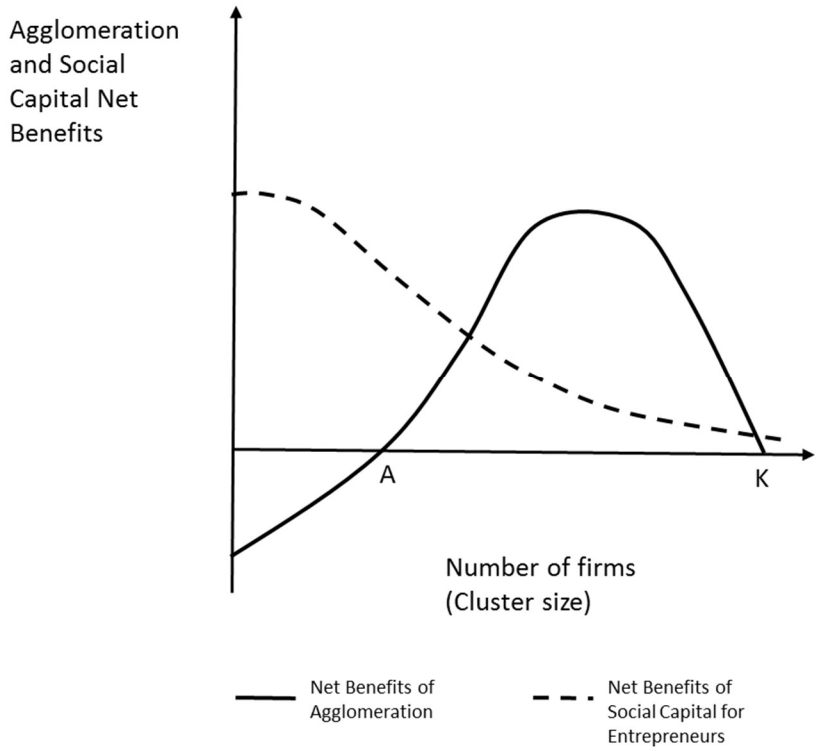
Maggioni's nomenclature); this is the minimal size for a cluster to exist. The main problem with this model is that it considers only two possible alternatives for reaching this minimal number of firms: a coordinated entry effort of firms to reach point A immediately; or direct intervention through public programmes to subsidise entry costs until point A is reached (Maggioni, 2006, p. 222).

However, the evidence shows that successful clusters are organically created, without coordinated acts of policy intervention (Feldman, 2001; Saxenian, 1994). Therefore, the question that remains is how the minimum level of firms in a sector and locality is attained organically. I propose that the number of firms in a cluster in its early stages is dependent on the entrepreneurs' social capital. In the early phase of cluster emergence, there are no agglomeration benefits, and locating a new venture in a sector and locality can offer benefits to an entrepreneur only if he or she can find a valuable business opportunity and can access the necessary resources to successfully create the firm. This assertion is supported by the data presented in this chapter. For the initial entrepreneurs, the benefits of their social capital need to be high enough to allow them to enter the market. If the high benefits of the social capital needed to start a company in a determined sector and locality coincide for several entrepreneurs, we will see an increase in the number of firms starting a proto-cluster phase.

When the number of firms in the cluster start to grow, the net benefits of agglomeration grow too. At the same time, the relative marginal benefits of an entrepreneur's social capital decrease since there is an increasing number of alternatives in terms of accessing resources or acting on opportunities. For example, venture capital firms might be more likely to invest in firms in a cluster once they perceive that it is growing. Therefore, the financial capital an entrepreneur requires

to start a business can be obtained not only through social capital, but from other institutionalised sources too.

Figure 5.9 Model for Cluster Emergence Considering Social Capital Benefits



It should be recognised that there is heterogeneity in the social capital of entrepreneurs. Entrepreneurs have inequalities in their levels of collective assets and positions in their social networks, as identified by Lin (2001), which causes differences in the access and mobilisation of resources through these networks, generating differences in social capital. Thus, not all entrepreneurs will effectively create a start-up in the first stages of a cluster – only those that can obtain positive returns on their social capital will be able to do so. Consequently, holding all else constant, a cluster will never emerge in a given locality if the number of entrepreneurs with the social capital required to start a business, before there are net agglomeration benefits, is too low (the proto-cluster will never reach point A in Figure 5.9). In economies where social networks are even more important for

gaining access to resources, we could expect a lower probability for observing organic clusters.

It should be mentioned that this analysis considered social capital only at the individual level. According to Lin (2001), there is also a collective level of analysis in social capital. The latter emerges in a cluster when its size and the relations between clustered agents develop a social network. Therefore, the collective social capital is a consequence of clusters and it is trivial in the proto-cluster stage (i.e. before reaching point A in Figure 5.9).

In summary, this section presented a formal analysis of the role of entrepreneurs' social capital in the early stages of a cluster. It was argued that in stages where agglomeration net benefits do not exist, entrepreneurs' social capital becomes a determinant for mobilising and accessing the necessary resources to create a firm. Heterogeneity in entrepreneurs' social capital can explain why not all entrepreneurs benefit from their social capital when they aim to create a firm, and might also explain why it is not always possible to observe the emergence of a cluster organically.

5.6 CONCLUSION

The present chapter has aimed to study the relationship between social networks and the location decision of firms in the emergence of a cluster. It was possible to determine from the literature on clusters that agglomeration factors are mainly closeness to clients and suppliers, reduction in costs, access to resources in a region and knowledge spillovers. From the entrepreneurship literature, it is also possible to identify access to resources and opportunity recognition as the two main drivers of the entrepreneurial process. However, it is possible to combine both streams of

literature since some resources in the region are entrepreneurial drivers; other regional factors – such as closeness to clients and suppliers, collaborations between agents, etc. – could be considered necessary to identify an opportunity to start a company. In this context, social relations – the personal and business connections of the entrepreneur – allow better access to resources and opportunity recognition, affecting not only the decision to create a new firm but also the location of this new venture. The proposition of this study is that entrepreneurs will locate their companies where the benefits of their networks are maximised, determining the location and creation of their firms.

Using a combination of qualitative and quantitative methodologies to study the main hypotheses of this work, it was possible to sustain the proposition of this chapter in the case of the biotechnology sector in Chile. Results from the content analysis of open-ended questions and interviews identify a strong association between a perceived positive impact of social relations and access to resources, mainly financial capital and knowledge. The importance of social relations to accessing financial capital is in line with previous results (Hsu, 2007; Uzzi, 1999). If there is a lack of a strong and developed financial system for entrepreneurs, this is compensated for with social relations, which form a social network that may function as a parallel system of trust, leading to financing for new projects, especially in sectors with high information asymmetries and risk, such as biotech. Also, from the content analysis procedure, it was possible to identify a positive association between social relations and factors associated with opportunity recognition. These results support Hypotheses 1a and 1b. Finally, from this exercise it was possible to observe that social relations were positively associated with the process of the creation of firms.

Kruskal-Wallis tests were then conducted to estimate significant relations between the number of connections and different factors for location, and obstacles to the creation of firms. The results presented in Section 5.4.2 give support to Corollary 1 on firms' location and creation. It was possible to establish that the location and creation of firms are affected by access to resources and also by factors related to opportunity recognition; these, in turn, are affected by the social relations of firms. Overall, all factors were highly related to knowledge and technology, and social relations (business or personal) are highly related to access to knowledge as well. These results support the knowledge spillover theory of entrepreneurship proposed by Audretsch and Aldridge (2008), but advance their proposition in the sense that social capital is behind the effective access and use of the knowledge.

The high relative importance of personal factors in location decisions (Figure 5.2) reflects the weight that social relations have for entrepreneurs starting up a company. Although this might seem to contradict a more rational view of entrepreneurship and cluster formation, I argue that the reliance on social relations is rational since it allows entrepreneurs to have better access to resources and opportunity recognition, a claim that is supported by the data presented in this chapter. However, these results need to be further studied in order to clarify the entrepreneurial process and the role of social capital in it.

Overall, the results suggest that social relations are significant for access to resources, mainly financial capital, high-skilled workers, and knowledge; these are crucial for the location and creation of firms. Also, it identifies that, within factors of opportunity recognition, social relations are important for relating to suppliers and clients, which is fundamental to the creation of a company. These results are in line with social capital theory (Lin, 2001).

The last section developed a formal analysis to move from the individual level to the emergence of clusters. It shows that in the early stages of cluster formation, when agglomeration net benefits are negative, entrepreneurs rely mainly on their social capital to access and mobilise resources for creating a company. When this process coincides for several entrepreneurs, the cluster may move towards a proto-cluster phase that might lead to cluster development. However, there are inequalities in the entrepreneurs' social capital that arise from differing assets and positions of the entrepreneurs in their own social network. These inequalities might lead to a situation where the cluster cannot develop because only a few entrepreneurs can effectively obtain resources to start their own companies, and so the number of firms necessary to obtain positive net benefits of agglomeration is never reached.

A limitation of the analysis presented in this chapter is that it is not possible to generalise from this case study. Additionally, this study identifies only successful firms and does not include the analysis of firms that have failed. Future research should identify differences between successful and non-successful entrepreneurs to determine the role of social capital in both groups. Also, it would be important to test for potential differences between sectors with different resource requirements. It would further be interesting to study the extent to which entrepreneurs are aware that they are participating in a cluster when they are locating a company.

Some policy recommendations that can be drawn from this chapter are that policies promoting the emergence of clusters should include measures to facilitate access to resources and opportunity recognition for those entrepreneurs that have a viable business idea but do not have the necessary social capital to obtain those

resources on their own. A system of mentoring could be developed, together with other measures connecting new with experienced entrepreneurs.

Overall, this chapter attempts to bring together cluster and entrepreneurship literature, showing that both streams of literature refer to similar ideas in the entrepreneurial process. Additionally, it is the first study to measure qualitatively and quantitatively social relations in the business and personal realm, determining that social relations are crucial to the entrepreneurial process and to cluster emergence.

6 PERSONAL AND BUSINESS NETWORKS WITHIN THE CHILEAN BIOTECH SECTOR

6.1 INTRODUCTION

Firms within a cluster tend to collaborate with one another at higher rates than they do with firms outside the cluster, achieving higher levels of productivity and innovation as a result (Audretsch and Feldman, 1996; Boschma and Ter Wal, 2007). In strategic alliances literature, collaborations between firms manifest different features, depending on the objectives of the collaboration, the sectoral factors, the environmental features, and the types of partner. Firms will create formal agreements and business collaborations with other firms with different objectives, such to reduce costs or to innovate (Hagedoorn et al., 2000; Vonortas and Okamura, 2009). Collaborations also depend on the type of partner, the objectives and strategic considerations of their collaboration, changes within the industry, the country context and the level of competition that the partners experience (Cassi et al., 2015; Gulati, 1995b; Hagedoorn et al., 2000; Uzzi, 1997; Vonortas and Okamura, 2009).

In addition, studies in economic geography have shown that different types of proximity between clustered firms affect the creation of knowledge collaborations and innovation (Balland et al., 2013; Boschma, 2005; Boschma et al., 2014; Knoben and Oerlemans, 2012, 2006). Boschma (2005) introduced five types of proximity that affect the innovation performance of firms in a cluster: geographical; cognitive; institutional; organisational; and social. Several studies have found that there are interactions between these different types, affecting innovation and research-

oriented collaborations in a cluster (Hansen, 2014; Huber, 2012a; Mattes, 2012) and suggesting that geographical co-location alone is not enough to allow access to the beneficial effects on innovation and productivity found among clustered firms. Recent research by Caniëls, Kronenberg and Werker (2014) has introduced another important proximity for the innovation process in clusters: personal proximity. Personal proximity relates to similarities in personal features of individuals within a cluster, and has been linked to the creation of research collaborations (Werker et al., 2016) and to the governance and growth of clusters (Ooms and Ebbekink, 2015). In previous studies, personal closeness was associated with social proximity (Boschma, 2005; Knoben and Oerlemans, 2006); however, Caniëls et al. (2014) differentiate social proximity from personal proximity by stating that social proximity relates to social communities (scientific communities, for example) and the relations between actors in that community, or the network formed by the actors in the community.

It is also clear that the relations between firms in a cluster form networks in which material and immaterial flows occur (Boschma and Ter Wal, 2007; Giuliani and Bell, 2005; Gulati, 1995b; Lawton Smith, 2008; Owen-Smith and Powell, 2004). Usually, there are multiple networks in place simultaneously between a group of actors (Kadushin, 2012). The overlap of networks in a cluster emerges from the different collaborations that occur at the same time between firms. Types of collaboration are intertwined within a cluster; there are several types of relations and different types of flows between firms – a process called 'multiplexity' in SNA (Kadushin, 2012). How different types of relations affect one another has still not yet been deeply studied; in particular, there is scope to analyse the effects of informal ties on the emergence of formal ties between agents in a cluster (Breschi

and Malerba, 2005; Kadushin, 2012; Lawton Smith, 2008). For example, in the work conducted on the Chilean wine cluster by Giuliani (Giuliani, 2007; Giuliani and Bell, 2005), personal relations between workers in a cluster are considered informal ties for firms, while business relations among them are thought to constitute formal relations.

Although the role of trust between actors and firms in a cluster has been important for the creation of business collaborations between firms in clusters, and although personal relations and repetitive interactions are thought to be the basis of trust (Breschi and Malerba, 2005; Gulati, 1995b; Owen-Smith and Powell, 2004; Uzzi, 1997), the relationship between personal relations and business collaborations has not been directly addressed in the previous literature. The purpose of this chapter is to identify how intra-cluster business relations emerge and to assess if the personal network in which the cluster is embedded determines the intra-cluster business structure; the aim is to contribute to the existing literature on relations between firms. This chapter explores the relationship between personal and business relations using the case study of the biotechnology sector in Chile, assuming that personal proximity generates personal relations between individuals in different firms of the sector, leading to a business relation between those firms. In other words, is there a positive relationship between the personal and business links in a cluster? It is not clear from previous research if the importance of personal relations in creating a business relation is positive and significant after controlling for other factors relating to the decision to form a business link. This chapter will shed light on this.

In addition, few studies have tried to identify the effect of personal relations in a cluster. This study contributes to earlier research by using a novel data set that

identifies from surveys personal relations and business relations in the biotechnology sector in Chile.

Personal relations between workers or individuals in a cluster have been named 'social relations' in the literature of clusters using SNA (Casper, 2007b; D'Amore et al., 2010) and also have been included as part of social proximity in works related to the proximity literature (Balland et al., 2015; Boschma, 2005; Knoben and Oerlemans, 2006). Additionally, 'social network' may allude to any type of social interaction between actors in a network (Kadushin, 2012; Wasserman and Faust, 1994), generating a confusion to some extent between the relation among individuals and the social structure that emerges from these interactions. In this study, 'personal relation' is defined as a relation between two persons working in different firms in a cluster. Also, 'business relations' are defined as any relation between companies, regardless of the objective of the relation (for example, commercial, research, collective action, etc.) and the type of partner (competitors, universities, investors, etc.).

A PCA was conducted with data on effective business relations to identify the main factors explaining the variability of cases. The results suggest that an important factor in business relations is geographic and personal proximities. Additionally, multilevel logit model estimations were conducted to study the creation of business relations, taking the dependence of links within a firm into account, following Van Duijn et al. (1999). The probability that a personal relation will lead to a business relation was analysed using a two-level multilevel model. The results suggest that personal relations are positive and statistically significantly related to the probability of establishing a business relation.

The chapter is organised as follows. Section 2 summarises the key literature and develops the research hypothesis. Section 3 presents the model used and the methodology of the survey, and then describes the data. Section 4 presents the study context, describing the business and personal relations. Sections 5 and 6 present the results of the PCA and the multilevel model estimations respectively. Section 7 discusses the contributions and limitations of the study and offers some conclusions.

6.2 LITERATURE AND HYPOTHESIS

RELATIONS BETWEEN FIRMS IN A CLUSTER

A fundamental factor attracting firms to agglomerate, and a cause of success in innovative clusters, is interaction between firms; this generates networking among workers and leads to knowledge diffusion and learning (Audretsch, 2003; Breschi and Malerba, 2005). As Breschi and Malerba (2005) state:

> *A key feature of successful high-technology clusters is related to the high level of embeddedness of local firms in a very thick network of knowledge sharing, which is supported by close social interactions and by institutions building trust and encouraging informal relations among actors* (Breschi and Malerba, 2005, p. 3).

According to a review of the literature on high-tech clusters by Lawton Smith (2008), there are three types of network between firms in a high-tech cluster: production-oriented networks, where downstream and upstream connections exist; innovation networks, where horizontal links with competitors, universities and research institutions are central; and informal networks, where mainly horizontal social relations emerge (Lawton Smith, 2008).

Recent literature on economic geography, social networks and clusters has

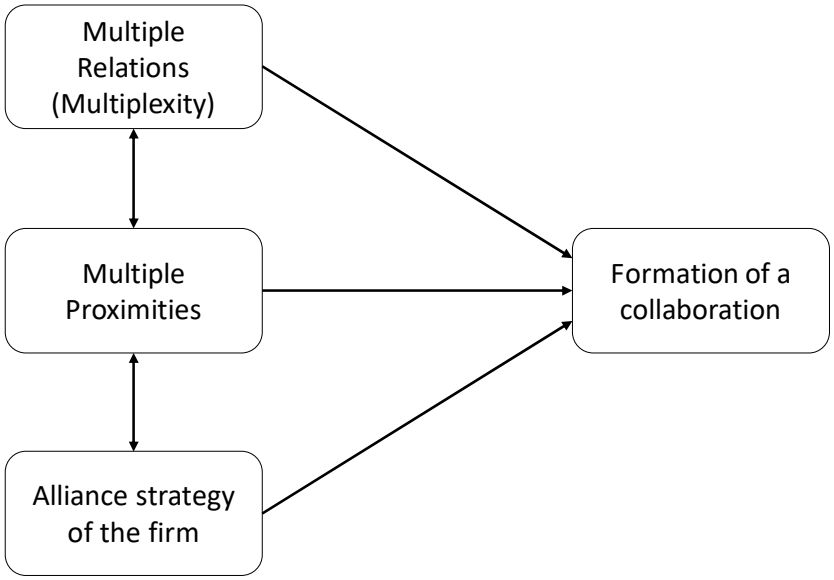
provided new insights into the role of geographic closeness and the role of networks in the exchange of resources, particularly knowledge, among clustered firms (Bathelt, 2005; Boschma, 2005; Giuliani and Bell, 2005). Boschma (2005) specified five types of proximities that are important for knowledge networks and innovation in clusters – geographical, institutional, organisational, cognitive and social – clarifying that it is not only geographic closeness that affects the innovation of clustered firms.

From this work, a new stream of literature has emerged focusing on complementarities, substitution and the non-linear effects of proximities on innovation in firms (Hansen, 2014; Huber, 2012b; Knoben and Oerlemans, 2012; Mattes, 2012). Moreover, studies of clusters using SNA have shown the importance of the network structure for innovation and knowledge transfer. Giuliani and Bell (2005) found that the relative position of firms within the knowledge network in the Chilean wine cluster determined their knowledge sources and the diffusion of knowledge. Thus, SNA can be integrated into the proximity framework to explore the effects of different proximities and relations on firms' performance (Balland et al., 2015; Massard and Mehier, 2009).

In addition, the creation of R&D collaborations or formal joint ventures, according to the strategic management literature, is determined not only by the features of the partners, but also by economic and strategic considerations, as well as the features of the industry (Hagedoorn et al., 2000; Vonortas and Okamura, 2009). The considerations affecting firms' willingness to collaborate are closely related to the literature on proximities and social networks. Therefore, the creation of a business relation between two firms is determined by the strategy of the firm, the effect of different proximities, and the multiple networks and connections in a

cluster (Figure 6.1). Each part of this conceptual framework will be developed further below.

Figure 6.1 Conceptual framework for the emergence of business collaboration between firms



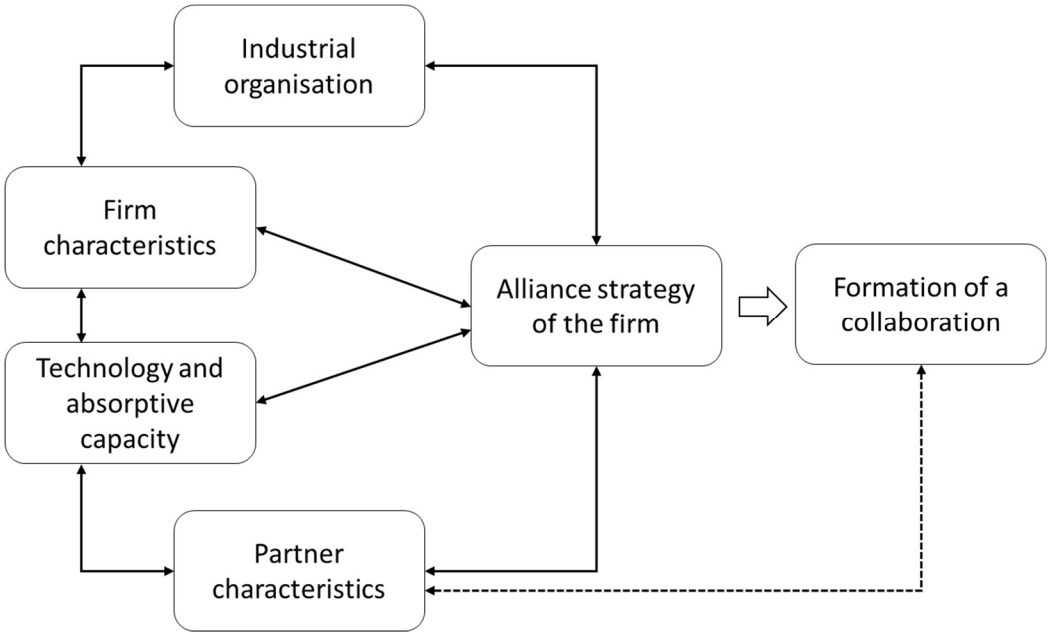
Source: Author's elaboration

THE DETERMINANTS OF BUSINESS RELATIONS

The decision to form a business relation can be based not only on a cost-benefit analysis, but also on strategic and long-term considerations (Hagedoorn et al., 2000; Vonortas and Okamura, 2009). According to Hagedoorn et al. (2000), three theoretical perspectives on collaboration between firms can be distinguished: transaction costs; strategic management; and industrial organisation.[16]

[16] A detailed analysis of those perspectives on business collaborations was presented in Chapter 2 of this thesis.

Figure 6.2 Diagram of Collaboration Decision



Source: Author's elaboration based on Hagedoorn et al. (2000).

A diagram of these theoretical perspectives and firms' decisions to form collaborations with other organisations is presented in

Figure 6.2; a summary is shown in Table 6.1. Within this conceptualisation of the reasons for creating a relationship between organisations, the characteristics of the partner, for example if it has complementary resources or is a direct competitor, are important. However, neither the role of trust or personal relations nor the role of geographical proximity are central in the literature of strategic alliances. The role of proximities and personal relations will be discussed below.

Table 6.1 Theoretical perspectives on firm collaborations

Theoretical perspective	Approach	Reasons to form a business relation
Transaction Costs	Economically efficient way to organise transactions	Minimise transaction costs Circumvent incomplete contracts Avoid opportunistic market behaviour Avoid high costs of internalising the activity
Strategic Management	Competitive force	Improving competitive position Coordinate value chains with coalition partners Develop broader scope of activities without entering new market segments Profit from economies of scale and scope Co-opt competition
	Strategic network	Share R&D costs Pool risks Improve competitive position Increase efficiency, synergy and power through a network
	Resource-based view of the firm	Access complementary resources to exploit own resources
	Dynamic capabilities	Collaborations as learning vehicle to accumulate and deploy new skills and capabilities Learn from partners Transfer technology Effectiveness of knowledge transfer Deal effectively with new technological and market uncertainty
	Strategic options to create new technologies	Collaborations to reduce risk exposure to new technologies and markets in the presence of uncertainties
Industrial Organisation	Non-tournament models	Share R&D costs Take advantage of R&D spillovers Pool risks Economies of scale and scope
	Tournament models	Co-opt competition Accelerate return on investments Access complementary resources on R&D Increase market power

Source: Based on Hagedoorn et al. (2000)

MULTIPLE PROXIMITIES

The central role of geographic proximity as a catalyst of knowledge spillovers and collaborative settings between firms located in the same region or district has been studied in economic geography (Balland et al., 2015). Other types of proximities, such as cognitive, institutional, organisational, and social proximities, have been

identified in the previous literature (Boschma, 2005; Huber, 2012b; Knoben and Oerlemans, 2006; Werker et al., 2016). Definitions of these types of proximities have been developed and reformulated by different authors (Boschma, 2005; Caniëls et al., 2014; Knoben and Oerlemans, 2006; Werker et al., 2016); in some cases the differences are significant and do not clarify how these proximities can be measured.[17]

This definitional ambiguity has led to the inclusion by authors of other forms of proximity to clarify previous concepts and include missing dimensions. For example, Knoben and Oerlemans (2006) include technological and cultural proximities, while Caniëls, Kronenberg and Werker (2014) have introduced the concept of personal proximity. The definitions followed in this chapter are based on Werker, Ooms and Caniëls (2016), as the most up-to-date research (see Table 6.2).

Table 6.2 Definitions of proximities from the literature

Proximity Concept	Definition	Author(s)
Geographical	Spatial proximity – geographical distance between two organisations	Boschma (2005)
Institutional	Similar formal and informal institutions (law, norms) at a national or regional level	Boschma (2005)
Organisational	Structure, rules, regulations and culture of organisations	Werker, Ooms and Caniëls (2016)
Cognitive	Knowledge base of an organisation, determined by their absorptive capacities	Boschma (2005)
Social	Embeddedness of an organisation in the community studied (cluster, economic community, social community, knowledge community, etc.)	Boschma (2005). Werker, Ooms and Caniëls (2016). Caniëls, Kronenberg, and Werker (2014)
Personal	Similarities between individuals with respect to the individual's characteristics	Caniëls, Kronenberg, and Werker (2014)

Source: Based on Boschma (2005), Werker, Ooms and Caniëls (2016) and Caniëls, Kronenberg, and Werker (2014).

[17] For detailed reviews on the subject, see Balland et al. (2015) and Knoben and Oerlemans (2006).

Social proximity and personal proximity are the most important proximities in this study. In some cases, social proximity has also been represented as relational or personal proximity (Knoben and Oerlemans, 2006) and has also been associated with personal relationships between actors (Balland et al., 2015). However, in the definitions presented in Table 6.2, personal proximity is defined at the level of the individual, while social proximity is considered a meso-level dimension and is related to a network. In social network theory, a relationship between two individuals is highly correlated with the similarities of both individuals, a process known as homophily (Kadushin, 2012).

As might be evident, homophily and personal proximity, as defined by Caniëls, Kronenberg and Werker (2014), are closely related. This closeness in individual features can generate a personal relation between two individuals, which in turn affects the social proximity of the two individuals. If we consider that personal proximity is between individuals, but that these individuals are part of different firms, then a personal relation can promote a business relation between the firms. This aspect is the main argument in this chapter and will be developed further in the following sections.

The Role of Personal Relations

As mentioned in Chapter 2 (page 32), it is expected that firms choose a partner based on the probability that the other organisation fulfils the contract between them. When the available information of potential partners does not allow a differentiation between them, the decision might be based on other sources of information, such as personal relations, because these might establish foundations of trust between two parties (Owen-Smith and Powell, 2004). Personal relations build trust because they provide extra information – usually not observable – to

each party.[18] Information from previous personal relations is important only for initial interactions. Later, the set of information is actualised by the experience of earlier interactions.

Previous analysis and reviews of relations between firms and actors in a cluster highlight the existence of multiple relations among the same set of actors in a cluster. This has been called 'multiplexity' in the SNA literature. According to Kadushin (2012), multiplexity can refer to the fact that there are different types of relations or links between two actors, which has been called 'role multiplexity'; different types of flow exist between two actors with one type of relation, for example knowledge, advice and friendship, which is called 'content multiplexity' (Kadushin, 2012, p. 36). Multiplexity is an important concept because it indicates that there are complex processes at work simultaneously in a network. Kadushin says that 'given the multiple bases upon which relationships can be formed within a community, multiplexity has an important role in theorizing about economic forms' (Kadushin, 2012, p. 37). In addition, it emphasises that formal and informal relations can be connected and even that one type of relation could be the foundation for other types. However, the consequences of multiplexity can be positive or negative (Kadushin, 2012). The existence of multiple links could intensify existing relations and create trust between members of a community. Conversely, it could create a conflict of interest in certain circumstances, such as unwanted knowledge leakage for a firm, or could even lead to collective actions that could reduce benefits for the community. This last consequence is what Uzzi (1997, 1996) has described as the 'over-embeddedness' of a network and applies in particular to firms embedded in a

[18] For example, many owners of the first generation of biotech firms in Chile continued teaching in different universities. Also, former students later created their own companies. Their interactions in the academic context inform both parties about the reliability of the other party.

social structure that underlies the economic structure in which firms interact. While the institutional context and the structure of the network can influence the effect of multiple relations on the development of a network or cluster, as Kadushin (2012) points out, it has been difficult to test hypotheses on multiplexity quantitatively. Furthermore, Porter, Bunker Whittington and Powell (2005) point to the importance of identifying multiple networks in high-tech clusters in understanding their development and innovative capacity, although they recognise that secondary data usually does not provide information on this to allow us to understand which type of relations sustain other relations over time.

As mentioned in Chapter 1 (page 10), there are several types of firms within the biotech cluster. This chapter will study the biotechnology cluster, focusing only on the group of DBFs and their relations, since this is the core of the sector and is where new knowledge and biotechnology products are produced. The question that I will attempt to answer is: Are personal relations important for the formation of business relations in biotechnology in an emerging economy? Biotechnology is a sector with inherently high information asymmetries and uncertainty. In addition to this, in Chile there is a lack of a well-developed venture capital system and inconsistent public policies in relation to biotechnology. If personal relations are necessary to build trust, and trust is needed to create business relations, there will be a positive and statistically significant relationship between previous personal relations and the creation of a business relation. From the previous analysis of the literature, and as mentioned in Chapter 2, the following hypothesis will be tested:

> *Hypothesis 2: DBFs are more likely to create business relations with institutions with whom they have had a previous personal relation.*

The hypothesis assumes that personal relations are based on social capital. Personal relations build trust between owners or CEOs of different companies, which could be fundamental to new business relations. Thus, it might be assumed that a personal relation between the owners or managers of two organisations will lead to a business relation between those organisations in a cluster. However, not all types of business relations need trust in order to be formed, nor will personal relations affect all business relations to the same degree. Therefore, personal relations will mainly affect business relations that need trust between actors if they are to emerge. The next section details the methodology employed for analysing and gathering the data used in the study, as well as the limitations of the study.

6.3 METHODOLOGY AND DATA

6.3.1 MODEL SPECIFICATION

A business relation between two companies or organisations will be created and it will be observable only when this relation is expected to generate expected net benefits for both parties. Expected net benefits from a business relation depend on several aspects that are not usually observed by other companies or researchers. In the data set collected for this study, it is possible to observe when a firm reports the existence of a business relation. This problem set is usually defined as a latent variable model.

In this case, y_{ij}^{*} represents the unobserved joint net expected value of the business relation between organisations *i* and *j*, which is an unobservable latent variable. For there to be a business relation between two organisations, this variable must be positive, representing a positive net benefit for both organisations.

Therefore, only y_{ij} is observed; this takes a value of 1 if a business relation exists between *i* and *j*, and 0 otherwise. The probability of forming a business relation between two organisations in the cluster will be estimated by taking into account that links are not independent within a firm, since each relation could affect the probability of creating a new relation and is also affected by the past relations of each organisation (Van Duijn et al., 1999). Based on the model of Van Duijn et al. (1999) for the frequency of contacts within the social networks of a sample of Dutch people, a multilevel model with fixed and random effects will be modelled, grouping observations of links by firm to account for the interdependence of links created by every firm.

The multilevel model for the latent dependent variable y_{ij}^{*} is presented in equation (1), which is the first level of the model.

$$y_{ij}^{*} = \beta_{0j} + X_{ij}^{'}\beta_{1j} + r_{ij} \qquad (1)$$

Each observation represents a relationship between firm *i* and firm *j*. The sub-index *j* identifies the respondent firms (which are called *ego* in SNA) and the sub-index *i* identifies the organisations named by the respondent as business partners and other organisations in the network studied (which are called *alters* in SNA). Explanatory variables of the relation (such as distance and the existence of previous personal relations) and the features of *alter* organisations (such as type of organisation and age of the firm) are included as variables in the matrix $X_{ij}^{'}$. Errors are random effects represented by the vector r_{ij} and it is assumed that a logistic

distribution applies.[19] Coefficients of the first level of the model vary over respondent firms or *egos*, and therefore the model includes a random intercept and random slopes by the respondent firm. The second level of the model estimates these random coefficients with variables of the respondent firm ($Z_j^{'}$) as explanatory variables.

$$\beta_{0j} = \gamma_{00} + Z_j^{'}\gamma_{01} + u_{0j} \tag{2}$$

$$\beta_{1j} = \gamma_{10} + Z_j^{'}\gamma_{11} + u_{1j} \tag{3}$$

Coefficients in the second level of the model are called fixed effects, while the error terms u_{0j} and u_{1j} represent the unexplained variation between relations within firms. By substituting equations (2) and (3) in (1), it is possible to identify the final multilevel model.

$$y_{ij}^{*} = \gamma_{00} + X_{ij}^{'}\gamma_{10} + Z_j^{'}\gamma_{01} + Z_j^{'}X_{ij}^{'}\gamma_{11} + u_{0j} + X_{ij}^{'}u_{1j} + r_{ij} \tag{4}$$

The final model includes fixed effects and random effects. Interaction between level-one and level-two explanatory variables ($Z_j^{'}X_{ij}^{'}$) is called cross-level interaction. Term u_{0j} introduces random intercepts and $X_{ij}^{'}u_{1j}$ introduces random slopes. Assuming that r_{ij} has a logistic distribution, it is possible to write:

$$y_{ij} = \begin{cases} 1 & if \quad y_{ij}^{*} > 0 \\ 0 & if \quad y_{ij}^{*} \leq 0 \end{cases} \tag{5}$$

Then:

[19] A logistic distribution of the errors is assumed in the estimation procedure. Estimations were conducted using STATA 13.0.

$$P(y_{ij}=1) = P(y_{ij}^{*}>0)$$
$$P(y_{ij}=1) = \gamma_{00} + X_{ij}^{'}\gamma_{10} + Z_{j}^{'}\gamma_{01} + Z_{j}^{'}X_{ij}^{'}\gamma_{11} + u_{0j} + X_{ij}^{'}u_{1j} \quad (6)$$

Equation (6) identifies the final model in which the probability of having a business relation between two firms depends on features of the relationship and *alter* firms (in $X_{ij}^{'}$), features of *ego* firms (in $Z_{j}^{'}$), cross-level interactions (in $Z_{j}^{'}X_{ij}^{'}$), random intercepts (u_{0j}) and random slopes ($X_{ij}^{'}u_{1j}$). The dependent variable will be defined as *Comm* and is a dichotomous variable that takes value 1 if there is a business relation between two firms, and 0 otherwise. Variables included as explanatory variables are described below. In this study, cross-level interaction variables are not considered because there are no interactions between the variables of the respondent firm ($Z_{j}^{'}$) and the *alter* firms ($X_{ij}^{'}$) which could affect the formation of business relations from a theoretical perspective. The following subsections detail the data-gathering process, the independent variables used and their expected effects on the dependent variable, as well as the descriptive statistics of the variables employed in the model.

6.3.2 DATA

The data requirements for conducting this analysis are considerable (Breschi and Malerba, 2005; Kadushin, 2012; Lawton Smith, 2008; K. Porter et al., 2005). Secondary data, such as patent database and publications, provide only information on one type of relation and the flow between institutions (Breschi and Malerba, 2005). Most of the data on multiple relations in a network is qualitative (Kadushin, 2012). The construction of a rich quantitative dataset with multiple relations and

flows between firms in a cluster is one of the contributions of this study.[20]

As stated early, the survey focused on four regions of Chile. Considering only these regions, it was possible to collect information for 87 out of 201 organisations working in the biotechnology field, and for 55 out of 101 DBFs and R&D oriented firms in Chile (see Table 6.3). This chapter focuses on DBFs and R&D focused biotech firms,[21] since this is where biotechnology knowledge is mainly produced and also because within this group the data has high nodal and relational response rates. Results will be representative of this group of firms in the biotechnology sector of Chile.

Table 6.3 Rate of Responses of the Directed and Undirected Network

	Total Firms	Total Possible Linkages		Surveyed Firms	Response Rate	Relational Response Rate	
	N	Undirect	Direct	N	%	Undirect	Direct
Non-Biotech Firms	38	703	1406	16	42.1	67.1	42.1
Biotech Firms	163	13203	26406	71	43.6	68.3	43.6
-Non-DBFs	62	1891	3782	16	25.8	45.3	25.8
-DBFs + R&D oriented*	101	5050	10100	55	54.5	79.5	54.5
Total	**201**	**20100**	**40200**	**87**	**43.3**	**68.0**	**43.3**

Source: Author's computation based on Knoke and Yang (2008).
* DBFs + R&D oriented: dedicated biotech firms, laboratories using biotech, research centres using biotech, and consortia of universities and firms.

As mentioned in Chapter 3, and considering the rate of response (Table 6.3), the data will be analysed using the concept of *ego*-networks. Data on DBF firms has a higher response rate, which implies that all DBF firms and their links with any organisation for which I have full information will be considered for the analysis in this chapter.

[20] See Chapter 3, section 3.3, for details on the construction of the Dataset.
[21] This group of firms are DBFs, Lab Services using Biotech, Private Research Centers, and Consortia.

6.3.3 VARIABLES AND DESCRIPTIVE STATISTICS

This section describes the variables used in the model, discusses their expected effects and presents descriptive statistics for them.

FEATURES OF THE RELATIONSHIP

Two variables that determine the features of a link are included: the personal relation and the distance between firms. The variable of interest for this study is *personal relation*, which can be considered a proxy for personal proximity between two organisations. This variable takes a value of 1 if there is a personal relation between managers, owners or workers of organisations *i* and *j* before the beginning of the business relation, and 0 otherwise. It also takes a value of 1 if there is a personal relation between two organisations and if, up to the day of the interview, there is no business relation between them. The estimated coefficient associated with this variable is expected to be positive and statistically significant, showing a strong and positive relation between personal and business relations.

The variable *distance* captures lower transaction costs when both organisations are geographically close. Relation management entails costs and close proximity could reduce these. The variable is measured as the inverse of the square root of distance in metres,[22] identifying geographic proximity, and is expected to have a positive and significant coefficient.

FEATURES OF EGO AND ALTER FIRMS

Experience generating relations. From the literature on transaction costs, firms with previous experience in collaborations will generate new collaborations at a lower

[22] In the cases where the distance was zero, it was replaced by a value of 200 metres.

cost. Since the data is a cross-section of the cluster, it is not possible to analyse the dynamics of business relations formation. The experience of the firm is approximated by the number of years that the firm has operated in the market. It is expected that older firms will have more experience in previous collaborations, which will increase the probability of creating a business link.

Competitors. Additionally, it is expected that firms will tend to collaborate on R&D with research institutions or institutions that are not in the biotechnology sector in order to complement their resources. However, as mentioned above, the biotechnology sector shows features of a tournament research competition and therefore there will be a lower probability of two DBF firms cooperating. The *Alter DBF* variable identifies this effect, and can be considered a proxy for organisational proximity. It is expected that the coefficient will be negative if both organisations are DBF firms. However, it is also possible that these firms could have business interactions in other realms. For example, fieldwork revealed that several DBF firms were also distributors for international reagent companies. This duality was observed especially for the initial firms established in the country, since the activities of reagent distribution provide a company with a more stable cash flow to support other, more uncertain activities, such as R&D. Therefore, these firms are suppliers for other DBF firms, creating a business relation in a realm different from R&D. If this effect is predominant in this cluster, the coefficient associated with the variable *Alter DBF* could be positive; the final expected sign for this variable is uncertain.

Access to foreign markets. For the variables *Alter Exports* and *Ego Exports*, it is expected that if one of the partners exports, there is a higher probability of

generating a business link for strategic reasons. Exporters might have access to greater markets as well as to newer technologies, frontier knowledge and products. Therefore, if one of the firms does not export, it could search for a business relation with an exporter. However, this might not have an effect if both firms export or if they do not export. The expected sign of the coefficients is uncertain. The same applies to firms with foreign capital. Nonetheless, multinational firms could have fewer relations with local companies and rely less on social interactions, since their business relations would be focused on external markets. In particular, it was observed that most foreign-owned companies related to the biotech cluster are distributors of reagents or equipment produced abroad.

Size of organisations. The size of organisations, measured by a categorical variable from 1 to 9 based on the firm's sales,[23] might influence business interactions. It may be the case that small firms prefer to create a business relation with large firms for strategic reasons and to gain possible access to capital. However, it might be that large firms do not have incentives to collaborate with others since, for example, they can carry out all research internally. Yet organisations of a similar size could have similar levels of knowledge, technology and absorptive capacity to take advantage of the benefits of a business relation. It is not clear which effect would dominate.

Knowledge gap. The importance of the technology gap, the difference in technology and absorptive capacities between two firms, has been analysed in the literature on knowledge transfer and foreign direct investment (Girma, 2005; Girma and Görg,

[23] Interviewees were asked directly for the level of sales in 2012. In the case of no response they were presented with nine categories of sales (with 1 the lowest level of sales, identifying micro-enterprises, and 9 the highest, which identifies large firms, according to the classification of the National Statistics Institute in Chile). This categorical variable was selected to maximise the number of observations of this variable.

2007). At the moment, there are two different hypotheses. If the technological gap is low then two firms would not benefit from a collaboration that could include research, knowledge or technology transfers, since there is no room to learn from the other firm. If firms have a medium technology gap then they have the necessary absorptive capacities to take advantage of new knowledge transferred during the collaboration and also have something to absorb from the other firm. Finally, if the technology gap is too large then firms will not benefit from each other because it would be impossible to transfer knowledge between them. This is the inverted-U approach. However, there have been empirical studies (Girma and Görg, 2007) that have found a U-shaped relationship. The variables *Alter Areas of Biotech* and *Ego Areas of Biotech* are defined as the number of different biotech areas[24] in which the firm is actively engaged. These variables are related to the concept of cognitive proximities in the literature (Boschma, 2005). A larger number of areas would imply that firms have a wider technology base or apply their technology in different sectors. It might be the case that firms tend to generate business relations with firms working in other areas in order to gain access to a wider knowledge base, or that they tend to work with more specialised firms in similar areas of biotech. This is an empirical question to be tested.

Internal R&D capacities. In addition to these variables, internal R&D capacities are part of the absorptive capabilities of a firm (Cohen and Levinthal, 1990), which can determine the learning outcomes of collaborations (Boschma, 2005; Cohen and Levinthal, 1990) and can be related to cognitive proximities between firms (Balland

[24] The different biotechnology areas follow the OECD (2009) classification. They are: Health and Diagnosis; Food and Nutrition; Aquiculture and Marine Biology; Agriculture; Dry Zones Biotechnology; Patents and Publications; Bioindustry; Classic Fermentation and Bioprocesses; Bioinformatics and Nano-biotech.

et al., 2015; Boschma, 2005). The internal R&D capacities of a firm is proxied by a dummy variable that takes a measure of 1 if the firm engages in R&D activities (in-house or outsourced), and 0 otherwise.[25] The significance and sign of these variables depend on the type of business relations. If relations have a research-oriented focus, these variables would be expected to have positive coefficients. However, given the industrial organisation of the sector, the engagement of firms in R&D might not be positive and significant for other types of relations, such as supplier–client.

6.3.3.1 Descriptive Statistics of Variables in the Model

The data used describes the relation between each DBF firm and other types of firms interviewed during fieldwork. Overall, the total number of potential interactions was 5,712. Descriptive statistics of variables used for estimation are presented in Table 6.4 and Table 6.5, while the correlation matrix is presented in Table 6.6. Table 6.4 shows that only 1% of the observations are business relations, after including only observations for which both institutions, *ego* and *alter*, answered the survey. This is equivalent to saying that there are 74 business relations between firms in the group analysed. The low number of cases imposes additional challenges for estimation procedures,[26] and therefore the results must be interpreted carefully. Given this scenario, a PCA was conducted as an exploratory analysis to identify different components of these 74 business links. The results of this analysis are presented in Section 5. Table 6.4 also shows that *ego* variables have lower standard deviations in comparison to *alter* variables, although this analysis considered

[25] Different measures of R&D capacities were tested as variables, such as dummies for in-house R&D, natural logarithm of researchers, natural logarithm of R&D expenditures, share of expenditures on R&D over sales, share of researchers, among others. The variable chosen had the most non-missing values.

[26] It is not possible to test for different effects of variables for each type of business relation, since there are too few positive cases or effective relations in the sample.

multiple observations per *ego* since each observation is a relation.

Table 6.5 presents descriptive variables considering only one observation per *ego* and one observation per *alter*, in order to compare both groups. It is possible to conclude that there is a larger diversity of *alter* firms, especially in variables such as years, number of biotech areas, and proportions of firms that conduct R&D, and that the number of *alters* is almost twice that of *ego*s.

The correlation matrix (Table 6.6) shows that most *ego* variables are intercorrelated, as well as *alter* variables, while correlations between *ego* and *alter* variables are low. However, correlations are never higher than 0.47, ruling out a potentially serious problem of multicolinearity in the estimation.

Table 6.4 Descriptive Statistics for Variables in the Model

Matrix	Variables	Description	Obs	Mean	Std. Dev.	Min	Max
	Dependent Variable						
Y_{ij}	Business Relation	1 if there is a business relation between i and j, 0 otherwise	5712	0.01	0.11	0	1
	Level-one Explanatory Variables						
X_i	Years of Alter	Years since the establishment of organization i	4217	17.09	18.26	2.0	92.0
	Alter DBF	1 if alter organization is a Dedicated Biotechnology Firm (DBF), 0 otherwise	5712	0.54	0.50	0.0	1.0
	Alter Exports	1 if alter organization is an exporting firm, 0 otherwise	5712	0.32	0.47	0.0	1.0
	Alter Foreign	1 if alter organization has foreign capital, 0 otherwise	5712	0.15	0.35	0.0	1.0
	Alter Areas of Biotech	Number of biotech areas of alter organization	5712	1.61	1.97	0.0	8.0
	Alter Size	Categorical variable from 1 to 8 based on total level of sales	5436	5.06	2.92	1.0	9.0
	Alter Knowledge Capacity	1 if alter conducts R&D, 0 otherwise	4492	0.79	0.41	0.0	1.0
X_{ij}	Distance	Inverse of square root of distance in meters (min of 200 m)	5712	0.03	0.24	0.0	3.2
PER_{ij}	Personal Relation	1 if there is a personal relation between i and j, 0 otherwise	5712	0.02	0.15	0.0	1.0
	Level-two Explanatory Variables						
Z_j	Years of Ego	Years since the establishment of organization j	3978	12.64	9.35	2.0	45.0
	Ego Exports	1 if ego organization is an exporting firm, 0 otherwise	5712	0.34	0.47	0.0	1.0
	Ego Foreign	1 if ego organization has foreign capital, 0 otherwise	5712	0.16	0.37	0.0	1.0
	Ego Areas of Biotech	Number of biotech areas of ego organization	5712	2.23	1.97	0.0	6.0
	Ego Size	Categorical variable from 1 to 8 based on total level of sales	5316	4.95	2.96	1.0	8.0
	Ego Knowledge Capacity	1 if ego conducts R&D, 0 otherwise	4488	0.82	0.39	0.0	1.0

Source: Author's survey

Table 6.5 Descriptive Statistics for Firms in the Model

Variables	Obs	Mean	Std. Dev.	Min	Max
Alters					
Years of Alter	76	17.05	18.32	2.0	92.0
Alter DBF	103	0.54	0.50	0.0	1.0
Alter Exports	103	0.32	0.47	0.0	1.0
Alter Foreign	103	0.15	0.35	0.0	1.0
Alter Areas of Biotech	103	1.61	1.98	0.0	8.0
Alter Size	98	5.06	2.94	1.0	9.0
Alter Knowledge Capacity	81	0.79	0.41	0.0	1.0
Egos					
Years of Ego	39	12.64	9.47	2.0	45.0
Ego Exports	56	0.34	0.48	0.0	1.0
Ego Foreign	56	0.16	0.37	0.0	1.0
Ego Areas of Biotech	56	2.23	1.99	0.0	6.0
Ego Size	53	5.04	2.96	1.0	8.0
Ego Knowledge Capacity	44	0.82	0.39	0.0	1.0

Source: Author's survey

The results from different forms of analysis are presented and discussed in the following sections. First, a descriptive analysis of responses to the survey, in particular with respect to business and social links, will be presented. Second, results from the PCA will be discussed. Finally, the results from the econometric model presented in this section will be analysed.

Table 6.6 Correlation Matrix

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Business Relation															
2	Years of Alter	0.05*														
3	Alter DBF	0.02	-0.25*													
4	Alter Exports	0.00	0.44*	0.05*												
5	Alter Foreign	0.04*	0.15*	0.04*	0.07*											
6	Alter Areas of Biotech	0.02	-0.03	0.34*	-0.06*	0.31*										
7	Alter Size	0.03*	0.42*	-0.07*	0.22*	0.02	-0.35*									
8	Alter Knowledge Capacity	-0.01	0.23*	0.08*	0.00	0.37*	0.34*	-0.03								
9	Distance	0.00	-0.05*	0.06*	-0.03*	-0.05*	-0.06*	0.07*	-0.10*							
10	Personal Relation	0.40*	0.05*	0.04*	0.02	0.04*	0.03*	0.01	-0.03*	0.00						
11	Years of Ego	0.05*	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.03					
12	Ego Exports	0.06*	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	-0.05*	0.04*	0.35*				
13	Ego Foreign	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-0.03*	0.03	0.13*	-0.01			
14	Ego Areas of Biotech	0.04*	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.08*	0.02	0.24*	0.47*	-0.13*		
15	Ego Size	-0.04*	0.06*	-0.01	0.08*	0.03	-0.01	0.04*	0.02	0.07*	-0.03*	0.45*	-0.15*	0.16*	-0.39*	
16	Ego Knowledge Capacity	0.03	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.03	-0.06*	0.24*	0.41*	-0.20*	0.37*	-0.18*

Surce: Author's survey

Note: * Indicates that the linear pearson correlation between the two variables is significant with a 5% of confidence level

6.4 COLLABORATIONS IN CHILEAN BIOTECHNOLOGY SECTOR: DESCRIPTIVE ANALYSIS

Descriptive analysis of the relations between organisations in the biotechnology sector in Chile is presented in this section (Table 6.7 and Table 6.8). There were 587 business relations and 148 personal relations identified between organisations in this sector. Almost half of the business links in the network (47%) originated through the personal connections of the owners, managers or researchers. Similarly, the social network reported that 47% of social links led to a business relation, while business relations led to a personal relation 26% of the time. This is an important difference, since business links are reported for the firm while the social network is reported for the interviewee. If we consider the social network of a company as the union of the social networks of owners, managers and researchers of the organisation, there will inevitably be a gap in the information collected.

The features of business links and their differences from social links are important to understanding the connections made by companies in this sector. Table 6.7 and Table 6.8 show that while 72% of business relations have a high importance for firms, only 41% of personal relations from interviewees are considered highly important for the firm. The average length of business relation is 8.4 years, 3.5 years shorter than the average personal relation, which could be explained because the sector is relatively new in the country. In addition, 24% of links are related to research activities. Among research relations are collaborations

in publicly funded projects, bilateral and privately funded projects, and collaborations in research with private companies or consortia.

Table 6.7 Features of the Business Network

Business Network	Percentage/ Statistic
Importance of the relation	
Low importance	27.3%
High importance	71.7%
Length of the relation	
Average years	8.4
Min	1
Max	51
Types of commercial relations	
Supplier	25.6%
Client	36.9%
Export partner	0.0%
Import partner	0.0%
Research partner	23.2%
Service provider	9.4%
Consultant	4.5%
Members in a consortium or research centre	0.5%
Capitalist Partner in the Firm Surveyed	0.3%
Firm Surveyed is Partner of Firm named	0.9%
Business Partners of other firms	0.7%
Trade/Industrial Assotiation member	0.3%
Other	3.1%
How this commercial relationship started?	
Owner(s) or director personal connections	28.6%
Manager or CEO's personal connections	15.0%
A researcher personal connections	6.1%
Previous clients	4.7%
Previous partner in a research project	3.7%
Partner in another company	0.0%
Partner in a Consortium	1.0%
Trade/Industrial Assotiation	1.7%
They contacted the company	3.0%
The company contact them	10.8%
Through other commercial relations	4.0%
Previous worker of the company	0.3%
Spin-off	0.5%
Conference	1.2%
Other	9.8%
No answer	9.6%

Source: Author's survey

Relations of client, supplier and service provider account for 72% of total business relations. There are more client relations than supplier relations registered, given that most of the biotech companies provide reagents produced on international markets to local companies and research institutions. Also, most of the firms sell their services to companies outside the cluster of DBFs and there are more potential clients than producers or distributors of products in the country, which explains the difference.

Another important type of business relation is participation in other firms in the sector; a total of 2.4% of business relations reported by the organisations involve a partner supplying capital in another company or the recipient of that investment. These investments have become more frequent in recent years: the main investors are venture capital companies, other biotech companies and individual investors. The formation of spin-off companies is still low and only a couple of cases (0.5%) are known.

When focusing on the origins of business relations, there are two main sources: personal relations and purely business considerations. Overall, personal relations between organisations' owners, managers, researchers and previous workers are the principal source (50%) of business links. Another 23% of links emerge purely motivated by business reasons: one of the parties contacts the other to buy or sell their products. Finally, 4% of business relations originate from previous research projects.

Table 6.8 Features of the Personal Network

Personal Network	Percentage / Statistic
Importance of the relation	
Low importance	58.8%
High importance	41.2%
Length of the relation	
Average years	11.9
Min	1
Max	44
Type of social relationship	
Former university classmates	0.7%
Former school classmates	1.4%
Family ties	2.0%
Former co-workers	11.5%
Former professor	10.8%
Childern go together to school	0.0%
Religious context	0.0%
Political context	0.0%
Trade/Industrial Association	9.5%
Conferences	12.8%
Professional	8.8%
Friendship	8.8%
Former Student	0.0%
Other	6.8%
The position in the company that your acquaintance have	
Owner	20.9%
General Manager/CEO	20.3%
Commercial Manager	4.1%
Financial Manager	0.7%
Research Manager	6.8%
Manager of other department	2.7%
Other administrative position	0.7%
Researcher	28.4%
Other	3.4%

Source: Author's survey

With respect to personal relations, professional and academic environments are highly important for the creation of such links in this sector. Table 6.8 shows that 13% of personal relationships started at conferences. Interviewees stressed the importance of national and international seminars and conferences for networking. These activities are important during university, graduate studies and in a professional or working environment. Biotechnology requires companies to conduct their own research, which implies that they need to be aware of the latest discoveries and on-going research by their peers in universities or other companies. Conferences and seminars are an important source of knowledge and allow scientists and entrepreneurs to identify quickly the latest knowledge in a particular area.

Another source of professional relations is university. Personal relations formed in a university – classmates, professors and students – represent 12% of the total. However, interviewees did not consider as their university classmates students on the same degree course but in different years, or at the same university but on different degree courses, since they did not attend classes together. This could increase the importance of professional relations if such relations are considered to be with university classmates.

Relations with former co-workers make up 12% of total personal relations, identifying an important source of knowledge spillovers within the sector through labour mobility. Personal relationships, such as friendships and family ties, represent 11% of total personal relations. Personal relations formed in religious, political or other contexts seem unimportant in this sector.

The majority of personal relations are with researchers (28%), CEOs (20%) or the owners (21%) of other companies. The relative importance of researchers in the network might be a reflection of the knowledge-based nature of the biotechnology sector. Additionally, this reinforces the weight of professional personal relations, since the network of researchers is closely related to the academic world.

In summary, personal relations seem related to the formation of business relations. Two main groups of personal relations are significant for the cluster: professional and personal. The relative importance of professional relations might be a consequence of the knowledge-based nature of the biotechnology sector.

Until now, the analysis has mainly reviewed the statistical results of the survey. However, econometric analysis of the determinants of business relations could bring new insights to the study of collaborations within a sector. This analysis will be presented in the following sections.

6.5 NON-PARAMETRIC ANALYSIS OF RELATIONS

In this case, the PCA allows us to study different types of business links and the role of social links within them. In this section, the results from the PCA are presented in order to identify the main features of business relations present in the Chilean biotechnology sector. The PCA, traditionally used to identify factors that group different variables, will be used in this study to determine the different factors that affect the variability of the 74 business relations observed.

Initially, a PCA factor analysis was conducted only with variables from *alter* organisations, distance and the existence of previous personal relations. The results of the rotated matrix (Table 6.9) suggest that there are three main factors that explain 73% of the variance of business relations.

Table 6.9 PCA with *Alter* Variables, Geographic Distance and Previous Personal Relations

	Factor		
Variables	(1) Partner Features	(2) Partner Knowledge	(3) Closeness
Years of Alter	**0.873**	0.311	-0.106
Alter Size	**0.762**	-0.026	0.111
Alter Foreign	**0.730**	-0.062	-0.213
Alter Exports	0.419	**0.748**	-0.181
Alter DBF	-0.487	**0.687**	-0.048
Alter Knowledge Capacity	0.134	**0.922**	0.042
Distance	-0.222	0.137	**0.815**
Previous Social Relation	0.016	-0.255	**0.823**
Proportion of Variance Explained by the factor	0.294	0.258	0.181

Number of observations is 60. Three factors with eigenvalue >1 were detected, explaning 73.3% of total variance

Extraction method: Principal components factors; rotations: oblimin oblique

Each factor will explain in part the business relations observed. The first factor identified could be considered a factor of 'partner features', since it mainly consists of variables regarding the features of *alters*, such as the experience, size, and foreign capital of *alter* organisations. The second factor is well explained by the knowledge features of *alter* organisations, such as exposure to foreign markets (if the *alter* exports), if the *alter* is a DBF, and if the *alter* conducts R&D. The last factor is largely explained by the geographic closeness between organisations and the existence of previous personal relations or personal proximity.

Given the proportion of the variance explained by each factor, it appears that the features of the *alter* firm are the most important for the creation of a business relation (this factor explains 29% of the variance), followed by the knowledge capacity of the *alter* (this factor explains 26% of the variance), and finally the

geographic and personal closeness (this factor explains 18% of the variance). The previous results suggest that personal relations could explain a type of business relations, although it seems that they are less important than other factors related to the partner.

A second PCA computation was conducted using variables that measure the differences between *egos* and *alters* in different respects. Instead of including variables of *ego* in the PCA analysis, it might be informative to identify how different or similar *egos* and *alters* need to be for different types of business relations. The results (Table 6.10) suggest that in this case it is possible to identify four factors affecting business relations. These four factors explain 67% of the variance in business relations. The factors identified are consistent with the factors previously found in the first PCA analysis.

The first factor is related to partner features, indicating that there is a tendency among DBF firms to generate business relations with organisations different in size, age and foreign ownership. This factor is the most important for business relations, explaining 19% of the variance. The second factor is identified only by geographic and social closeness, i.e. geographic distance and the existence of a previous personal relation. Social and geographic closeness explains 17% of the variance, and is the second factor in importance for explaining business relations.

A third type factor is related to obtaining what I will call 'complementary knowledge'. This factor is largely explained by contexts in which one of the organisations exports (having access to knowledge of external markets) and in which the main biotechnology area of both organisations is different (having access to knowledge from other areas and markets).

Table 6.10 PCA with Variables of Differences Between *Egos* and *Alters*

	Factor			
Variables	(1) Partner Features	(2) Closeness	(3) Complementary Knowledge	(4) Partner Knowledge
Difference of Years	**0.808**	-0.164	0.243	0.070
Difference in Size	**0.572**	0.280	0.008	0.239
Difference in Foreign ownership	**0.701**	-0.015	-0.163	-0.142
Difference in R&D activities	-0.300	-0.031	0.092	**0.755**
Difference in Type of Organization	0.404	0.037	0.003	**0.771**
Distance	-0.079	**0.845**	0.102	-0.198
Previous Social Relation	-0.001	**0.763**	0.033	0.303
Difference in Export behaviour	0.016	-0.040	**0.865**	-0.057
Difference in Main Biotech Area	0.127	0.281	**0.752**	0.192
Proportion of Variance Explained by the factor	0.194	0.165	0.158	0.158

Number of observations is 55. Four factors with eigenvalue >1 were detected, explaning 67.4% of total variance

Extraction method: Principal components factors; rotations: oblimin oblique

The final factor identified is related to knowledge factors, indicating that relations are formed between one organisation that conducts R&D and another that does not. In addition, this type of relations is more frequent between one DBF organisation and another type of organisation. Each of the last two factors explain 16% of the variance. PCA identifies that the factor of closeness, which is comprised of social closeness – or the existence of prior personal relations – and geographic closeness, on its own explains between 17% and 18% of business relations. Even when this type of analysis cannot confirm causality, it helps to identify stronger correlations between personal and business relations.

6.6 DETERMINANTS OF COLLABORATIONS: MULTILEVEL MODEL ESTIMATION RESULTS

The previous description of social and business networks in the biotechnology sector in Chile indicates that it is possible to consider that the personal relations of the sector determine the business relations to a significant degree. In addition, given that the number of positive cases of business relations with complete information on both organisations involved is low (only 74), PCA was used to explore further the relation between social and business relations. It was possible to determine that social and geographical closeness are important components in explaining business relations. To continue studying the role of personal relations in the creation of business relations in a cluster, a multilevel model was estimated. The results are presented in this section.

Estimation results from different specifications (Table 6.11) indicate that there is a positive and significant relation between personal and business links. By running a chi-squared test between the multilevel model and a logistic regression (without considering the clustered nature of the data), it can be concluded that multilevel estimations are preferable given the data structure.

The results show that the experience of the *alter*, as expected, affects positively and significantly the probability of creating a business relation, although this is not the case for the *ego* experience. If the *alter* is a DBF, there is a higher probability of generating a business relation; however, if the *alter* organisation conducts R&D, this reduces the probability. These results indicate that business relations between two DBF companies might have purposes that differ from R&D collaboration. Finally, if the *alter* is a foreign company, there is a lower probability of generating business

relations. It is possible, as discussed above, that foreign firms could have fewer social and business relations in the biotech sector in Chile.

Export orientation was expected to be positively associated with business relations; however, the results identify a positive but not significant relation, and therefore no evidence was found that the export behaviour of the *alter* or *ego* firm affects the probability of observing a business relation. Also, the number of biotechnology areas in which the firms operate is negative and non-significant, indicating that there is no strategic desire to get more access to more biotech areas when creating a business relation. *Alter* size is positive and significantly related to business relations; however, its significance is lost when including *ego* variables. This result suggests that there is a tendency for DBFs to create business relations with larger partners.

None of the *ego* variables are significant, which could be explained by the high correlation between the variables. Another explanation is the similar features of all *ego* firms, since all of them are DBFs firms and they have less variability in their descriptive variables. This leads to the conclusion that for DBFs, the features of the partner are important when creating a business relation. It might also suggest that DBFs have similar strategies for business relations; no differences in their experience, size or export orientation are identified.

Table 6.11 Determinants of Business Linkages in Chilean DBFs

	(1) Business Relation			(2) Business Relation			(3) Business Relation			(4) Business Relation			(5) Business Relation		
Variables	**Coef.**	**Standard Error**	**P-value**	**Coef.**	**Standard Error**	**P-value**	**Coef.**	**Standard Error**	**P-value**	**Coef.**	**Standard Error**	**P-value**	**Coef.**	**Standard Error**	**P-value**
Level-one Explanatory Variables															
Years of Alter	0.032**	0.01	0.00	0.04**	0.01	0.00	0.06**	0.01	0.00	0.04**	0.01	0.00	0.04**	0.01	0.00
Alter DBF	1.44**	0.39	0.00	1.74**	0.42	0.00	2.05**	0.46	0.00	1.45**	0.50	0.00	1.56**	0.53	0.00
Alter Foreign	-1.70**	0.46	0.00	-2.02**	0.48	0.00	-2.07**	0.49	0.00	-1.63**	0.56	0.00	-1.35**	0.57	0.02
Alter Exports	-0.02	0.33	0.96	0.51	0.38	0.18	0.70*	0.39	0.08	0.48	0.46	0.29	0.53	0.47	0.26
Alter Areas of Biotech	-0.08	0.09	0.36	-0.05	0.09	0.62	-0.05	0.10	0.60	-0.07	0.11	0.56	-0.10	0.11	0.38
Alter Size	0.24**	0.07	0.00	0.22**	0.06	0.00	0.16**	0.06	0.01	0.15**	0.07	0.04	0.12	0.08	0.12
Alter Knowledge Capacity				-1.86**	0.48	0.00	-2.06**	0.51	0.00	-1.37**	0.60	0.02	-1.15*	0.63	0.07
Distance							54.42**	7.78	0.00	36.90**	8.89	0.00	37.27**	9.83	0.00
Same organization															
Personal Relation										3.86**	0.45	0.00	3.63**	0.46	0.00
Level-two Explanatory Variables															
Years of Ego													0.02	0.04	0.51
Ego Exports													0.74	0.66	0.26
Ego Foreign													-0.67	0.95	0.49
Ego Areas of Biotech													0.02	0.17	0.89
Ego Size													-0.17	0.13	0.19
Ego Knowledge Capacity													0.25	1.23	0.84
Constant	-7.84**	0.67	0.00	-7.16**	0.71	0.00	-7.88**	0.73	0.00	-7.45**	0.69	0.00	-7.22**	1.32	0.00
Random-effects Parameters															
Random Intercept	4.19	1.87		4.88	2.24		3.74	1.74		1.79	0.84		1.08	0.64	
Number of Observations	3996			3940			3940			3940			2529		
Number of groups	56			56			56			56			39		
Average Obs per group	71.4			70.4			70.4			70.4			64.8		
Obs per group:															
min	71			70			70			70			3		
avg	71.4			70.4			70.4			70.4			64.8		
max	72			71			71			71			70		
Log Likelihood	-254.79			-240.72			-219.40			-177.53			-154.93		
Chi-Square Test (LR test vs. logistic regression)	81.13			86.02			66.36			28.47			13.75		
Prob>=chibar2	0.00			0.00			0.00			0.00			0.00		
Akaike Information Criterion (AIC)	509.58			481.45			438.80			355.07			309.85		

Note: * significant at 10%; ** significant at 5%. Rocust Estándar Errors presented. Estimation Method: Multilevel Model. AIC: Akaike Information Criterion.

Other specifications were conducted with random slopes of *ego* variables; however, these estimations did not perform better and, after conducting likelihood ratio tests, it was not possible to determine whether one of the specifications was better than the basic multilevel model.

In terms of distance, since the variable is defined as the inverse of the square root of the distance in metres, it was expected that its coefficient would be positive and significant, indicating lower transaction costs in relations where firms are geographically close. The results support this hypothesis, highlighting the importance of geographic proximity to the creation of business relations.

Finally, personal relations are positively associated with the probability of observing a business relation. Given that personal relations and business relations could influence one another, the variable that identified personal relations was chosen to minimise any potential endogeneity since it only considers cases where the social interaction occurred before the business relation or cases where there is only a personal relation between firms. To verify this, an endogeneity test was conducted. To test for the existence of endogeneity in a non-lineal equation, an alternative procedure was followed.[27] A biprobit was estimated, since it performs a simultaneous estimation of two equations. Testing for endogeneity was approximated by testing for the significance of the covariance of the errors (reported as athrho) of both equations. The results of this procedure, shown in Table 6.12, suggest that there is no evidence in favour of endogeneity between business and personal relations. The Wald test for correlation of the errors in both equations cannot be rejected, meaning that there is not a significant correlation between the

[27] There is no endogeneity test that considers the cases where the dependent variable and the endogenous variable are dichotomic; therefore, an alternative method was chosen to identify if both variables are related.

errors of both equations. Also, the non-significance of the covariance estimated (athrho) between the errors indicates that it is not possible to reject the hypothesis that the correlation is zero.

However, this test must be interpreted with caution, given that the instrument variables to estimate personal relations (the independent variables in the *personal relation* equation) are variables related to the firms and not to the owners or managers of them. Factors that lead to one type of relation may not be the same as those that lead to another type of relation (Kadushin, 2012), which needs to be borne in mind during the analysis in this section. Since personal relations are between persons while business relations are between institutions, there is an underlying assumption in this test about the factors affecting the existence of a personal relation between two companies that could be captured in variables at the firm level. Thus, it is possible that endogeneity still exists between social and business relations, although it cannot be tested using the available data.

Overall, it is possible to recognise that there is evidence to support the main hypothesis that personal relations are an important factor for the creation of business relations, even when taking other factors, such as partners' features, into consideration.

Table 6.12 Endogeneity Test for Social and Business Relations

	Bivariate Probit		
	Coefficient	Standard Error	P- value
Business Relation Equation			
Years of Alter	0.02**	0.00	0.00
Alter DBF	0.73**	0.24	0.00
Alter Foreign	0.29**	0.10	0.00
Alter Exports	-0.56**	0.20	0.01
Alter Areas of Biotech	-0.05	0.04	0.22
Alter Size	0.05	0.03	0.13
Alter Knowledge Capacity	-0.53**	0.17	0.00
Distance	19.59**	2.78	0.00
Social Relation	1.64**	0.52	0.00
Years of Ego	0.02	0.01	0.23
Ego Exports	0.	0.22	0.12
Ego Foreign	-0.10	0.32	0.75
Ego Areas of Biotech	0.03	0.07	0.64
Ego Size	-0.08	0.05	0.13
Ego Knowledge Capacity	0.31	0.39	0.43
Constant	-3.71**	0.42	0.00
Personal Relation Equation			
Alter Foreign	-0.21*	0.12	0.07
Alter Knowledge Capacity	-0.42**	0.13	0.00
Ego Foreign	-0.13	0.23	0.59
Ego Knowledge Capacity	-0.14	0.28	0.61
Same organization	0.01	0.09	0.95
Distance	24.15**	5.80	0.00
Same Biotech Area	0.97**	0.20	0.00
Constant	-1.92**	0.33	0.00
athrho	0.04	0.19	0.83
Observations		2529	
Wald		4703.11	
Log pseudo-Likelihood		-490.12822	
Wald-test (rho=0) chi2(1)		.04424	
Prob > chi2		0.8334	

Notes: Coefficient reported, * significant at 10%; ** significant at 5%

athrho: In the maximum likelihood estimation, ρ (rho) is not directly estimated, but atanh ρ (athrho) is. Their relationship is:

$$\operatorname{atanh}\rho = \frac{1}{2}\ln\left(\frac{1+\rho}{1-\rho}\right)$$

6.7 DISCUSSION AND CONCLUSION

This Chapter studied the significance of personal connections in the formation of business relations between actors in a cluster. According to the theoretical perspectives, firms will engage in a business relation to reduce costs, increase the scale of production or research, gain access to new resources, or for strategic reasons (Hagedoorn et al., 2000; Vonortas and Okamura, 2009). Also, geographic, institutional, organisational, cognitive, social and personal proximities will affect the formation of relations between firms in a cluster (Boschma, 2005; Ooms and Ebbekink, 2015; Werker et al., 2016). Finally, from the SNA perspective, there are multiple relations that affect one another in a cluster (Boschma and Ter Wal, 2007; Giuliani and Bell, 2005); it is expected that personal relations between individuals will increase trust and reduce information asymmetries, increasing the probability that a business relation between firms will be generated. Although the literature acknowledges the importance of the interactions between different proximities and relations to the innovative outcomes of clustered firms, the interactions between different types of relations in a cluster have not been studied in-depth. In particular, the effect of informal relations, such as personal connections, on the creation of business relations in a cluster has been considered of importance but rarely directly assessed. The aim of the research presented in this chapter is to develop quantitative evidence in this respect.

To study the relationship between personal and business links in a cluster quantitative data was collected regarding the personal and business relation of biotechnology firms in four regions of Chile. I used PCA and econometric analysis, taking other factors and features of organisations into account, to analyse the data. The probability of creating a business relationship was estimated using a multilevel

logit model suitable for assessing the non-independence of observations present in social network data.

The results suggest a positive and highly significant relation between social and business links. This result is consistent across several estimations. The relative importance of personal relations is reduced compared with the descriptive statistics when controlling for the features of firms. It was also possible to test for potential endogeneity between personal and business relations; no robust statistical presence of endogeneity was found. However, the methodology used to test for endogeneity is not the most conventional and there is a conceptual endogeneity that cannot be solved with the current estimation methods. Estimations can be improved with the newest estimation methods developed recently (Lazega and Snijders, 2016), opening new avenues for research into multiple networks in clusters.

The results show that geographic closeness was estimated to be positive and significant to the probability of creating a business relation, in line with the perspective that geographic proximity is important for collaboration between firms (Boschma, 2005; Hansen, 2014). Strategic considerations, such as gaining access to new resources and complementarities, were tested by including dichotomic variables on the type and size of organisations. It was found that business relations between two DBF companies are likely to occur; however, it is less likely that they will occur if both firms have research capabilities. Both results combined may indicate that firms do search for complementary resources in collaborations, and that these collaborations between DBF firms are less likely to occur for research reasons, which is in line with the industrial organisation perspective that in certain sectors the way firms compete may or may not encourage collaboration between firms. In biotechnology, the tournament competition between DBFs (Hernández-

Cuevas, 2007; Owen-Smith and Powell, 2004) makes collaboration for R&D purposes less likely, which is in line with the findings in this article. The size of firms, measured by a logarithm of the number of employees, is positively related to the probability of generating a business relation, confirming the idea of strategic complementarities for business relations (Hagedoorn et al., 2000). However, it is not statistically significant when considering the variables of the *ego* firm.

Access to other resources or markets, estimated by the export behaviour of the firms, is positively related to the probability of forming a business relation but is not significant. However, if *alter* firms have a percentage of their capital owned by foreign firms, it is significant and negatively related to the probability of forming business links. This result indicates that foreign firms might be relatively isolated in the business network of the cluster.

Overall, the existence of personal relations is positive and significantly related to business relations. This result was found in the econometric estimations, the descriptive analysis of the relations, and in the PCA. The triangulation of results suggests that personal relations are an important factor for the creation of business relations between organisations in a high-tech cluster. This result confirms the conclusions from previous studies on personal proximities in clusters (Caniëls et al., 2014; Ooms and Ebbekink, 2015; Werker et al., 2016). The present study provides additional evidence on the impacts of personal relations in a cluster. Given that personal relations within the cluster are important for the creation of linkages between firms, it might be possible that the cluster effects a lock-in of knowledge and access to capital, which may lead to the creation of a business clique. If this is the case, firms face not only difficulties in terms of R&D uncertainties and financial restrictions, but also in terms of access to the 'right' social network that they need

to grow. These effects might reduce the foundation of new companies and start-ups, potentially hindering cluster growth. These findings support the notion that there are drawbacks in terms of personal relations for cluster growth in line with Uzzi (1997, 1996) and Ooms and Ebbekink (2015).

In conclusion, this study has allowed an assessment of the importance of personal relations in the creation of business relations after controlling for other important factors. Implications for public policies regarding cluster development and regional economic development might consider these results when designing instruments to promote collaborations between firms in a cluster or region. To obtain the benefits in terms of innovation and knowledge spillovers in a cluster, it is necessary to have business interactions between firms; however, policies promoting these collaborations should consider the importance of personal connections between individuals in the cluster and understand that these relations will shape the business collaborative network within it. Therefore, if the policy objective is to increase collaborations and knowledge diffusion throughout a cluster, complementing grants for business collaboration with social activities should be considered to promote personal connections between the owners, managers and researchers of a cluster. However, further research still needs to be conducted. It would be interesting to estimate the different impact of personal relations on the growth of the firm. Also, it is still not possible to assess in this study if personal relations are more important to some types of business relations, for example in research and innovation, than for others. Additionally, longitudinal data would be required to conduct further analysis of the evolution of relations in a cluster and how this affects cluster evolution overall. Furthermore, it would be possible to test for changes in common institutions, such as the creation of sectoral associations,

policies and subsidies. However, even when panel data is not currently available, the magnitude of the importance of personal relations in the existence of business relations in this study gives an indication that personal proximities and relations can be more important than initially thought in a cluster. Personal relations are important resources to consider in the creation of links between firms. This chapter presents a first attempt to measure those links directly and estimate their importance.

7 SOCIAL NETWORKS, EXTRA-CLUSTER LINKS AND KNOWLEDGE CREATION

7.1 INTRODUCTION

As discussed in Chapter 2, networks and connections between companies, formal or informal, are fundamental for knowledge spillovers and for exploiting the advantages of agglomeration (Boschma and Ter Wal, 2007; Giuliani, 2007; Giuliani and Bell, 2005). The impacts of links between clustered firms have mainly been studied with regard to productivity and innovation (Boschma and Ter Wal, 2007; Giuliani, 2013a, 2013b; Gorgoni and Pietrobelli, 2010), but there is still scope to understand the extent and nature of intra- and extra-cluster links and how these could affect knowledge transfer within a cluster (Boschma and Fornahl, 2011). Furthermore, the creation of knowledge within firms has not been studied in this context; the literature has focused only on performance variables. This study will analyse the effects of different types of links on the creation of knowledge in the Chilean biotechnology sector. Extra-cluster links will be considered international links. It will be also possible to identify different types of partner as well as business versus personal connections, which is a main contribution of this chapter to the literature on clusters.

As is well known, the creation of new technologies is concentrated in a few developed countries (Freeman and Hagedoorn, 1994; Keller, 2004). In this context, technology and knowledge transfer from developed to less developed countries is crucial to increasing total productivity and to enhancing economic growth in less developed countries (Keller, 2004, 2002). The channels of technology transfer that

have been studied the most are imports, exports, foreign direct investment and labour mobility. However, international collaborations or links between firms could also be considered a channel of technology transfer, usually called 'global pipelines' in the economic geography literature (Bathelt et al., 2004; Maskell et al., 2006). As with other channels, the adoption of new technologies and knowledge will contribute to increasing firms' productivity and economic performance (Belderbos et al., 2004; Fritsch, 2003; Medda et al., 2006; Tether, 2002). This perspective, however, does not consider the impact of international collaborations on the knowledge creation of firms from less developed countries. This aspect is crucial given that it has been argued in the literature that clusters may suffer from a lock-in of knowledge, hampering cluster development (Uzzi, 1996). Extra-cluster links are seen as having the capability to diminish the lock-in effect and the over-embeddedness of a cluster (Bathelt et al., 2004; Boschma and Fornahl, 2011; Gulati, 1999; Morrison et al., 2013; Uzzi, 1997). However, there could be a trade-off between local links and external links with regard to collaboration and knowledge diffusion within a cluster (Morrison et al., 2013; Morrison and Rabellotti, 2009), highlighting the importance of local connections for the development of clusters.

For high-tech sectors in emerging countries, international links can be highly important since leading organisations creating knowledge are located in developed countries (Keller, 2004). It is not obvious how high-tech firms in less developed countries could emerge and survive in a context where firms are a long way, geographically and technologically, from the world leaders in knowledge creation. Therefore, to study extra-cluster links between high-tech firms in emerging economies is important; however, there have been only few studies focusing on this aspect.

The present chapter aims to provide evidence to account for this shortcoming by analysing different types of link in the biotechnology sector in Chile and their effects on knowledge creation, contributing to the literature and theory of knowledge creation in clusters in less developed countries. The findings of the research will shed light on the determinants of knowledge creation among high-tech firms in emerging economies, especially the role of intra- and extra-cluster links, using a case study of Chilean firms in the biotech industry.

Different networks will be analysed, distinguishing between different aspects such as business and personal connections, type of partner (whether focused on R&D or not), and the location of the partner (national or international), as well as all the combinations of these. The creation of knowledge is measured by the number of publications and patents: this allows for the identification of differences in the creation of knowledge close to the market (measured by patents) or in scientific knowledge (measured by publications). The main hypothesis to be tested is whether R&D links, national or international, are important to the creation of scientific knowledge, and whether other types of link, national or international, can affect the creation of knowledge close to the market. It is expected that international links have a greater impact on knowledge creation than national links, since through them firms gain access to new knowledge not present in the local sector (Boschma and Ter Wal, 2007).

The empirical analysis is carried out using non-parametric techniques in order to identify, first, the effects of the firms' features on the number of connections, and, second, the impact of different types of connections on firms' knowledge creation. Additionally, an econometric analysis is conducted in order to assess the effects of business and personal links in the process of knowledge creation, while controlling

for firms' characteristics. The results suggest that R&D business connections are positively related to the number of publications, while international R&D business relations have a higher impact than national connections on the number of publications. Other types of links, including personal relations, are not significantly related to the number of publications. International links do not seem to affect significantly the number of patents created, while national R&D links, business and social, are positively and significantly related to this variable, although other national links are negatively related to the number of patents. Overall, extra-cluster links, measured as international links, with R&D-focused partners such as universities and research centres, positively affect scientific knowledge creation (publications), although they seem not to be related to the creation of knowledge close to the market (patents).

The chapter is structured as follows. In Section 7.2, I present a review of the important literature, identifying the shortcomings of the current analyses, and introduce the hypothesis to be tested. Section 7.3 describes the data and methodology used. Section 7.4 presents the empirical results and Section 7.5 offers conclusions.

7.2 LITERATURE REVIEW

Existing studies have shown that cooperation could lead to an increase in innovation activities (Fritsch, 2003; Medda et al., 2006; Tether, 2002). In particular, R&D cooperation and technical support collaborations between firms are related to higher innovation performance (Belderbos et al., 2004; Boschma and Ter Wal, 2007; Giuliani, 2013a; Gorgoni and Pietrobelli, 2010).

However, the over-embeddedness of firms in their networks could have detrimental effects on innovation and knowledge creation (Bathelt, 2005; Bathelt et al., 2004; Bell and Albu, 1999; Uzzi, 1997, 1996). As Uzzi (1997) argues, local ties have a positive effect on productivity and the adaptation of firms, but there is a threshold 'after which embeddedness can derail economic performance by making firms vulnerable to exogenous shocks or insulating them from information that exists beyond their network' (Uzzi, 1997, p. 35). Uzzi's results are consistent with the phases of cluster decline proposed by Menzel and Fornahl (2009); these are characterised by a decline in firms' innovation and productivity performance, as well as a lower rate of firm creation in a cluster. These theories give extra-cluster or extra-network links the potential to maintain a knowledge-creation base in a cluster, reducing potential knowledge lock-in or over-embeddedness (Bathelt, 2005; Bathelt et al., 2004; Boschma and Fornahl, 2011; Uzzi, 1997, 1996).

Empirical evidence concentrates mainly on the effects of firms' external links on innovation or firm's productivity. Colombo et al. (2009) analyse the effects of international R&D alliances on the performance of high-tech start-ups measured by total factor productivity, using a Generalised Method of Moments estimation of panel data from Italian firms. Their results suggest that international R&D alliances are most beneficial to high-tech start-ups if: (1) they involve industrial partners located in a variety of countries; and (2) these countries are closer to the world knowledge sources. These conclusions hold when studying less technologically intensive sectors. Boschma and Ter Wal (2007) have studied the effects of the local and external links of firms in a footwear district in Italy. They conducted non-parametrical correlation estimations to establish that a strong local network position of firms impacted positively on firms' innovation performance, concluding

that co-location was not sufficient alone to allow firms to profit from local knowledge. In addition to this, they reported that firms with external links were more innovative than purely locally connected firms.

Morrison and Rabellotti (2009) study the extra-cluster and intra-cluster links for knowledge and information exchange in an Italian wine cluster (in Piedmont). Their results show that for knowledge networks, there were two groups of firms in the clusters: firms in the core of the network – which were closed to direct extra-cluster linkages, and were smaller and less innovative; and firms at the periphery of the network – which were larger, more innovative and open to external knowledge. The authors suggest that extra-cluster connections might not necessarily benefit the entire cluster, which was tested later by a simulation model developed by Morrison et al. (2013). These results suggest that clustered firms that are well connected with external actors can benefit the entire cluster only if they are also well connected locally in the cluster.

The effects of international collaborations on firms in emerging economies have not been widely studied. Previous work focuses on natural resource-based sectors, such as the wine and meat-processing sectors. Giuliani et al. (2016) study patents co-invented between firms from Brazil, India or China with firms in the European Union. They find that collaborative patents between firms from these emerging economies and European firms have a higher level of citations, meaning that they are more valuable, and that they are more general, which means that they were cited in different fields. These results show that formal international collaboration for the creation of patents results in valuable new knowledge. Giuliani (2013a) studies the relationship between different kinds of networking (local and extra-cluster) in the innovation performance of firms. Her research focuses on the

importance of local embeddedness[28] and external openness for new product success in two wine clusters in Chile and Italy. Estimating a negative binomial model, she concludes that local embeddedness positively influences the development of successful products but with decreasing returns, while external openness is more significant than local embeddedness for explaining a firm's successful development of innovative products.

In high-tech sectors, however, the evidence suggests that international collaboration occurs mainly between firms in developed economies. Freeman and Hagedoorn (1994) determine that during the 1980s most international R&D strategic technology partnering (over 95%) was between firms in developed countries (Freeman and Hagedoorn, 1994, p. 773). This evidence suggests that only a few firms in high-tech sectors in emerging economies are able to participate in leading technological research, but a lack of empirical evidence to identify the effects of local and external links on other types of high-tech firms' performance, such as knowledge creation or patents, does not allows us to draw conclusions here. The importance of studying intermediate outcomes, such as knowledge, is more suitable to studying the case of a high-tech sector where the knowledge base is at the core of the development of the sector (Bell and Albu, 1999). This chapter aims to provide new evidence on the importance of external links on firms' knowledge creation in a high-tech sector in the early stages of development in an emerging economy.

The chapter will analyse the case study of the biotechnology sector in Chile. Biotechnology in Chile was chosen because it is a relatively new sector, one which has experienced rapid growth in the number of firms in recent years and which has

[28] Local embeddedness was measured by structural holes, using the definition of brokerage by Burt (1992); network closure was measured by the out-and-in degree (number of connections) of firms.

different organisations interacting among themselves. Case study-based research has advantages for studying the different dimensions of firms' relations, such as type of partner, the objectives of the relation, and the geographical dimension of these relations, among others. In this context, it is particularly interesting to study a high-tech sector, which is not based on natural resources, in an emerging economy attempting to diversify exports, such as Chile. Biotechnology is a knowledge-based sector where spatial location may be less related to knowledge spillover benefits given that knowledge is not necessarily geographically bounded, highlighting the importance of links for knowledge transfer. Given this, the first hypothesis to be tested in this chapter concerns the international and national aspect of links:

> <u>Hypothesis 3a</u>: *Extra-cluster links, measured as international links, are likely to be positively related to the knowledge creation of firms in the Chilean biotechnology sector.*

However, local links are also important for knowledge creation. Gorgoni and Pietrobelli (2010) have studied the impact of local networks of technical knowledge on the probability of innovation in the Chilean meat sector. Using a binary logistic regression, they identified that firms with more local connections and firms receiving technical knowledge from firms more central in the sector have higher probabilities of innovating. Therefore, an additional hypothesis will be tested:

> <u>Hypothesis 3b</u>: *National links are likely to be positively related to the knowledge creation of firms in the Chilean biotechnology sector, but their magnitude or effects are likely to be lower than the effects of international links, given the importance of external sources of knowledge.*

An important aspect is that different types of links would not be equally important for knowledge creation and diffusion, as shown in previous studies (Boschma and Ter Wal, 2007; Colombo et al., 2009; Morrison and Rabellotti, 2009). Another dimension of links to consider is related to different types of network. Connections between firms and universities have shown to have a positive impact on the creation of knowledge and the innovation performance of firms (Almeida et al., 2011; Hohberger et al., 2015). Also, Almeida et al. (2011) shows that collaborations of firms on R&D with individual scientists at the personal level have positive impacts on the number of patents of firms. In addition, research by Giuliani et al. (2010) and Giuliani and Rabellotti (2012) show that firms collaborate more with scientists who are more central in the national academic network and show academic excellence. Knowledge networks between firms and universities have been studied before; however, different partners – and therefore different types of network – can also transmit knowledge. This study will consider this aspect, testing for different realms of relations and also testing for different partners simultaneously. Differences between links arise from the types of institution that are part of a relation. It is possible to argue that the orientation of a partner could lead to different types of knowledge transfer. In the biotechnology sector, taking DBFs as the core of the cluster, relations with R&D-oriented partners will be among DBFs but will also be with other institutions, such as universities and research institutions, where the main focus is on R&D activities. Other relations, on the other hand, will be with institutions across the value chain, for example with pharmaceutical companies in biomedicine, or with salmon farming companies in marine biology biotechnology. Other potential partners whose main focus is not R&D are venture capital firms, trade associations and governmental agencies,

among others. It is possible that relations with partners oriented towards R&D activities might have a higher impact on the production of knowledge. Considering these aspects, the following hypothesis is proposed:

> *Hypothesis 3c: Links with partners that are R&D-oriented are significant and positively related to the knowledge creation of firms in the Chilean biotechnology sector.*

Another aspect to consider is the formality of the links. It could be argued that business links are more formal and could include relationships where formal knowledge is transferred, while personal relations between owners or the CEOs of companies could be mechanisms for informal knowledge transfer.

Given that business relations are between companies, while personal relations are between individuals, it is expected that knowledge transferred through business channels would be more formal in nature, while knowledge transferred through personal channels would be at the individual level and so less formal. Dahl and Pedersen (2004) identify that informal contacts among engineers in a cluster of wireless communication firms in northern Denmark are an important source of the diffusion of technical knowledge. However, Morrison and Rabellotti (2009) find that there is a difference between knowledge and information within informal networks in a cluster. They find that knowledge networks are sparser and are characterised by reciprocal ties between a smaller group of firms in the cluster, while information networks do not require reciprocity and have a larger set of actors. Therefore, the impact of personal links on knowledge creation is not clear. There is a potential benefit in knowledge diffused by personal networks, but the real effect of it would depend on the actual access to and use of resources that individuals have from their

social capital and networks (Lin, 2001). Therefore, there is no clear hypothesis that could be drawn from the literature; however, it is possible make an empirical comparison of differences in the effects between business and personal networks on knowledge creation. The following hypothesis will be tested:

> *Hypothesis 3d: Personal links are likely to be positively related to the knowledge creation of firms in the Chilean biotechnology sector.*

Finally, cross hypotheses between geographical aspects and types of networks can be tested, leading to the last hypothesis. As Teixeira et al. (2008) identify, international R&D projects by European small and medium firms that are successful are also technologically more advanced in comparison to geographically and culturally closer R&D cooperation projects. Also, Colombo et al. (2009) find that international R&D alliances are positively related to productivity increases in high-tech start-ups. Consequently, it is possible to think that formal business links with R&D-oriented partners located outside the country will have the highest impact on knowledge creation, since these links are closely related to formal R&D collaborations and to partners in countries with different knowledge bases than local firms. The following hypothesis has been derived from these ideas:

> *Hypothesis 3e: International links with partners that are R&D-oriented are likely to be positively related to the knowledge creation of firms in the Chilean biotechnology sector and their relevance or marginal effect is likely to be higher than the effect of any other type of link.*

International relations considered in this study are connections between Chilean firms and institutions in countries leading technological research, such as the USA and European countries; there are also connections with institutions in

other non-leading regions, such as Latin America. Therefore, it needs to be borne in mind that international relations will capture access to both frontier knowledge and knowledge developed in other emerging economies, and it will not be possible to disentangle these two effects. The following section will introduce the data and methodology used in this study; the fourth section presents the main results.

7.3 DATA AND METHODOLOGY

Primary data from Chilean biotechnology firms was collected in a survey, collecting complete information for 66 companies. An analysis of the difference of mean between complete observations and total surveyed firms on key variables was conducted (see Appendix 5) and the groups are statistically similar in terms of the proportion of biotech firms, DBFs, total publications and total patents. A significant difference was found in the proportion of firms located in the Metropolitana region,[29] which implies that the results in this study will mainly identify the situation of the biotechnology sector in that region of Chile.

This primary data was matched with secondary data on publications[30] and patents.[31] Publications are related to scientific knowledge and open access of knowledge, while patents are related to knowledge used in the creation of new products or processes and restrict the use of that knowledge to the organisations filing the patent. Both sources are important for a knowledge-based sector such as biotechnology; however, knowledge from patents is closer to the market.

[29] The Metropolitana region includes the capital of Chile, Santiago; 66% of biotech firms in the country and 68% of firms included in this study are concentrated there.
[30] Publication data was collected from the Web of Knowledge browser using the address of authors as the key variable. The search was restricted to articles only, and included SciELO and ISI journals.
[31] Patents were collected from the PATENTSCOPE database from the World Intellectual Property Organization at http://patentscope.wipo.int/ and also from the web page of the Chilean National Institute of Intellectual Property at http://www.inapi.cl/.

From responses to the business and personal relations in the survey it is possible to determine the networks of each firm. As in previous Chapters, interviewed firms will be called *egos* and their contacts will be called *alters*, obtaining *ego*-networks. Information collected for *alters* include their country and type of institution, for example universities, firms, public institutions, etc. The importance of the relation for the *ego* firm was collected using a four-point Likert scale. This information made it possible to calculate for each company a *degree* variable, which corresponds to the total number of relations, and a *weighted-degree* variable, which corresponds to the total number of relations weighted by their importance for the company interviewed. These variables were calculated for different types of networks resulting from the combination of three different dimensions, as shown in Table 7.1. Although other network measures could be included in the analysis, total degree is the most basic measure identifying the number of connections of each interviewed firm. Other network measures require certain assumptions for the network as a whole. For example, to calculate a brokerage measure, it would be necessary to assume that all *alters* are part of the biotechnology cluster. However, there are several cases where this method may not work effectively. In the case of bio-agro companies, for example, these firms have small agriculture firms or individuals as clients but these are not biotechnology firms. Considering these agricultural companies as part of the biotechnology cluster as a whole would imply that biotech firms in other areas, such as biomedicine, could have contact with these agricultural firms, but there is no connection observed between them, as is more probable. This procedure would artificially reduce the importance of some firms in the biotechnology cluster when considering the whole network and including every *alter* mentioned in the survey.

A first approach to determine a relation between different types of networks and knowledge creation will be conducted using non-parametric methods – the Kruskal-Wallis test and the Kendall tau-b correlation – following Boschma and Ter Wal (2007). These measures identify the existence of a significant correlation and the direction of the relation between two categorical variables. If both methods present significant results, it is possible to conclude that a significant relation exists between the two variables. These procedures will determine the relation between the features of firms and their number of relations (or openness), and also between the number of relations and knowledge performance variables.

In addition, a regression model was estimated to analyse the importance of network variables when considering firms' features simultaneously. A negative binomial estimation was followed, given the count nature of knowledge variables, the number of publications and the number of patent applications. The negative binomial estimation was preferred given the over-dispersion of the data. The dependent variables are the total number of publications or the total patent applications. Independent variables referring to the features of firms are a dummy variable that identifies with value 1 firms with more than 100 employees, the age of the firm, the number of different biotechnological areas in which a firm is engaged, and a dummy variable that identifies a DBF. Also, independent variables include variables of different networks, as in Table 7.1. Several specifications for business and personal networks will be considered, exploring the national and international dimension, as well as the R&D dimension. The list of variables considered in this chapter in presented in Table 7.2.

Table 7.1 Definitions of the Different Types of Network Used in the Study

Spatial Dimension of the Networks	Type of Partner and Type of Network						
		Business			Personal		
		Total	R&D Network	Other Network	Total	R&D Network	Other Network
	Total	Every relation with a business purpuse	Every business relation with Dedicated Biotechnology Firms, Universities, and Research Institutes.	Every business relation with other companies or institutions that are not part of the R&D Network (e.g. Venture Capital, Pharmaceuticals, Clients)	Every relation with a personal purpuse	Every personal relation with Dedicated Biotechnology Firms, Universities, and Research Institutes.	Every personal relation with other companies or institutions that are not part of the R&D Network (e.g. Venture Capital, Pharmaceuticals, Clients)
	National	Every business relation with alters in Chile	Every business relation with Dedicated Biotechnology Firms, Universities, and Research Institutes located in Chile	Every business relation with other companies or institutions that are not part of the R&D Network and that are located in Chile.	Every personalrelat relation with alters in Chile	Every personal relation with Dedicated Biotechnology Firms, Universities, and Research Institutes located in Chile	Every personal relation with other companies or institutions that are not part of the R&D Network and that are located in Chile.
	International	Every business relation with alters outside Chile.	Every business relation with Dedicated Biotechnology Firms, Universities, and Research Institutes, located outside Chile	Every business relation with other companies or institutions that are not part of the R&D Network and that are located outside Chile	Every personal relation with alters outside Chile.	Every personal relation with Dedicated Biotechnology Firms, Universities, and Research Institutes, located outside Chile	Every personal relation with other companies or institutions that are not part of the R&D Network and that are located outside Chile

Table 7.2 Description of Variables Used in Estimations

Variable Name	Description	Mean	Standard Deviation	Min.	Max.
Network Variables					
Business Network					
deg_bus	Degree of Total Business Network	12.02	7.29	1	38
deg_bus_nat	Degree of National Total Business Network	10.09	6.65	0	35
deg_bus_int	Degree of International Total Business Network	1.92	2.54	0	12
deg_bus_rd	Degree of R&D Business Network	3.70	5.04	0	26
deg_bus_others	Degree of Other Business Network	8.32	6.59	0	29
deg_bus_rd_nat	Degree of National R&D Business Network	3.18	4.63	0	23
deg_bus_rd_int	Degree of International R&D Business Network	0.52	1.33	0	8
deg_bus_oth_nat	Degree of National Other Business Network	6.91	5.58	0	22
deg_bus_oth_int	Degree of International Other Business Network	1.41	2.31	0	12
wdeg_bus	Weighted Degree of Total Business Network	42.55	26.28	4	130
wdeg_bus_nat	Weighted Degree of National Total Business Network	36.24	24.02	0	114
wdeg_bus_int	Weighted Degree of International Total Business Network	7.08	9.05	0	42
wdeg_bus_rd	Weighted Degree of R&D Business Network	13.29	17.62	0	86
wdeg_bus_oth	Weighted Degree of Other Business Network	29.48	24.32	0	112
wdeg_bus_rd_nat	Weighted Degree of National R&D Business Network	11.64	17.25	0	84
wdeg_bus_rd_int	Weighted Degree of International R&D Business Network	2.03	5.23	0	32
wdeg_bus_oth_nat	Weighted Degree of National Other Business Network	24.39	19.19	0	76
wdeg_bus_otht_int	Weighted Degree of International Other Business Network	5.35	8.70	0	42
Personal Network					
deg_per	Degree of Total Personal Network	7.91	13.66	0	72
deg_per_nat	Degree of National Total Personal Network	7.23	12.49	0	71
deg_per_int	Degree of International Total Personal Network	0.68	1.92	0	10
deg_per_rd	Degree of R&D Personal Network	2.14	4.78	0	27
deg_per_oth	Degree of Other Personal Network	5.77	10.92	0	72
deg_per_rd_nat	Degree of National R&D Personal Network	2.09	4.79	0	27
deg_per_rd_int	Degree of International R&D Personal Network	0.05	0.27	0	2
deg_per_oth_nat	Degree of National Other Personal Network	5.14	10.08	0	71
deg_per_oth_int	Degree of International Other Personal Network	0.64	1.87	0	10
wdeg_per	Weighted Degree of Total Personal Network	20.68	32.14	0	154
wdeg_per_nat	Weighted Degree of National Total Personal Network	18.30	30.62	0	159
wdeg_per_int	Weighted Degree of International Total Personal Network	2.11	6.24	0	36
wdeg_per_rd	Weighted Degree of R&D Personal Network	6.02	13.18	0	70
wdeg_per_oth	Weighted Degree of Other Personal Network	15.64	32.04	0	218
wdeg_per_rd_nat	Weighted Degree of National R&D Personal Network	5.77	12.51	0	62
wdeg_per_rd_int	Weighted Degree of International R&D Personal Network	0.18	1.09	0	8
wdeg_per_oth_nat	Weighted Degree of National Other Personal Network	13.68	25.35	0	174
wdeg_per_oth_int	Weighted Degree of International Other Personal Network	1.89	5.71	0	32
Firms Characteristics					
large	Dummy variable = 1 if number of employees is larger than 100 and 0 otherwise	0.14	0.35	0	1
age	Firm Age (in years)	16.38	18.04	2	92
areas	Number of biotechnology areas that the firm provides goods and services	2.12	2.07	0	8
ln_rdexp_emp	Natural Log of R&D Expenditures over Total Employees	1.55	2.13	-2.53	11.37
dbf	Dummy variable = 1 if firm is dedicated biotechnology firm, 0 otherwise	0.53	0.50	0	1
Knowledge Production Variables					
tot_pub	Total Scientific Publications such as Articles (accumulated)	4.30	20.57	0	166
tot_pat	Total Patents Applications (accumulated)	10.20	51.22	0	410

Note: Sample size is 66 for all statistics presented

An important aspect to consider is the cross-sectional nature of the data. Knowledge-creation processes are dynamic and the nature of the data collected in

the survey cannot reflect this aspect; therefore, the results need to be interpreted with caution. The results of the non-parametric and econometric estimations are presented in the following section.

7.4 NETWORKS AND KNOWLEDGE CREATION

The preceding sections established that links might have a positive impact on firms' knowledge outcomes. This paper introduces novel hypotheses about the outcome of different types of networks and considers national and international links. Section 7.4.1 examines the relation between firm characteristics and the level of openness of firms in different networks using non-parametric correlations. It also studies the relationship between firms' openness and knowledge variables. Section 7.4.2 presents the results of the negative binomial regressions and compares results derived from the two methodologies.

7.4.1 THE NON-PARAMETRIC APPROACH

To determine the relation between firms' features and their openness in different aspects or networks, non-parametric Kruskal-Wallis tests and Kendall tau-b correlations were conducted. Dependent variables for the first stage of estimations are the degree (the number of connections) and the weighted degree (the number of connections weighted by their importance to the respondent firm or *ego*) for each network. Given that results are similar and do not present significant differences, the results for the degree variables of networks are presented. The independent variables in the first stage were the features of firms, such as a dummy for size, age, number of biotechnology areas in which the firms work, R&D expenditure per employee, and a dummy variable that identifies a DBF. Continuous variables for the

features of firms were categorised by quintile, in cases such as R&D expenditure; a separate category for firms that do not invest on R&D was included.

The results for the business networks in Table 7.3 show that variables related to absorptive capacities, such as R&D expenditure per employee, are positive and significantly related to the R&D business network, independently of the geographic location of the partner or *alter*. Firm size is positively related to the R&D international business network, while firm age has no significant impact on the business openness of firms. The diversification of biotechnology areas is positively related to R&D networks. DBFs present more connections in R&D business networks, national and international, but they have fewer business relations with other types of partners, nationally and internationally.

From the results for personal connections, presented in Table 7.4, it is possible to see that size and age are not significantly related to any type of personal network. The number of biotechnology areas is positively related to the R&D personal network, in particular at the national level, and slightly related to the international personal network with other partners. Variable R&D expenditure per employee is positive and significantly related to international personal networks, especially with partners that are not focused on R&D. It is also positive and significantly related to the R&D personal network, particularly in the national realm. A DBF is likely to be positively and significantly related to the number of contacts in the R&D personal network at the national and international level.

Table 7.3 The Features of Firms on Business Openness: Non-Parametric Estimation Results

Independent Variables		DF	Business Network: Total Network	National Network	International Network	R&D Network	Other Network	R&D National Network	R&D International Network	Other National Network	Other International Network
Dummy variable for firms with more than 100 employees	Kruskal-Wallis (chi2)	1	1.36	1.05	0.77	1.34	0.24	1.08	**5.8****	0.37	0.07
	Kendall tau-b		0.108	0.0952	0.0873	0.1129	0.0458	0.1018	**0.2558****	0.0572	-0.027
Categories of Firm Age	Kruskal-Wallis (chi2)	4	2.94	4.82	1.78	1.13	4.83	1.47	0.39	6.36	2.39
	Kendall tau-b		0.1177	0.1563	-0.0954	0.0758	0.0538	0.1022	-0.0098	0.0996	-0.0969
Number of biotechnology areas of the firm	Kruskal-Wallis (chi2)	7	5.84	5.11	11.85	**24.26*****	10.17	**21.11*****	**24.17*****	9.09	8.97
	Kendall tau-b		0.0698	0.0306	0.1752*	**0.3351*****	-0.1216	**0.2601*****	**0.3852*****	-0.1484*	0.0023
Categories of R&D Expenditures per Employee	Kruskal-Wallis (chi2)	5	4.65	3.96	5.33	**17.16*****	8.13	**13.86****	**11.02***	6.69	7.47
	Kendall tau-b		-0.017	-0.0567	0.1139	**0.2392****	-0.1099	**0.1621**	**0.3157*****	-0.1315	-0.0598
Dummy variable for dedicated biotechnology firms	Kruskal-Wallis (chi2)	1	0.55	0.91	0.00	**49.77*****	**23.89*****	**39.62*****	**18.36*****	**24.76*****	**5.52****
	Kendall tau-b		-0.0671	-0.0872	0.0058	**0.6756*****	**-0.4466*****	**0.6058*****	**0.4476*****	**-0.4577*****	**-0.2363****

Note: Significance levels * p < 0.10, ** p < 0.05, *** p < 0.01

Table 7.4 The Features of Firms for Personal Openness: Non-Parametric Estimation Results

Independent Variables		DF	Personal Network								
			Total Network	National Network	International Network	R&D Network	Other Network	R&D National Network	R&D International Network	Other National Network	Other International Network
Dummy variable for firms with more than 100 employees	Kruskal-Wallis (chi2)	1	0.12	0.08	0.22	0.00	0.01	0.00	0.69	0.04	0.35
	Kendall tau-b		-0.0317	-0.027	0.0493	-0.0065	-0.0103	0.0058	-0.0909	-0.0195	0.0626
Categories of Firm Age	Kruskal-Wallis (chi2)	4	3.56	3.29	3.45	3.27	3.65	3.55	2.95	2.82	3.78
	Kendall tau-b		0.0036	-0.0142	0.1014	-0.0606	0.0441	-0.0359	-0.15	0.0139	0.1367
Number of biotechnology areas of the firm	Kruskal-Wallis (chi2)	7	2.92	1.98	**12.89***	**19.76*****	3.84	**19.83*****	6.43	3.25	14.20
	Kendall tau-b		0.034	0.0118	**0.2170****	**0.2332*****	-0.0457	**0.2215****	0.1648*	-0.0713	0.2029**
Categories of R&D Expenditures per Employee	Kruskal-Wallis (chi2)	5	10.55*	9.04	**12.84****	**11.84****	6.40	**10.86***	5.56	6.81	**10.84***
	Kendall tau-b		0.1574	0.1087	**0.3280*****	**0.2736*****	0.0832	**0.2470****	0.2409**	0.0343	**0.3016*****
Dummy variable for dedicated biotechnology firms	Kruskal-Wallis (chi2)	1	1.63	1.65	0.00	**39.14*****	0.67	**37.43*****	**3.53***	0.45	0.05
	Kendall tau-b		0.1168	0.118	0.0052	**0.6184*****	-0.0758	**0.6059*****	**0.2016***	-0.0625	-0.024

Note: Significance levels * p < 0.10, ** p < 0.05, *** p < 0.01

To establish how network openness impacts knowledge production, another set of Kruskal-Wallis tests and Kendall tau-b correlations was conducted using measures of knowledge production as dependent variables and variables of networks as independent variables. Knowledge variables include the total number of publications and patents, the stock of publications and patents to December 2012, and publications and patent applications from January 2013 to February 2015. These distinctions were made to identify lag differences between network openness and effects on knowledge creation; however, patent data is significantly reduced for the most recent years, with only eight firms with patents applications from 2013 onwards, in comparison with publications in the same period. Network variables were categorised into three categories: the first for firms without any connections (degree and weighted degree zero); the second for firms with connections equal to or under the mean number of connections; and the third for firms with more than the mean number of connections.

The results presented in Table 7.5 and Table 7.6 suggest that personal networks with R&D-focused partners, particularly at the national level, are positive and significantly related to the production of scientific knowledge. Only national R&D personal networks seem to be weakly related to the stock of patents. Business networks with R&D partners, nationally or internationally, seem to be related to the scientific production of knowledge and patent applications. In particular, total and national R&D connections are positive and significantly related to stock and the number of patents and publications. Total and international R&D business networks are positively related to the number of publications from 2013 onwards, or the generation of new scientific knowledge. International networks with partners not

focused on R&D are negatively related to the stock and total number of patents, which indicates that firms that have more connections with firms or institutions not related to research outside the country make fewer patent applications. This result suggests that international connections with firms or institutions not focused on R&D are not being capitalised on in the creation of knowledge, but could have implications in other areas not measured in this study, such as the commercialisation of existing products or services.

The results from non-parametrical correlations seem to suggest that connections with R&D-focused partners, formal (business) or informal (social), have important positive effects on the creation of knowledge, in particular for scientific knowledge. International formal (business) networks seem to have an impact on knowledge production. International R&D business networks are positively related to the creation of publications, while international business networks with firms or institutions not focused on R&D is negatively related to the number of patent applications. Personal relations with R&D-focused institutions at the national level are important for the creation of knowledge, identifying an important aspect for non-formal knowledge transfers. The next section will present the results of the econometric model estimated, accounting for possible interactions between the features of firms and network openness in the process of knowledge generation.

Table 7.5 Firm Business Openness and Knowledge Production: Non-parametric Estimation Results

Networks		Dependent Variables: Total Publications	Publications from 2013 onwards	Stock of Publications until 2012	Total Patents	Patents from 2013 onwards	Stock of Patents until 2012
deg_bus	Kruskal-Wallis (chi2)	1.07	0.06	1.32	0.53	1.66	0.64
	Kendall tau-b	0.0946	0.0227	0.1059	-0.0666	-0.1272	-0.0734
deg_bus_nat	Kruskal-Wallis (chi2)	6.82**	9.14**	6.87**	0.02	1.37	0.05
	Kendall tau-b	0.0482	-0.0432	0.0784	-0.0071	-0.0761	-0.0157
deg_bus_int	Kruskal-Wallis (chi2)	1.07	0.98	1.39	7.47**	3.17	6.56**
	Kendall tau-b	0.0576	0.0854	0.0424	-0.1326	-0.1292	-0.1296
deg_bus_rd	Kruskal-Wallis (chi2)	**12.07*** **	**6.90** **	**12.32*** **	**9.92*** **	3.11	**9.06** **
	Kendall tau-b	**0.2977*** **	**0.2266** **	**0.3042*** **	**0.147***	-0.0069	**0.1517***
deg_bus_others	Kruskal-Wallis (chi2)	1.69	1.94	1.26	1.82	1.05	2.08
	Kendall tau-b	-0.1129	-0.1141	-0.0945	-0.0957	-0.0912	-0.1062
deg_bus_rd_nat	Kruskal-Wallis (chi2)	**6.38** **	1.83	**7.85** **	**9.82*** **	3.35	**8.97** **
	Kendall tau-b	**0.2221** **	0.1219	**0.2444*** **	**0.1726** **	0.0104	**0.1758** **
deg_bus_rd_int	Kruskal-Wallis (chi2)	**6.39** **	**5.38***	**6.82** **	6.74**	1.83	6.88**
	Kendall tau-b	**0.1838** **	**0.2083** **	**0.1804** **	0.0261	-0.1049	0.0366
deg_bus_oth_nac	Kruskal-Wallis (chi2)	2.37	2.65	1.85	2.69	0.48	3.12
	Kendall tau-b	-0.1371	-0.1385	-0.1203	-0.1419	-0.0657	-0.1533*
deg_bus_oth_int	Kruskal-Wallis (chi2)	1.44	3.66	1.10	**6.97** **	5.66*	**6.16** **
	Kendall tau-b	-0.1017	-0.1123	-0.0925	**-0.1843** **	-0.0839	**-0.1845** **

Note: * significant at level 0.10; ** significant at level 0.05; *** significant at level 0.01

Table 7.6 Firm Personal Openness and Knowledge Production: Non-parametric Estimation Results

Networks		Dependent Variables: Total Publications	Publications from 2013 onwards	Stock of Publications until 2012	Total Patents	Patents from 2013 onwards	Stock of Patents until 2012
deg_per	Kruskal-Wallis (chi2)	1.44	1.07	1.72	1.03	2.60	0.76
	Kendall tau-b	0.0905	0.0381	0.1168	0.0431	0.091	0.0318
deg_per_nat	Kruskal-Wallis (chi2)	1.44	0.82	1.20	0.19	0.05	0.24
	Kendall tau-b	0.0733	0.0328	0.0906	0.0309	-0.0203	0.0405
deg_per_int	Kruskal-Wallis (chi2)	0.62	0.01	0.92	1.22	3.37	1.94
	Kendall tau-b	0.0669	0.0028	0.0848	0.0177	0.1618*	0.0081
deg_per_rd	Kruskal-Wallis (chi2)	**7.72****	3.91	**6.16****	3.67	0.78	4.31
	Kendall tau-b	**0.1935****	0.0921	**0.1972****	0.1568*	0.0747	0.1706**
deg_per_oth	Kruskal-Wallis (chi2)	0.88	0.45	0.98	2.91	2.24	2.50
	Kendall tau-b	0.0804	0.0596	0.0856	0.0459	0.1005	0.034
deg_per_rd_nat	Kruskal-Wallis (chi2)	**8.80****	4.57	**6.96****	4.29	0.88	**4.96***
	Kendall tau-b	**0.2027****	0.0994	**0.2056****	0.1656*	0.0779	**0.1793****
deg_per_rd_int	Kruskal-Wallis (chi2)	0.75	2.36	0.32	2.89	4.14	2.74
	Kendall tau-b	-0.0787	-0.1332	-0.0517	-0.0421	0.0698	-0.0368
deg_per_oth_nac	Kruskal-Wallis (chi2)	0.47	0.68	0.57	1.51	0.36	1.24
	Kendall tau-b	0.0522	0.0412	0.0528	0.0368	0.0529	0.0257
wdeg_per_oth_int	Kruskal-Wallis (chi2)	0.91	0.02	1.16	0.98	3.41	1.61
	Kendall tau-b	0.0771	0.0106	0.0945	0.0274	0.1655*	0.0174

Note: * significant at level 0.10; ** significant at level 0.05; *** significant at level 0.01

7.4.2 ECONOMETRIC APPROACH

In order to estimate the impact of different types of connection in different types of network, together with the features of firms, a negative binomial model was created. Several specifications were tested; the results presented correspond to the best estimations.[32] Estimations were conducted separately for the business and social dimensions of networks, given that these dimensions are highly correlated. Nevertheless, other dimensions, such as geographic location and type of partner, did not generate variables that are highly correlated, which allows us to test the hypotheses presented earlier in this paper. Correlation matrices and a test for multicollinearity, based on the condition number of the independent variables matrix (Greene, 2000, p. 258), were estimated for each regression (see Appendix 6). There was no evidence of a strong multicollinearity problem in any of the estimations made.

Marginal effects at the mean values are presented in the following tables. Marginal effects for dummy variables represent the difference between the base level (the variable equals 0) and the positive value of the variable. The results for estimations considering variables of degree or weighted degree are similar and present the same information. Overall, there is evidence to support the negative binomial over the poisson model since the parameter *lnalpha* (the logarithm of the over-dispersion parameter α) is statistically different from zero and the likelihood ratio test for α=0 is rejected in all estimations.

[32] The base model was chosen on the basis of Akaike's information criterion and the Bayesian information criterion.

7.4.2.1 PUBLICATIONS AND NETWORKS

The results for business networks with respect to scientific knowledge measured by total number of publications are presented in Table 7.7. The basic model indicates that large firms (more than 100 employees) have higher levels of publications, although the effect becomes non-significant when variables of networks are included. Newer firms are also more productive in the creation of scientific knowledge, as are DBFs. Diversification, measured by the number of biotech areas in which firms operate, is generally positive and significant for number of publications. The variable of R&D expenditure per employee is, as expected, positive and significantly related to the number of publications.

Variables of different business networks are important for the number of publications. It is possible to observe that international and national business networks are positively associated with the number of publications; however, the marginal effects of the international network on publications is three times larger than the marginal effect on the national network. This result supports the hypothesis presented as Hypothesis 1 in this chapter. Additionally, R&D business links are positive and significantly related to the number of publications, while other types of relations are not significant, supporting Hypothesis 2.

Finally, when including all types of networks in the model (estimations 5 and 9), it is possible to determine that R&D national and international networks are significantly and positively related to the number of publications. Furthermore, the marginal effects for the international R&D networks are at least twice as large as the marginal effects for the national R&D business network, which supports Hypothesis 3e presented above.

Table 7.7 Negative Binomial Results: Business Relations Effects on Publications (Marginal Effects Presented)

	(1) Total Publications	(2) Total Publications	(3) Total Publications	(4) Total Publications	(5) Total Publications	(6) Total Publications	(7) Total Publications	(8) Total Publications	(9) Total Publications
large	4.931**	2.471	2.422	2.392	1.563	2.565	2.585	2.698	1.592
	(2.303)	(1.920)	(2.087)	(1.786)	(1.307)	(2.047)	(2.111)	(1.978)	(1.283)
age	-0.031**	-0.025**	-0.020	-0.033***	-0.027**	-0.022*	-0.019	-0.032***	-0.025**
	(0.013)	(0.012)	(0.014)	(0.012)	(0.013)	(0.013)	(0.013)	(0.012)	(0.012)
areas	0.302***	0.251**	0.214**	0.177**	0.128	0.243**	0.213**	0.161**	0.137
	(0.114)	(0.099)	(0.106)	(0.072)	(0.088)	(0.098)	(0.107)	(0.073)	(0.091)
ln_rdexp_emp	0.283*	0.312**	0.324**	0.245**	0.228**	0.322**	0.323**	0.255**	0.245**
	(0.150)	(0.159)	(0.163)	(0.110)	(0.111)	(0.161)	(0.163)	(0.107)	(0.123)
dbf	1.477***	1.406***	1.404***	0.147	0.111	1.469***	1.410***	0.115	0.228
	(0.521)	(0.522)	(0.526)	(0.559)	(0.546)	(0.537)	(0.533)	(0.511)	(0.542)
deg_bus		0.047*							
		(0.024)							
deg_bus_nat			0.038*						
			(0.021)						
deg_bus_int			0.105*						
			(0.062)						
deg_bus_rd				0.139**					
				(0.058)					
deg_bus_others				-0.011					
				(0.022)					
deg_bus_rd_nat					0.126**				
					(0.054)				
deg_bus_oth_nat					-0.011				
					(0.035)				
deg_bus_rd_int					0.298**				
					(0.131)				
deg_bus_oth_int					0.037				
					(0.056)				
wdeg_bus						0.012*			
						(0.007)			
wdeg_bus_nat							0.010*		
							(0.006)		
wdeg_bus_int							0.031*		
							(0.017)		
wdeg_bus_rd								0.040***	
								(0.015)	
wdeg_bus_oth								-0.004	
								(0.006)	
wdeg_bus_rd_nat									0.031**
									(0.015)
wdeg_bus_oth_nat									-0.002
									(0.010)
wdeg_bus_rd_int									0.075**
									(0.034)
wdeg_bus_otht_int									0.009
									(0.016)
Coefficients from main model									
cons	-2.2604***	-2.9490***	-3.0295***	-1.7032**	-1.7022**	-2.9755***	-3.0232***	-1.7324***	-1.7879**
	(0.5204)	(0.6917)	(0.7204)	(0.6931)	(0.6984)	(0.7144)	(0.7122)	(0.6635)	(0.6970)
lnalpha	1.0718***	0.9883***	0.9507***	0.7811***	0.6459**	0.9954***	0.9487***	0.7511***	0.6919**
	(0.2928)	(0.2923)	(0.3067)	(0.2877)	(0.3167)	(0.2920)	(0.3098)	(0.2873)	(0.3170)
Pseudo R2	0.162	0.171	0.174	0.196	0.207	0.170	0.174	0.200	0.201
Log Likelihood	-95.216	-94.206	-93.876	-91.362	-90.107	-94.292	-93.869	-90.952	-90.824
Likelihood-ratio test of alpha=0 (Prob>=chibar2)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Akaike's information	204.4327	204.4113	205.7521	200.725	202.2131	204.585	205.7383	199.9034	203.647
Bayesian information	219.7603	221.9285	225.459	220.4319	226.2993	222.1022	225.4452	219.6103	227.7332
Observations	66	66	66	66	66	66	66	66	66

Notes: Standard errors in parentheses
Significance levels: * p < 0.10, ** p < 0.05, *** p < 0.01

Table 7.8 Negative Binomial Results: Personal Relations Effects on Publications (Marginal Effects Presented)

	(1) Total Publications	(2) Total Publications	(3) Total Publications	(4) Total Publications	(5) Total Publications	(6) Total Publications	(7) Total Publications	(8) Total Publications	(9) Total Publications
large	4.931**	3.424*	4.229*	3.307	3.899	3.294*	3.817*	3.288*	4.118*
	(2.303)	(1.974)	(2.473)	(2.024)	(2.392)	(1.916)	(2.243)	(1.951)	(2.449)
age	-0.031**	-0.028**	-0.029**	-0.028**	-0.028**	-0.028**	-0.030**	-0.028**	-0.029**
	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.013)	(0.012)
areas	0.302***	0.299***	0.299***	0.299***	0.298***	0.296***	0.292***	0.295***	0.296***
	(0.114)	(0.115)	(0.108)	(0.115)	(0.108)	(0.113)	(0.110)	(0.114)	(0.105)
ln_rdexp_emp	0.283*	0.217	0.192	0.214	0.208	0.202	0.193	0.209	0.193
	(0.150)	(0.147)	(0.129)	(0.146)	(0.133)	(0.142)	(0.134)	(0.143)	(0.130)
dbf	1.477***	1.427***	1.469***	1.368***	1.329***	1.465***	1.460***	1.407***	1.395***
	(0.521)	(0.521)	(0.510)	(0.524)	(0.485)	(0.529)	(0.521)	(0.536)	(0.509)
deg_per		0.018*							
		(0.011)							
deg_per_nat			0.037						
			(0.032)						
deg_per_int			-0.123						
			(0.141)						
deg_per_rd				0.031					
				(0.041)					
deg_per_others				0.011					
				(0.018)					
deg_per_rd_nat					0.060				
					(0.082)				
deg_per_oth_nat					0.018				
					(0.020)				
deg_per_rd_int					-0.628				
					(0.502)				
deg_per_oth_int					-0.117				
					(0.189)				
wdeg_per						0.008*			
						(0.005)			
wdeg_per_nat							0.014		
							(0.012)		
wdeg_per_int							-0.033		
							(0.039)		
wdeg_per_rd								0.010	
								(0.015)	
wdeg_per_oth								0.006	
								(0.007)	
wdeg_per_rd_nat									0.019
									(0.029)
wdeg_per_oth_nat									0.010
									(0.009)
wdeg_per_rd_int									-0.150
									(0.126)
wdeg_per_otht_int									-0.033
									(0.055)
Coefficients from main model									
cons	-2.2604***	-2.2453***	-2.5031***	-2.1851***	-2.3908***	-2.2794***	-2.3850***	-2.2207***	-2.4975***
	(0.5204)	(0.5007)	(0.4814)	(0.5436)	(0.5151)	(0.4950)	(0.4779)	(0.5279)	(0.4960)
lnalpha	1.0718***	0.9948***	0.9622***	0.9931***	0.9328***	0.9848***	0.9634***	0.9864***	0.9207***
	(0.2928)	(0.3069)	(0.3083)	(0.3062)	(0.3099)	(0.3042)	(0.3076)	(0.3069)	(0.3109)
Pseudo R2	0.162	0.167	0.171	0.167	0.176	0.168	0.170	0.168	0.177
Log Likelihood	-95.216	-94.621	-94.172	-94.596	-93.663	-94.494	-94.271	-94.527	-93.471
Likelihood-ratio test of alpha=0 (Prob>=chibar2)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Akaike's information	204.4327	205.2428	206.345	207.1926	209.326	204.9886	206.5426	207.0537	208.9428
Bayesian information	219.7603	222.76	226.0519	226.8995	233.4122	222.5059	226.2495	226.7606	233.029
Observations	66	66	66	66	66	66	66	66	66

Notes: Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

In the case of personal relations, the results from Table 7.8 show that the inclusion of network variables reduces the significance of R&D expenditure while increasing the significance of DBFs. The main results between the features of firms and publication productivity holds when including personal networks variables; however, there is no significant impact on personal networks. There is only low significance for total personal networks, although their marginal effect is small. Therefore, there is no evidence to suggest that Hypothesis 3d holds for publications, and thus there is no evidence that personal networks could have a larger impact than business networks on the number of publications.

7.4.2.2 PATENTS AND NETWORKS

The results for the number of patent applications as a dependent variable are presented in Table 7.9 and Table 7.10. With respect to the features of firms, there are some interesting results. There is a negative and significant relation between firm size and the number of patents. Also, there is a positive and significant relation between the age of the firm and the number of patents. The signs of the coefficients and marginal effects associated with firm size and age are the opposite of the results found in the estimations for publications. A possible explanation is that the production of knowledge shifts with age and size. For example, it is possible that bigger firms tend to concentrate on the promotion of previously developed products, reducing their production of new patents. This explanation was actually observed in one of the biggest DBFs in Chile while conducting fieldwork. The firm decided to close their R&D division and concentrate on expanding the markets for their existing products and on being an importer of reagents for international firms in the country. With respect to age, it is expected that during their early years of

existence the company needs to develop a distinctive product with new scientific research, increasing the quantity of publications. After the first period of development, firms tend to concentrate on developing knowledge closer to the market.

With respect to diversification in biotech areas, there is no effect on the production of patents. R&D expenditure per employee is positively related to the number of patent applications, a finding which is in line with previous research, and DBFs are also positively, and in most cases significantly, related to the number of patents. The marginal effects of these last two variables, however, have larger magnitudes than in the case of publications. It could therefore be argued that R&D resources have a higher impact on the production of knowledge closer to the market, such as patents, than for publications. Additionally, DBFs invest in both types of knowledge, but they are more intensive in terms of patents.

Focusing on business variables, it is possible to see that only R&D business links are positively related to the number of patents, as shown in equations 4 and 8, but is not possible to determine if national or international links are important, given the results of equations 5 and 9. Business relations with partners that are not focused on R&D have a negative and significant relation with the number of patents; in particular, the national dimension of these links is also negative and significantly related to total patent applications.

Table 7.9 Negative Binomial Results: Business Relations Effects on Patents (Marginal Effects Presented)

	(1) Total Patents	(2) Total Patents	(3) Total Patents	(4) Total Patents	(5) Total Patents	(6) Total Patents	(7) Total Patents	(8) Total Patents	(9) Total Patents
large	-2.294*	-2.133	-2.189	-2.606***	-2.468**	-2.263*	-2.004	-2.540**	-2.777**
	(1.353)	(1.336)	(1.493)	(0.948)	(1.040)	(1.291)	(1.551)	(1.005)	(1.165)
age	0.288***	0.291***	0.290***	0.259***	0.261***	0.289***	0.293***	0.251***	0.282***
	(0.107)	(0.110)	(0.109)	(0.082)	(0.082)	(0.110)	(0.110)	(0.084)	(0.095)
areas	-0.021	0.025	0.032	-0.101	-0.163	-0.009	0.029	-0.120	-0.093
	(0.431)	(0.480)	(0.496)	(0.328)	(0.343)	(0.496)	(0.494)	(0.363)	(0.393)
ln_rdexp_emp	0.823*	0.859*	0.843	1.003**	1.086**	0.832*	0.897	1.059**	1.070**
	(0.491)	(0.514)	(0.580)	(0.430)	(0.456)	(0.502)	(0.600)	(0.477)	(0.500)
dbf	8.554**	8.636**	8.648**	2.735	2.431	8.573**	8.550**	2.875	3.437
	(3.695)	(3.760)	(3.778)	(1.812)	(1.749)	(3.737)	(3.739)	(1.988)	(2.195)
deg_bus		-0.027							
		(0.104)							
deg_bus_nat			-0.020						
			(0.128)						
deg_bus_int			-0.063						
			(0.330)						
deg_bus_rd				0.286**					
				(0.137)					
deg_bus_others				-0.356**					
				(0.179)					
deg_bus_rd_nat					0.272				
					(0.187)				
deg_bus_oth_nat					-0.403**				
					(0.176)				
deg_bus_rd_int					0.460				
					(1.181)				
deg_bus_oth_int					-0.188				
					(0.290)				
wdeg_bus						-0.002			
						(0.028)			
wdeg_bus_nat							-0.014		
							(0.039)		
wdeg_bus_int							0.007		
							(0.093)		
wdeg_bus_rd								0.083**	
								(0.042)	
wdeg_bus_oth								-0.090*	
								(0.049)	
wdeg_bus_rd_nat									0.056
									(0.051)
wdeg_bus_oth_nat									-0.093*
									(0.057)
wdeg_bus_rd_int									0.162
									(0.318)
wdeg_bus_otht_int									-0.044
									(0.077)
Coefficients from main model									
cons	-2.2589***	-2.2510***	-2.2480***	-1.2271	-1.1525	-2.2566***	-2.2418***	-1.2757*	-1.4379*
	(0.7592)	(0.7520)	(0.7559)	(0.7577)	(0.7375)	(0.7597)	(0.7461)	(0.7751)	(0.7460)
lnalpha	1.7943***	1.7967***	1.7969***	1.7481***	1.7419***	1.7951***	1.7963***	1.7531***	1.7688***
	(0.2306)	(0.2310)	(0.2310)	(0.2380)	(0.2414)	(0.2317)	(0.2316)	(0.2374)	(0.2391)
Pseudo R2	0.075	0.075	0.075	0.087	0.087	0.075	0.076	0.085	0.083
Log Likelihood	-123.276	-123.260	-123.257	-121.765	-121.660	-123.275	-123.238	-121.990	-122.284
Likelihood-ratio test of alpha=0 (Prob>=chibar2)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Akaike's information	260.5522	262.5199	264.5143	261.5302	265.3207	262.5504	264.4757	261.9795	266.568
Bayesian information	275.8798	280.0371	284.2212	281.2371	289.4069	280.0676	284.1826	281.6864	290.6542
Observations	66	66	66	66	66	66	66	66	66

Notes: Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 7.10 Negative Binomial Results: Personal Relations Effects on Patents (Marginal Effects Presented)

	(1) Total Patents	(2) Total Patents	(3) Total Patents	(4) Total Patents	(5) Total Patents	(6) Total Patents	(7) Total Patents	(8) Total Patents	(9) Total Patents
large	-2.294*	-2.834**	-2.945**	-1.937**	-1.654**	-2.820**	-2.911**	-1.706**	-1.696***
	(1.353)	(1.227)	(1.226)	(0.718)	(0.622)	(1.238)	(1.224)	(0.738)	(0.621)
age	0.288***	0.282***	0.271***	0.188***	0.161***	0.281***	0.282***	0.182***	0.162***
	(0.107)	(0.102)	(0.098)	(0.059)	(0.046)	(0.102)	(0.102)	(0.059)	(0.048)
areas	-0.021	-0.025	-0.260	0.125	-0.033	-0.021	-0.182	0.177	0.011
	(0.431)	(0.417)	(0.514)	(0.250)	(0.262)	(0.420)	(0.533)	(0.241)	(0.262)
ln_rdexp_emp	0.823*	0.585	0.269	0.572*	0.336	0.588	0.346	0.541*	0.360
	(0.491)	(0.479)	(0.511)	(0.339)	(0.354)	(0.488)	(0.549)	(0.294)	(0.361)
dbf	8.554**	7.529**	8.258**	2.259	2.557	7.666**	8.128**	1.825	2.394
	(3.695)	(3.342)	(3.607)	(1.612)	(1.627)	(3.406)	(3.707)	(1.601)	(1.686)
deg_per		0.064							
		(0.042)							
deg_per_nat			-0.045						
			(0.082)						
deg_per_int			0.798						
			(0.588)						
deg_per_rd				0.654***					
				(0.228)					
deg_per_others				-0.361**					
				(0.159)					
deg_per_rd_nat					0.477**				
					(0.230)				
deg_per_oth_nat					-0.434***				
					(0.138)				
deg_per_rd_int					-0.341				
					(0.693)				
deg_per_oth_int					0.267				
					(0.468)				
wdeg_per						0.024			
						(0.017)			
wdeg_per_nat							-0.002		
							(0.034)		
wdeg_per_int							0.187		
							(0.205)		
wdeg_per_rd								0.252***	
								(0.088)	
wdeg_per_oth								-0.135**	
								(0.058)	
wdeg_per_rd_nat									0.189*
									(0.097)
wdeg_per_oth_nat									-0.161***
									(0.052)
wdeg_per_rd_int									-0.080
									(0.197)
wdeg_per_otht_int									0.083
									(0.166)
Coefficients from main model									
cons	-2.2589*	-2.2772*	-1.9002*	-1.9992*	-1.7219*	-2.2640*	-2.0736*	-2.1788*	-1.8149**
	(0.7592)	(0.7930)	(0.8120)	(0.7096)	(0.7210)	(0.7893)	(0.8024)	(0.7219)	(0.7138)
lnalpha	1.7943**	1.7608**	1.7442**	1.6743**	1.6485**	1.7651**	1.7505**	1.6754**	1.6487***
	(0.2306)	(0.2365)	(0.2394)	(0.2440)	(0.2523)	(0.2357)	(0.2379)	(0.2421)	(0.2467)
Pseudo R2	0.075	0.079	0.082	0.094	0.098	0.078	0.081	0.095	0.099
Log Likelihood	-123.276	-122.806	-122.431	-120.745	-120.193	-122.882	-122.577	-120.689	-120.052
Likelihood-ratio test of alpha=0 (Prob>=chibar2)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Akaike's information	260.552	261.612	262.863	259.491	262.387	261.763	263.153	259.379	262.1039
Bayesian information	275.88	279.129	282.57	279.198	286.473	279.281	282.86	279.085	286.1901
Observations	66	66	66	66	66	66	66	66	66

Notes: Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

This result could be explained by the nature of the links. If this type of link was mainly focused on the promotion of products then the knowledge transmitted through this channel would not be positively related to knowledge creation. These results are in line with the findings of Morrison and Rabellotti (2009). They find that firms in the core of the knowledge network of a cluster in Italy are well connected within them, are less open to extra-clusters actors, and tend to be less innovative. Therefore, an increasing number of local connections can increase the embeddedness of those firms, reducing the firms' creation of knowledge and innovation performance. Moreover, if links are costly to maintain for a firm then firms will be able to handle only a finite number of formal links. Therefore, the higher the number of links with non-R&D-oriented institutions, the fewer connections with R&D-oriented institutions a firm can have, reducing even more the effect on knowledge creation.

The same results hold when looking at personal network effects on the number of patent applications (Table 7.10). In particular, national R&D-oriented personal links are positive and significantly related to the total number of patent applications. Furthermore, the marginal effects of R&D personal networks are higher than those found in R&D business networks. These results give partial support to Hypothesis 3. With respect to the rest of the hypotheses developed in this study, it is not possible to find strong empirical support for them with respect to the number of patent applications, as was the case for the number of publications. This could be due to data restriction, given that the number of patent applications is in general lower than the number of publications for most firms.

7.4.2.3 POTENTIAL ENDOGENEITY

The risk of endogeneity is common in research related to innovation and R&D. It is possible that the networks in which a firm participates also affect the decision to invest in R&D, as well as the amount invested. To test for endogeneity (see Appendix 7), a two-step procedure was followed. First, a Heckman estimation with selection was conducted to determine the R&D investment per employee of each firm. Independent variables included in this estimation were firm variables and network variables. Second, the estimated residuals of the Heckman model were included as an independent variable in the negative binomial model to identify potential endogeneity. There was no indication of endogeneity for R&D per employee.

Also, potential endogeneity is suspected between network variables and knowledge variables. In a high-tech sector, firms with higher levels of knowledge creation in terms of publications and patents could be considered valuable partners and have higher levels of 'popularity' – as it is called in the SNA – therefore increasing the number of connections in different realms. Although SNA usually assumes the independence of these effects when estimating the impact of network dimensions on features of the firms or individuals in a network (Daraganova and Robins, 2013), this study will make an effort to test for this potential endogeneity.

Endogeneity tests were conducted only for the more general network variables: total business degree; total weighted business degree; total personal degree; and total weighted personal degree (see results in Appendix 7). A two-step procedure was followed. In the first step, a linear regression was estimated for the network variables with the features of the firm as independent variables. In the second step, the estimated residuals of the first step were included in the negative

binomial model. The results suggest that there is no evidence of endogeneity of business networks in any of the tests; however, there is some evidence of endogeneity for the personal networks. Evidence of endogeneity of weighted personal degree for the estimation of patents was found. When correcting for it, there was no major change in the significance or the sign of the network variable in the model. Endogeneity of total personal degree and total weighted personal degree was found in the estimation of publications. The results of estimations correcting for potential endogeneity increase the significance of the coefficients of network variables; however, the sign changes, implying a negative relation between total personal networks and the number of publications.

These results must be considered with caution since the linear regression between the number of connections and firms' features may not necessarily be the correct way of estimating the number of connections, since degree variables have a distribution of count data. Also, the inclusion of predicted network variables with a normal distribution in a negative binomial estimation could be controversial, since it could change the distribution of the model. In summary, this is a first attempt to identify endogeneity in a network context. If endogeneity exists, it would theoretically be expected that results could be overestimating the impact of networks in the production of knowledge.

7.4.3 Comparison of Results

In order to identify strong results, a comparison table is presented in Table 7.11. The results between network variables and knowledge variables that are the same in the non-parametric analysis and the econometric analysis are highlighted in bold,

and they will be considered as suggestive of strong and robust results. The results are the same for weighted and non-weighted variables.

Table 7.11 Comparison of Non-Parametric and Econometric Results (Signs of the significant results presented)

	Publications		Patents	
	Non-Parmetric	Negative Binomial	Non-Parmetric	Negative Binomial
deg_bus		+		
deg_bus_nat		+		
deg_bus_int		+		
deg_bus_rd	+	+	+	+
deg_bus_others				-
deg_bus_rd_nat	+	+	+	
deg_bus_rd_int	+	+		
deg_bus_oth_nac				-
deg_bus_oth_int			-	
deg_per		+		
deg_per_nat				
deg_per_int				
deg_per_rd	+			+
deg_per_oth				-
deg_per_rd_nat	+		+	+
deg_per_rd_int				
deg_per_oth_nac				-
deg_per_oth_int				
wdeg_bus		+		
wdeg_bus_nat		+		
wdeg_bus_int		+		
wdeg_bus_rd	+	+	+	+
wdeg_bus_oth				-
wdeg_bus_rd_nat	+	+	+	
wdeg_bus_rd_int	+	+		
wdeg_bus_oth_nac				-
wdeg_bus_otht_int			-	
wdeg_per		+		
wdeg_per_nat				
wdeg_per_int				
wdeg_per_rd	+			+
wdeg_per_oth				-
wdeg_per_rd_nat	+		+	+
wdeg_per_rd_int				
wdeg_per_oth_nac				-
wdeg_per_oth_int				

It is possible to observe that business relations with R&D-oriented institutions have more positive relations with knowledge variables than personal relations. The comparison of results also suggests that personal relations with R&D-oriented institutions and firms are positively related with patent applications but not with

publications. Business R&D connections are positively related with both types of knowledge variables, while the distinction between national and international R&D-oriented networks is significant for publications. From the econometric analysis, it is possible to establish that the marginal effects of international R&D business networks are at least twice those of the marginal effect of national R&D business networks. Additionally, the results for scientific knowledge measured as the number of publications seems more robust than for knowledge closer to the market, as measured by number of patents. This could be due to a statistical difference between both variables, since the number of patent applications is lower than the number of publications. The next section will briefly conclude this chapter.

7.5 DISCUSSION AND CONCLUSIONS

In the present chapter, the relation between network features and the production of knowledge was studied for the biotechnology sector in Chile. Using a novel data set, it was possible to identify different firms' networks, differentiating between networks at the national and international level, business and personal level, and the presence or otherwise of an R&D-oriented partner. These distinctions allow for the testing of different hypothesis with regards to knowledge diffusion and knowledge creation in a high-tech sector in an emerging economy.

The results suggest three main conclusions of this study. First, with respect to formal or business relations, it was possible to establish that international and national business relations are positively associated with the production of scientific knowledge measured by number of publications. Also, the international business connections had a higher impact on number of publications than national business links.

Second, connections with R&D-oriented firms and institutions are positively related to the number of publications and number of patent applications, confirming that after controlling for other types of relations, R&D connections have a higher impact than other types of networks on knowledge creation.

Third, it was observed that international business relations with R&D-oriented partners were positively related and more important than other networks in the creation of scientific knowledge; however, it was not possible to observe the same results for patents. This result suggests that international connections are an important channel for scientific knowledge diffusion and exchange, but that this knowledge is not being transformed into patents. A cross-sectional feature of the data could be a reason for this result and will be discussed further below. But it is also possible that firms tend to protect the patentable knowledge created and avoid undesired leakages of it – they therefore tend to develop this type of knowledge in isolation or with fewer partners.

Finally, it was expected that informal connections, such as the personal connections of owner or managers of interviewed firms, could also positively affect knowledge production through the diffusion or sharing of knowledge through non-formal channels; however, weak evidence was found for this. There is evidence that personal connections with partners in national R&D-oriented institutions are positively related to the number of patent applications, but not necessarily to publications. Potential endogeneity between personal networks and knowledge variables was found in a preliminary test, so the results could be positively biased. Overall, there is weak evidence that owners or managers of firms in the biotech sector in Chile effectively use their personal networks as a diffusion channel of knowledge – or at least there is no strong evidence of this.

As mentioned earlier, a few caveats of the study must be considered. While the relatively low number of observations does not allow for generalisation of the results to other situations, the conclusions of this study hold for the case study presented in this chapter, although the results might be more representative of the biotechnology cluster in the Metropolitana region of Chile than of elsewhere. Also, potential endogeneity between network variables and knowledge variables could be overestimating the importance of network variables; however, there is no strong evidence of this and the correction of potential endogeneity presents several difficulties regarding the available estimation methods. New methodologies in network analysis could improve the estimations. Finally, the cross-sectional nature of the data is the most important limitation on the study. Future research should focus on obtaining panel data for cluster connections, features of firms, and knowledge and innovation outcomes. With this, it would be possible to test hypotheses effectively with respect to network structures and knowledge or innovation outcomes in clustered firms.

This research presents new results with respect to extra-cluster links and knowledge creation in a high-tech sector in an emerging economy. It has been established that extra-cluster links, measured as international connections, are highly important for scientific knowledge creation, but it is also true that local connections with R&D-oriented partners are relevant for scientific knowledge and patenting. However, there might still be a potential risk of knowledge lock-in in this cluster if the knowledge shared between national R&D-oriented institutions is not close to the technological frontier. Future research could also extend this study by considering a measure of closeness to the technological frontier for R&D-oriented institutions related to biotechnology firms in Chile.

8 CONCLUSIONS

8.1 INTRODUCTION

This thesis has investigated the role of social relations in different aspects of cluster formation. I have assessed the relative importance of social relations, compared to other traditional explanations of agglomeration forces, in the creation of the biotechnology cluster in Chile. The role of social relations might be an important determinant of cluster formation, particularly in emerging economies, due to severer restrictions faced by entrepreneurs, such as lack of venture capital markets and information asymmetries (Audretsch and Feldman, 2004). The purpose of this thesis is to provide evidence of the role of personal and business relations in the formation of a high-tech cluster in the context of an emerging country, including the individual agency of entrepreneurs in this process. The results of this thesis draw on a case study of the biotechnology sector in Chile.

I have aimed to answer the question: Do relations between organisations positively affect the formation of a cluster? For the case studied, this can be refined to: Do personal and business relations between organisations positively affect the formation of the Chilean biotechnology cluster? This question was divided into three more specific questions:

1. How important are personal and business relations for the creation and location of a firm within a cluster?
2. Are personal relations positively associated with the creation of business relations within a cluster?

3. Does the personal and business network structure determine the development and knowledge creation of firms in a cluster?

The questions address three aspects of the process of cluster formation: the initial stage of location of companies; the creation of interactions between organisations; and the creation of new knowledge crucial for cluster development. Each question was addressed in a separate analytical chapter. Regarding the first research question, I studied the effect of personal and business networks on the location decisions of start-ups in Chapter 5. Using qualitative and quantitative analysis, I show that personal and business connections allow entrepreneurs to access resources and identify relevant opportunities, which are crucial for the decision to start and locate a new firm. Based on these results, I propose a model for the first stages of a cluster, which I call a 'proto-cluster': entrepreneurs will decide to locate their firm where they can access key resources and identify opportunities that will coincide with the location where their networks can provide them. When this process occurs for several entrepreneurs in the same location and economic sector, it will be possible to find the emergence of a proto-cluster that can lead to a fully developed cluster if the number of firms in the proto-cluster reaches a minimum level at which the benefits of agglomerations are realised.

The second research question was addressed in Chapter 6. To study the relation between two different types of linkages occurring simultaneously in a cluster, I used multilevel regressions to identify the effect of previous personal relations on the probability of creating business relations. The results show that previous personal relations positively affect the probability of creating a business relation between two organisations. The effect is significant, although it is of lower magnitude than geographic closeness.

Finally, Chapter 7 addressed the third question in this thesis. I examined whether personal and business network structure determine the knowledge creation of firms in a cluster by using an econometric estimation of the total output of scientific publications and patent applications. To study knowledge formation is important since it also shapes the development of a nascent cluster, particularly in high-tech sectors. My results show that the number of scientific publications is positively affected by the number of business relations with R&D-oriented partners, but also that relations with foreign R&D-oriented partners have a higher effect on publications than relations with national R&D-oriented partners. In the case of patent applications, the number of personal and business relations with R&D partners is positively associated with the number of patent applications made by firms, and in this case national relations with R&D-oriented partners have higher effects on patent applications. Also, personal and business relations with national non-R&D-oriented partners seem to hamper the development of new patentable knowledge. Therefore, different types of relations affect in different ways the process of knowledge creation, which determines the development of a cluster.

Overall, I presented evidence in this thesis that supports the main argument of this research, i.e. that networks, both business and personal, shape the decision to create and locate companies, the decision to develop relations between agents in a cluster, and the creation of knowledge within a cluster. These three main findings of the different analyses developed in this thesis will be summarised in the following section of this conclusion.

This chapter brings together the results of previous chapters to draw conclusions about cluster emergence and to provide a general view of the topics covered in this thesis. Section 2 presents the main findings. Section 3 highlights the

contributions of this research. Section 4 delineates some implications and policy recommendations that can be drawn from the results. Finally, Section 5 discusses the limitations of the study and further research questions emerging from the results.

8.2 MAIN FINDINGS

The thesis presented three main analytical chapters and consequently there are three sets of findings that will be summarised in this section. A first group of findings emerges from the qualitative analysis of the interviews and correlations with the quantitative data presented in Chapter 5. This chapter studied the role of social networks in the processes of the location and creation of companies. The content analysis of opinions and interviews conducted revealed that individuals considered personal relations to be positively associated with the process of firm creation. It was also possible to determine that entrepreneurs with more personal relations face a lower level of difficulties and restrictions in the process of creating a new firm than those with lower levels of connections. Firms with higher levels of personal and business relations face fewer financial restrictions and have better access to clients and suppliers. Additionally, the results showed that social relations help entrepreneurs to access resources and identify opportunities in the earlier stages of the companies. Overall, the results suggest that social relations are positively associated with the initial stages of start-ups, as proposed by Feldman et al. (2005). This relationship between firm formation and social capital might imply that entrepreneurs locate their companies where they can access key resources and identify opportunities through their networks. Therefore, social relations and social capital shape location decisions, which is a novel finding that traditional location

and entrepreneurship literature has overlooked (Carlton, 1983; Feldman, 2003; Pitelis, 2012; among others). Furthermore, I propose a model where if these circumstances occur simultaneously for different entrepreneurs in the same location and economic sector, a proto-cluster would emerge. This proto-cluster might later become a developed cluster if there are enough firms to generate positive agglomeration economies. This model is a novel contribution to the literature on clusters.

The second set of findings arose from the econometric analysis of the survey data in Chapter 6. The chapter studied how the personal networks between individuals influence the emergence of a business network in a cluster. Although it is recognised in SNA that multiple networks can become established simultaneously in a cluster, in a process called 'multiplexity' (Kadushin, 2012), the literature still has not studied how these different networks shape and determine one another. A multilevel logit regression estimation analysis was used and its results revealed that the existence of a previous personal relation between two organisations has a positive and significant impact on the creation of a business relation among agents. Therefore, after controlling for other variables that could affect the decision to create a business linkage, personal relations are the second most significant factor (after geographic closeness). These findings show that the personal social structure can shape the business structure of clusters. However, the results also show that agglomeration tends to generate business relations regardless of personal connections. Therefore, not only will personal relations affect the formation of business relations, but the traditional benefits of agglomerations will also shape the emergence of relations in a cluster. Although an effect was found linking personal

and business relations, the dynamic aspect of the generation of relations between firms was not studied.

Finally, the third main conclusion emerges from Chapter 7, which studied the role of different types of networks in a firm's creation of knowledge. It was possible to include business and personal networks in the estimations, differentiating between their national and international locations, as well as the type of partners classified as R&D-oriented or not. The econometric analysis also distinguished between scientific knowledge (measured by publications) and knowledge close to the market (measured by patent applications). The results indicate that not all types of connection are equally relevant for knowledge creation. From this analysis, it was possible to determine that business connections with R&D partners are positive and significantly associated with the creation of scientific knowledge and knowledge close to the market. Furthermore, international R&D business links have a greater impact on knowledge creation. Personal connections do not significantly affect the creation of scientific knowledge but they have a role in the creation of knowledge close to the market. In particular, national personal relations with R&D-oriented partners have a positive effect on the number of patent applications. These results suggest that relations with R&D partners have a significant impact on the creation of local knowledge, through both formal channels (business connections) and informal channels (personal connections). The effect that formal collaborations, such as strategic R&D alliances, have on the innovative outcome of firms confirms previous results in the literature (Audretsch and Feldman, 2004; Giuliani, 2007; Hagedoorn et al., 2000), whereas the effect of personal relations on knowledge has not been directly measured or quantified in the literature.

The findings from the different chapters and methods of analysis support one another, and taken together, support the main hypothesis of this thesis – that social relations are positively associated with the formation process of a cluster. These findings suggest that social relations and social capital drive cluster formation.

8.3 CONTRIBUTIONS

The findings of this thesis contribute to the literature on cluster formation in several ways. First, the data collected on relations between firms and entrepreneurs in a cluster makes it possible to study the interactions between different types of relations and networks in a cluster. The primary data used in this thesis measured personal and business relations directly, which contributes to assessing the relative importance of personal and business ties on the creation of a high-tech cluster in an emerging country. Also, the use of mixed methods in the collection and analysis of the information gives robustness to the conclusions reached in this thesis.

Secondly, the results from this study present new evidence on the importance of personal relations and social capital in the creation of a knowledge-based cluster in Chile. This thesis has shown the importance of social relations (personal and business relations) in the location decisions of new small start-ups, evidencing the need to include social networks in the development of a location decision theory for start-ups. Not only should theories of location differentiate by type and size of firms, and by the maturity of the sector that firms are entering, but they should also consider the role of social networks in accessing resources and identifying opportunities for entrepreneurs.

Thirdly, this work contributes to the literature on social networks by assessing the relation between different networks co-occurring in a cluster. The existence of

multiple networks within a cluster has been acknowledged, although the difficulty of collecting primary network data and measuring different networks between the same set of actors has limited research on the interactions between networks in the development of clusters. In particular, I analysed the effect of personal relations on the emergence of business relations in a cluster. The results confirmed that the personal network influences the business network, although the magnitude of the effect is moderate compared to the effect of other traditional explanations of business collaborations, such as geographical closeness.

Fourthly, the thesis also studied the effect of different types of network on the creation of knowledge, revealing that networks have diverse effects depending on the type of relation, the type of partner and the location of the partner. It has been argued that extra-cluster linkages have the potential to reduce the problem of knowledge lock-in and to compensate for the lack of technological innovation and adaptation found in declining clusters (Gulati, 1995a; Uzzi, 1999). The study of international relations on cluster performance has mainly focused on innovation and productivity performance (Boschma and Ter Wal, 2007; Giuliani et al., 2013) without directly addressing the creation of knowledge. This thesis contributes to the literature on external-cluster linkages by using a direct measure for firms' different types of relations, with different actors, in different locations. One contribution is the quantification of the effects of personal connections on the generation of new knowledge. It has been argued in the literature that tacit knowledge can be transmitted by personal interactions between individuals in a cluster (Giuliani, 2007). The results show that, even when personal relations can diffuse existing knowledge, not all personal relations will be beneficial for the creation of new knowledge. In fact, some types of personal relation, such as connections to non-

R&D-oriented partners at the national level, can reduce the creation of new knowledge given the commercial orientation of this type of relation. Future research should study further the interactions between different types of relations for positive and negative effects on the knowledge base of clusters.

Finally, the present study provides additional evidence on the trade-off between levels of social embeddedness and cluster emergence and growth, in line with previous research (Gulati, 1995b; Uzzi, 1997, 1996). With respect to cluster emergence, if social relations within the cluster are fundamental to the creation of companies and to generating linkages between them then it might be possible that entrepreneurs considering whether or not to enter the cluster will face increased difficulties in accessing resources and establishing a firm. In the early stage of a cluster – the proto-cluster – an over-reliance on social relations for the creation, location and generation of relations between firms might lead the proto-cluster to diverge towards the creation of a business clique. This situation might reduce the foundation of new companies and start-ups, hindering cluster formation and growth. If this is the case in several economic sectors in a region, where not only is there limited access to key resources to form a company, but the access to those resources depends also on the social network of entrepreneurs, then the local economic growth of a region might be restricted.

With respect to cluster growth, given that this thesis finds that networks are important for the creation of new connections between firms and for the generation of new knowledge, it could be that over-reliance by firms on their existing networks pushes a cluster towards knowledge lock-in, as noted by Uzzi (Uzzi, 1999). The creation of new knowledge is highly relevant for high-tech sectors (Lawton Smith, 2008; Lawton Smith et al., 2012), and a reduction in the creation of new knowledge

might reduce cluster growth and, in the case of a proto-cluster, might impede progress towards the development of a mature cluster. Extra-cluster relations in this case will not necessarily change the situation with a cluster manifesting knowledge lock-in, since this thesis has shown that not all international relations will have an impact on the creation of new knowledge by firms. Relations with R&D-oriented partners, at the national and international level, have the potential to produce new knowledge. International relations with other firms that are not oriented towards R&D will not affect the knowledge produced by a firm. These new insights represent a significant contribution by this thesis to the literature on clusters.

8.4 IMPLICATIONS AND POLICY RECOMMENDATIONS

Several implications for innovation policies emerge from the evidence presented throughout this thesis, not only for the Chilean case, but also for other economies with policies oriented towards the promotion of clusters. First, in line with findings for different Latin American clusters (Perez-Aleman, 2010, 2005, 2003; Pietrobelli and Rabellotti, 2004), public support for start-ups in high-tech and knowledge-intensive sectors should not only consider subsidies, collateral support and soft credits, but also networking support. The importance of networking is recognised in the private sector; for example, it is considered in business incubator programmes and in conferences and workshops organised by the private sector. These activities are more evident in mature clusters, as found in the biotech cluster of the Metropolitana region, which is the most developed of the regions studied. This makes networking activities in proto-clusters even more critical. Such relations can accelerate cluster growth or promote the transformation of proto-clusters towards

the formation of a mature cluster. However, networking activities are usually not considered systematically in publicly funded programmes. There might be an opportunity for including networking activities in public policies promoting the development of clusters, considering from the beginning of the programme an evaluation strategy for this type of activity.

In Chile, there are some public programmes that subsidise collaborative projects among firms (in CORFO),[33] among research centres (in CONICYT), and between firms, research centres and other organisations (in CORFO and CONICYT).[34] In all these cases, the role of the public agencies is passive, in the sense that they receive the applications of associative projects made by a group of firms and entities, but they do not actively promote the generation of new collaborations. Therefore, even when in some cases new collaborations can be generated to apply to these subsidies, the current programmes favour existing collaborations and networks, which can lead to a lock-in of knowledge and business cliques in clusters, as mentioned above. I will comment on two better known associative programmes that have been studied: the Associative Development Projects (*Proyectos Asociativos de Fomento* or PROFOs) of CORFO and the Technological Consortia (*Consorcios Tecnológicos Empresariales*) of CORFO and CONICYT.

CORFO implemented the PROFOs in 1993. This programme subsidises the activities of a group of firms towards increasing their productivity and to reach new markets. The programme is executed and administrated through independent

[33] Most programmes in CORFO were modified recently. Some of them maintain their name, but their features are different. The current CORFO programmes subsidising collaborative projects include: PROFOs, Nodos para la Competitividad, Centros de Extensionismo Tecnológico, Consorcios Tecnológicos, PymeLab Espacios Colaborativos de Trabajo.

[34] In CONICYT, programmes promoting collaborative research and research centres between universities are: FONDAP, Programa de Cooperación Internacional, Centros de Excelencia, Anillos de Investigación. The programmes subsidising collaborations between firms and research institutions are: FONDEF and Consorcios Tecnológicos.

actors (called intermediary agents).[35] PROFOs have been considered pillars in the development of new sectors (salmon farming and tomato processing industry) and of collaboration between actors in those sectors (Perez-Aleman, 2003, 2000). However, given the passive role of CORFO, if a group of firms wants to make an application then most probably they would rely on previous collaborations and interactions. In this sense, the programme will tend to reproduce the existing networks. The role of the intermediary agencies could change this, by actively bringing together firms and actors that have not collaborated before. In fact, an evaluation of the programme found that firms tend to collaborate more with other firms and institutions after being part of the PROFO (Benavente and Crespi, 2003). Recent studies of these intermediaries, however, have shown that these agencies have not reached the firms targeted by CORFO effectively, diffused the programme widely or focused on the effectiveness of the projects implemented (CORFO, 2009; Garcia Urbina, 2008). In addition, an important aspect of creating a network of enterprises and value chains is the process of identifying, selecting and reaching the firms (Dini, 2010, 2009). Therefore, an active role by the public agencies or intermediary agents is necessary to generate new connections between firms which have not worked together previously.

With respect to the programme of the Technological Consortia, these were developed in 2004 and some of them were financed by CORFO, others by CONICYT, and a small number by FIA.[36] The programme aimed to generate a new firm (the

[35] The programme was modified recently, reducing the timeframe for the implementation and total subsidies that beneficiary firms could receive from the programme. For a full description of the programme visit: https://www.corfo.cl/sites/cpp/convocatorias/pmy-2016-proyectos_asociativos_de_fomento

[36] There have not been new calls to develop new Technological Consortia since 2013. There is no more information about this programme on the CORFO webpage. In CONICYT there were two such calls, in 2004 and 2005. For more information about this programme, visit: http://www.conicyt.cl/pia/2004/08/02/consorcios-tecnologicos-empresariales-2004/

Consortium) that would focus on producing new research, patents and products relevant for the firms collaborating in the Consortium. They needed at least one university participating and three firms or a trade association. Subsidies were substantial, of up to 1 million dollars approximately, and could be spent for five years. An analysis of the first consortium created was conducted in 2009 (for detailed results, see Alvarez et al., 2012). The results show that the programme had not yielded benefits in term of the development of new products or spin-offs, which could be expected given the short time since the consortia were created. The results also identified that the origins of the consortia were mainly the result of individual researchers at universities contacting firms they knew or had worked closely with before. This analysis shows how previous relations can be the main source of partners for applications to public programmes subsidising associative projects.

If a government wants to create a new cluster, or increase the growth of a cluster, then to rely on programmes that subsidise associative projects presented by the groups of firms already in place might not be the best approach. An active attempt to promote new collaborations between actors needs to be pursued. This role can be conducted by the public agencies directly; however, this would require capacities on the part of the workers in these agencies that might be difficult to acquire. An alternative could be to use other intermediary agencies – such as incubators, business accelerators, business associations and trade associations – with the right incentives to reach new users and to create new collaborations.

Another type of public policies to promote the emergence of clusters can be to purposefully create linkages between new entrants and already established firms. Mentoring programmes for entrepreneurs and the promotion of links with international researchers and investors might also increase social relations and

reduce a cluster's potential for lock-in. The results might be relevant for the design of programmes promoting entrepreneurship and relations between actors in a cluster. In this respect, the well-known Start-up Chile programme has included networking and mentoring activities within the benefits offered to the entrepreneurs selected. However, a recent evaluation of the programme shows that these activities have not had a direct impact on the start-ups or entrepreneurs; this was mainly due to the lack of predefined outcomes expected from these activities, particularly in the mentoring scheme (VERDE, 2016). This evaluation also shows that the networking activities were mainly between beneficiaries of the programme, and that local entrepreneurs interacted little with foreign entrepreneurs. The close nature of these activities to other relevant agents in the entrepreneurial ecosystem may have contributed to the lack of impact of this aspect of the programme. Start-up Chile did not focus on cluster emergence or a single economic sector. Therefore, a cluster policy that includes the promotion of new entrants in a cluster through entrepreneurial support should consider activities to connect new entrants with established agents in the cluster.

Another policy implication of the thesis is the role of the network structures in cluster formation and growth. Cluster programmes need to consider the structure of the social network as one of the determinants of cluster development. Policies that aim to generate a cluster by providing only public goods and access to financial capital in a particular location may not be successful if potential entrepreneurs are not connected in some way to the specific location and to actors in the cluster who want to be promoted. Usually, cluster programmes are focused on those clusters that are already 'visible', i.e. clusters that can be identified as such since the number of firms in the cluster is sufficient to create positive benefits of agglomeration. This

bias in cluster programmes restricts the universe of supported clusters to those that can reach a critical size organically and misses the potential proto-clusters that could be promoted to a stage where there is endogenous growth of the cluster through public policies. Targeting a proto-cluster requires an active role on the part of the governmental agencies in the search for new sectors in a specific location that have the potential to become clusters and promote economic development.

Another implication involves the location of clusters. The importance of social networks (personal and business networks) in cluster formation implies that organic clusters will be observed in denser locations, areas where a high number of potential entrepreneurs are located and services and resources are abundant. It is observed in the literature that high-tech clusters are usually found in urban areas (Karlsson, 2008d; Lawton Smith, 2008; Kelley Porter et al., 2005). In a highly centralised country like Chile, this fact presents challenges to regional economic development policies. This results also provides evidence to understand why in some cases technology parks founded by governments are not effective in forming a cluster if they are located far from other services and entrepreneurs' social networks. Therefore, successful cluster programmes should also consider supportive policies and measures that affect the general environment or the entrepreneurial ecosystem in which these clusters will be developing.

One last important implication of the research involves the role of universities and the relations between universities and the industry in the emergence of a knowledge-based cluster. The high importance of professional relations in this type of cluster highlights the significant role of higher education in generating the necessary networks for entrepreneurs to succeed in a high-tech sector. In particular, the access to international networks of scientists is important in creating personal

relations, which may lead to business relations in the future. Therefore, the role of universities is not only important to cluster creation through their traditional role of training skilled labour. They might also reduce the negative effects of social networks in the formation and development of clusters by being the space in which connections between future scientists and entrepreneurs are created, reducing the creation of business cliques and lock-in of knowledge in a cluster. The findings of the thesis also have implications for the international scholarship schemes promoted by several emerging countries in Latin America. Given the positive effect of relations with international R&D-oriented partners in the creation of new scientific knowledge, scholarship schemes financing scientists to study in developed countries should consider how to increase and maintain the international relations generated through these experiences.

8.5 LIMITATIONS AND FURTHER RESEARCH

Although the analysis and results presented so far contributes to our knowledge about the emergence of clusters, there are some caveats that need to be noted regarding these findings. First, as mentioned in Chapter 3, even when the data collected is representative of the sector and case study chosen, it cannot be considered as representing the complete network of the cluster. If respondents are institutions in the cluster with a high number of social relations, the impact of social networks in the results might be overstated. Secondly, the data may suffer from 'survival bias' given that only existing firms were interviewed – no firms that were created but had not been successful were found. Despite this, the oldest biotech firms in the cluster are included in the sample, which implies that data for the very first stages of the clusters studied was included in the analysis. Finally, a dynamic

analysis of how relations are created and destroyed between the actors of the cluster can only be conducted using longitudinal datasets of the information on relations between agents. This aspect is crucial to understanding potential changes to the relevance of different relations across the processes of cluster emergence and growth. Future research should tackle some of these caveats to improve understanding of social relations and social capital in cluster formation and evolution.

Additional research needs to be done to establish whether these results hold in different contexts and to characterise which factors could mitigate the importance of social relations in cluster formation. Possible future studies could use the same or a similar research design to explore the effects of social relations in less knowledge-intensive sectors. Previous research suggests that social networks might have a greater role in clusters with high levels of uncertainty, risk and information asymmetries, such as in the biotechnology sector, as suggested by Audretsch and Feldman (2003). This could imply that results are positively biased, and that they show a greater importance of the role of social networks in cluster formation given the sector studied. *A priori*, it is possible to hypothesise that in sectors with lower levels of uncertainty and risks in the technology used, social relations could play a less significant role. However, social relations would still be important if information asymmetries and market failures persist. In this case, though, since there might not be a 'scientific language' or academic relations in common between the actors of a cluster, it could be the case that social relations and path dependency are even more important and the business lock-in might be more difficult to break. This is a question that needs to be assessed empirically in future studies.

It would also be interesting to explore further the role of international and national relations in cluster formation and how they might shape the balance of centrality and power within a cluster through time. It might be valuable to assess how international linkages could prevent knowledge and business lock-in dynamically. Also, it is necessary to study the differences between international and national relations in several technological and geographical settings. Within a single country, it could be important to distinguish between relations at the cluster level and relations with other regions of the same country. The same can be applied to international relations. Foreign relations with partners in industrialised countries could be more important for the creation of knowledge and innovations than relations with partners in regions with technological development similar to that of the local cluster studied. These and other nuances within relations in a cluster, and their effects on innovation and knowledge, should be further studied to clarify the emergence of relations and cluster.

Despite the importance of social relations for cluster formation, the promotion of clusters cannot rely solely on social networks. Following the literature on evolutionary economics, innovation is a systemic, path-dependent process, and therefore depends on the characteristics of the agents, the environment and their interactions. Consequently, the importance of social networks in cluster emergence and growth will differ depending the sector, location, the actors present in the cluster and the institutional context. To foster innovation, public policy aiming to promote clusters should be framed to fit the local settings, taking into account the intersection between social, regional and industrial features.

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APPENDICES

APPENDIX 1: SURVEY QUESTIONNAIRE

SURVEY OF BIOTECHNOLOGY COMPANIES
'Social Networks, Entrepreneurship and Clusters' Formation: Study of the Biotechnology Sector in Chile'

DEFINITIONS RELEVANT TO THIS STUDY

Biotechnology: The OECD defines biotechnology as 'the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.' Likewise, the OECD defines a list of techniques (as a guide) considered biotechnology techniques. They are: - DNA / RNA recombinant techniques (i.e. genomics, pharmacogenomics, DNA sequencing, genetic engineering); - Proteins and other molecules (i.e. Sequencing/synthesis/engineering of proteins and peptides); - Cell and tissue culture and engineering (i.e. Cell/tissue culture and engineering, vaccine/immune stimulants, embryo manipulation); - Process biotechnology techniques (i.e. fermentation, bioprocessing, bioleaching, bioreactors, etc.); - Gene and RNA vectors (gene therapy, viral vectors); - Stem Cells methods; - Bioinformatics and Nanobiotechnology
Biotechnology company: For this study, a biotechnology company is a firm that uses biotechnology techniques in central productive activities for the company and in Research and Development (R&D). Additionally, the study will consider related companies as suppliers of services or biotech companies using biotechnology techniques somewhere in the production process, but which final product is not a biotech product, such as provision of services or other products not considered to be biotechnology products.
Biotechnology product: It is a good or a service, whose development requires the use of one or more biotechnology techniques from the list provided above.
Biotechnological process is a process using one or more of biotechnological techniques provided above.
Cooperation agreements/collaboration: formal agreements between the company and other companies or organizations that involve sharing and/or pooling resources (i.e. scientific, technological, commercial or financial) between them.
Consulting: all contracts involving scientific and technical services related to the activities of Engineering and Industrial Design or improvements in management activities to external parties of the company. If the activities contracted to third parties relate to research and development or training you should consider them as contract activities to third parties on Research and Development and Training.
Research and Development (R&D) is the company's creative work undertaken on a systematic way, not occasional, with the aim of generating new knowledge (scientific or technical) or to apply or exploit an existing knowledge or knowledge developed by others. Within R&D three categories are distinguished: basic research, applied research and experimental development.
Innovative activities: These activities are defined as all scientific, technological, organizational, financial and business activities that effectively lead or are intended to lead to the introduction of innovations. Some of these activities are innovative themselves, others are not new but they are necessary for the introduction of innovations to the market. The research and development activities that are not directly related to the introduction of a particular innovation into the market are also included. Innovative activities include: Acquisition of machinery, equipment and software; Acquisition of external knowledge (patents, licenses, know-how); Training for innovation; Introduction of innovations to the market (including market research and advertising campaigns); Other activities necessary for innovation.
Patents: A patent is an exclusive right granted by the State to protect and exploit an invention for the time determined by law Patents provide exclusive rights that allow you to use and exploit your invention and prevent third parties from using it without your consent.
Industrial Design: It includes all technical preparations for production and distribution of an innovation but not included in R&D, such as drawings and graphics for defining procedures, technical specifications and operational characteristics; installation of machinery; industrial engineering; and production requirements.
Know-How Agreements: A form of technology transfer that describes the existing knowledge, not academic, including: techniques, secret information, theories and even private data (such as customers or suppliers). Know How agreements allow obtaining exclusivity for operating and maintaining industrial property on a process or product. Thus, it is used as a competitive advantage. It is important to consider that the process in question has to be something new and different.

I.1 GENERAL INFORMATION

1 Company name:

2 Name of interviewee:

3 Position within the company:

4 Years working for the company:

5 Year of formal establishment of the company:

6 Years of significant changes for the company in relation to its property (mergers, acquisitions, spin-offs, incorporation of partners, total or partial acquisition of other companies, etc.). WRITE ALL RELEVANT INFORMATION

7 The company is a subsidiary of another company? (YES/NO)

i. If yes, Can you give the name of the parent company?

ii. Is this a national or international company?

8 Does your company have one or more subsidiaries?

i. Yes, please name them and indicate their core business and location below

ii. No → **Go to question 9**

Name	Business	Location

9 Percentage of foreign ownership of the company %

*If there is no foreign ownership write zero 0

10 Company Type (Today)

i. Family Business (Owner or partners are part of one single family)

ii. Public company or State owned company

iii. Mixed company (State and Private owned)

iv. Non-profit Organization

v. Private company (eg. S.A., SRL, Ltda., etc.)

iv. Other (Specify)

11 Does your company provide products or services?

i. Products → Go to question 13 ☐
ii. Services → Go to question13 ☐
iii. Both ☐

12 What is more important in terms of sales for the company?

i. Products ☐
ii. Services ☐

13 Who is the principal client of the product or service of the company? Which markets do you aim, national or international? (Mark with an X all the alternatives that apply)

	A. Domestic Market	B. International Market
i. Final individual consumer		
ii. Another company in the biotechnology sector		
iii. A distribution or export company		
iv. An international distribution or export company		
v. Hospitals and Health Centres		
vi. Universities		
vii. A production company in another industry (Specify, e.g. mining, forestry, etc.)		
viii. Other (Specify)		

14 What was the amount (approximately) in UF (a constant monetary unit in Chile) or in million dollars of sales in 2012 ☐ *** If interviewee answers spontaneously go to question 16**

15 ONLY IF INTERVIEWEE DOES NOT ANWER QUESTION 14

Total sales in 2012 in UF (see card)

i. Less than 2.401 UF ☐
ii. Between 2.401 and 10.000 UF ☐
iii. Between 10.001 and 25.000 UF ☐
iv. Between 25.001 and 50.000 UF ☐
v. Between 50.001 and 75.000 UF ☐
vi. Between 75.001 and 100.000 UF ☐
vii. Between 100.001 and 150.000 UF ☐
viii. More than 150.000 UF ☐

16 Does your company export products or services?

i. Yes ☐
ii. No **-> Go to question 19** ☐

17 How much did your company exported as percentage of sales in 2012 ☐ %

18 **How were total exports geographically distributed in 2012?**

	%
i. USA	%
ii. Latin America	%
iii. Europe	%
iv. Asia or Oceania	%
v. Other region (Specify)	%
TOTAL	100%

19 **Total number of employees at December 2012**

i. Total number of employees as of December 2012	
ii. Number of part-time employees, consultants, or outsourced at December 2012	

20 **Total employees in December 2012 by level of education:**

i. Without Higher Education	
ii. Technical studies completed	
iii. Undergraduate studies completed	
iv. Master Studies completed	
v. Doctoral or Post-Doctoral studies completed	

21 **Your company has a Research and Development Unit or Division formally established?**

i. Yes
ii. No **-> Go to question 23**

22 **What is the number of researchers working in this division?** **→ Go to question 25**

23 **Your company has workers that perform research and development activities?**

i. Yes
ii. No **-> Go to question 26**

24 **What is the total number of workers engaged in research and development functions in your company?**

25 **How many Full-time equivalent (FTE) staff in Research and Development (including all researchers) does your company have? (For example, 2 part-time employees, is one full-time equivalent staff)**

26 **What is the investment in Research and Development of the company? Measured as percentage of sales in 2012. (Total investment, considering expenditures within the company, in collaboration with other companies or institutions, and outsourced) (PERCENTAGE)** %

27 **How much is the average annual R&D expenditures of the last three years? (Value in millions of Chilean pesos)**

28 **How much is the average annual Innovative Activities expenditures of the last three years? (Value in millions of Chilean pesos)**

29 How your company has financed its innovative activities and R&D expenditures in the last three years? (Write the percentage of total investments)

i. Own company resources (reinvestment of revenues and owners contributions)	%
ii. Resources from firms part of the business group of the company.	%
iii. Domestic Banks or Financial institutions	%
iv. Other National private sources (i.e. suppliers, customers, other companies)	%
v. Foreign Financial institutions	%
vi. Other Foreign private sources (i.e. suppliers, customers, other foreign companies)	%
vii. Public Agencies (CORFO, CONICYT, FIA, etc.)	%
viii. Family loans	%
ix. Other (specify)	%
TOTAL	100%

30 Over the last 3 years (2010, 2011, 2012), your company introduced:

	1. Yes 2. No
i. New or significantly improved goods, products or services, new to the firm but existing in the domestic market.	
ii. New or significantly improved goods, products or services, new to the company and new to the local market, but existing in the rest of the world.	
iii. New or significantly improved goods, products or services, new to the firm and new worldwide.	
iv. A new or significantly improved production process, distribution method, or support activity for the firm's products or services (involves changes in techniques, equipment and/or software)	
v. A new methodology in business practice (including knowledge and innovation management), organization of the workplace, or external relationships with other companies that have not been used in the company before (excludes mergers or acquisitions, even if It is for the first time).	
vi. The implementation of a new marketing concept or strategy that differs significantly from the existing method of marketing in the company and which has not been used before (including significant changes in product design or packaging, positioning, promotion or its pricing. Excludes routine, temporary or regular changes in marketing methods).	

31 With respect to the Biotechnology Sector. How would you classify your company?

i. Biotechnology company (where the main objective is the development of biotechnology-based products)	☐	
ii. Company that provides Services of Laboratory based on Biotechnological Techniques (services, such as lab tests, which require the use of biotechnology techniques)	☐	
iii. Company that provides Research Services to other firms (using biotechnology techniques in the research process)	☐	
iv. Company that uses biotechnology in their production processes but biotechnology products or services are not their primary objective (food company, mining company, aquaculture company, etc.)	☐	**→ Go to Section IV**
v. Consultancy Company (Management, Technological Development, Market Research)	☐	**→ Go to Section IV**
vi. Legal and IP Services company	☐	**→ Go to Section IV**
vii. Other (Specify)	☐	**→ Go to Section IV only if it does not have R&D activities in the firm**

In relation to the areas of biotechnology:

	32. In which area of Biotechnology does your institution works? (Multiple choice)	**33. What is the main biotech area of your institution? (One Response)**
i. Health and medical diagnosis		
ii. Food and nutrition		
iii. Aquaculture and marine biology		
iv. Agriculture		
v. Biotechnology or Arid Zones		
vi. Patents, publications and inventions		
vii. Bio-industry based on genetic technology		
viii. Classical fermentation and bioprocesses		
ix. Bioinformatics, nano-biotechnology		

	34. Indicate whether the company has or develops the following products or biotechnological processes.	**35. (Only if you have products in the biotechnological application indicated) Indicate the number of biotechnological products or processes that the company currently has in every stage of development.**			
	1. Yes 2. No -> Go to next category	**Research and Development**	**Preclinical trials/ Clinical trials**	**Regulatory phase**	**Approved / in the market/ being produced**
Biotechnological applications					
i. Human Health – biopharmaceuticals therapy and monoclonal antibodies produced by recombinant DNA technology					
ii. Human Health – other therapies, artificial substrates, cell cultures. Diagnostic methods.					
iii. Animal Health – all applications for animal health					

	34. Indicate whether the company has or develops the following products or biotechnological processes.	**35. (Only if you have products in the biotechnological application indicated) Indicate the number of biotechnological products or processes that the company currently has in every stage of development.**			
	1. Yes 2. No -> Go to next category	**Research and Development**	**Preclinical trials/ Clinical trials**	**Regulatory phase**	**Approved / in the market/ being produced**
iv. Agriculture GM Biotechnology (genetically modified) – new varieties of genetically modified plants, microorganisms and animals					
v. Agriculture non-GM Biotechnology – new non-GM varieties of plants, animals and microorganisms for use in agriculture, bio-pesticides control and diagnostic development using biotechnology techniques (DNA markers, cell cultures)					
vi. Processing Industry - bioreactors to produce new products (i.e. chemicals, food, ethanol, plastics), biotechnology applied to transformation processes.					
vii. Non-specific Applications – e.g. Research procedures or tools.					
viii. Others (Specify):					

36 Please, could you tell:

	In Chile	In EE.UU.	In Europa	In Other Countries	Total
i. **TOTAL** number of intellectual property rights that your company owns (including patents, copyrights, plant breeding and copyrights, industrial design; does not include trademarks)					
ii. Number of intellectual property rights claimed by the company **IN THE LAST 3 YEARS** (excluding trademarks)					
iii. Number of Know-How agreements (Transfers of unpatented knowledge) your company **CURRENTLY HAS**					

I.2 BEGINNINGS OF THE COMPANY

Now, I will ask questions about the origins of the company.

1 How the company started?

- i. Family business ☐
- ii. Spin-off of a University ☐
- iii. Spin-off of another company ☐
- iv. Collaboration between companies (Consortium) ☐
- v. Public initiative (by a Public Agency) ☐
- vi. Mixed initiative (Public and Private) ☐
- vii. Non-profit Organization ☐
- viii. Private company (e.g. S.A., SRL, Ltda., etc.) ☐
- ix. Other (Specify) ☐

2 How many partners or owners formed the company? (Number in all relevant categories)

- i. People (Entrepreneurs or Businessman) ☐
- ii. Member companies ☐
- iii. Venture Capital Firms ☐

3 Which were the sources of capital for the creation of the company?
(Multiple answers, check all that apply)

- i. Capital of the founding partners ☐
- ii. Capital from banks or other financial institutions ☐
- iii. Capital from Public Agencies (e.g. CORFO) ☐
- iv. National Venture Capital Firms ☐
- v. Foreign Venture Capital Firms ☐
- vi. Family Loans or Family Capital ☐
- vii. Other (specify) ☐

4 What year the company began to have sales? ☐

5 **What was the amount (approximately) of sales that year in UF (or million dollars)?** **(year of question 4)**

*** If interviewee answers spontaneously Go to question 7**

6 **ONLY IF INTERVIEWEE DOES NOT ANSWER SPONTANEOUSLY Question 5**

The amount of sales of the year [answer QUESTION 4] could have been:

i. Less than 2,401 UF
ii. Between 2,401 and 10,000 UF
iii. Between 10,001 and 25,000 UF
iv. Between 25,001 and 50,000 UF
v. Between 50,001 and 75,000 UF
vi. Between 75,001 and 100,000 UF
vii. Between 100,001 and 150,000 UF
viii. More than 150,000 UF

If the company does not export SKIP TO QUESTION 10

7 **What year the company began to export?**

*** If the company does not exports Go to Question 10**

8 **What was the percentage of sales exported the first year that your company exported?** %

9 **How total exports were distributed the first year your company exported?**

	%
i. USA	%
ii. Latin America	%
iii. Europe	%
iv. Asia or Oceania	%
v. Other (Specify)	%
TOTAL	100%

10 **Which is the area of biotechnology in which the company started?** **(Multiple Response)**

i. Health and medical diagnosis
ii. Food and nutrition
iii. Aquaculture and marine biology
iv. Agriculture
v. Biotechnology of Arid Zones
vi. Patents, publications and inventions
vii. Bio-industry based on genetic technology
viii. Classical fermentation and bioprocesses
ix. Bioinformatics, nano-biotechnology

11 What was the total number of employees (including all those who worked in the company even if they were the owners) the first year of operations of the company?

i. Total employees the first year of operations	
i i. Number of researchers the first year of operations	
ii i. Number of employees with PhD's the first year of operations	

12 Reasons to settle in the City and Region

	A. What were the reasons for establishing the company in this city and region? ALL RELEVANT ALTERNATIVES (Multiple Choice)	**B. What were the three most important reasons for establishing the company in this city and region? RANKING from 1 (most important) to 3 (third in importance)**
i. Proximity to Universities and Research Centres		
ii. Proximity to Suppliers Companies		
iii. Proximity to Customers		
iv. Proximity to financial partners, banks or venture capital firms		
v. To exploit an advantage in the company's area of biotechnology that exists in this City / Region		
vi. Closeness to the owners' family		
vii. I have always lived in this city / region and did not consider elsewhere in Chile to establish the company		
viii. Other (Specify)		

13 How relevant were the following local factors compared to other regions of the country to make the decision to settle in this city and region?

Mark with an X

		Importance		
		High	**Average**	**Low**
1	Access to supply of skilled workers			
2	Easy to attract skilled workers			
3	Improved quality of life			
4	Access to buy inputs from suppliers in the region			
5	Access to buy equipment from companies in the region			
6	Access to import inputs from abroad			
7	Access to import equipment from abroad			
8	Largest market (local demand)			
9	More facilities for export			
10	Facilities to find new customers			
11	Improving the reputation of my products or services			
12	Access to new technologies			
13	Access to new knowledge			
14	Greater opportunities for innovation and development of new products and services			
15	More facilities for doing research			
16	Increased cooperation with public research centres and universities			
17	Increased cooperation with private research centres			
18	Increased cooperation with other biotechnology companies in the region			
19	Participation in companies such as consortiums and trade/industry associations			
20	Greater cooperation with customers			
21	Increased cooperation with suppliers			

II.1 FOUNDERS INFORMATION

Regarding the founding partners of the company (Answer to Question 2.i Part I.2. If the company was founded only by companies go to question II.2)	**1. What was his/her educational level at the establishment of the company?**	**2. Does he/she have formal studies in subjects of Management or Innovation and Technology Management?**	**3. Does he/she have done some of their formal studies abroad?**	**4. Does he/she have participated in the creation of a new company before?**	**5. Was this company established abroad?**	**6. This company's main business was in an area related to biotechnology?**	**7. How many years has this company been active?**	**8. Does he/she have participated in the creation of a new company after the creation of this company?**	**9. Was this company established abroad?**	**10. This company's main business was in an area related to biotechnology?**	**11. How many years has this company been active?**
If no information is available or the interviewee does not know this information put **'not known'** response It is not necessary to individually identify the founders if the interviewee does not want to.	1. Complete Higher Education in a biotechnology related subject 2. Complete Higher Education in another subject 3. Master in a biotechnology related subject 4. Master in another subject 5. PhD in a biotechnology related subject 6. PhD in another subject 7. Post-doctorate in a biotechnology related subject 8. Post-doctorate in another subject	1. Yes. Diploma in General Management 2. Yes. Master in General Management 3. Yes. Doctorate in General Management 4. Yes. Diploma in Technology Management (or innovation) 5. Yes. Master of Technology Management (or innovation) 6. Yes. PhD in Technology Management (or innovation) 7. Yes. Other (specify) 8. No	1. Yes. USA 2. Yes. Europe 3. Yes. Asia or Oceania 4. Yes. Latin America 5. No	1. Yes 2. No -> Go to Question 8	1. Yes. USA 2. Yes. Europe 3. Yes. Asia or Oceania 4. Yes. Latin America 5. No If the founder has participated in the creation of more than one company indicate all relevant answers separated by the sign /	1. Yes 2. No If the founder has participated in the creation of more than one company indicate all relevant answers separated by the sign /	1. Between 0 and 2 years 2. Between 3 and 5 years 3. Between 6 and 10 years 4. Between 10 and 15 years 5. Between 15 and 20 years 6. More than 20 years If the founder has participated in the creation of more than one company indicate all relevant answers separated by the sign /	1. Yes 2. No -> Go to Next Person	1. Yes. USA 2. Yes. Europe 3. Yes. Asia or Oceania 4. Yes. Latin America 5. No. Entrepreneurship in Chile If the founder has participated in the creation of more than one company indicate all relevant answers separated by the sign /	1. Yes 2. No If the founder has participated in the creation of more than one company indicate all relevant answers separated by the sign /	1. Between 0 and 2 years 2. Between 3 and 5 years 3. Between 6 and 10 years 4. Between 10 and 15 years 5. Between 15 and 20 years 6. More than 20 years If the founder has participated in the creation of more than one company indicate all relevant answers separated by the sign /

	9. Other (specify)											
Founding Partner 1												
Founding Partner 2												

II.2 CEO INFORMATION

Regarding the first CEO and current CEO	**12. How many years of previous experience in similar positions did the CEO have?**	**13. What was his/her educational level at the time he/she started working for the company?**	**14. Does he/she have formal studies in subjects of Management or Innovation and Technology Management?**	**15. Does he/she have done some of their formal studies abroad?**	**16. Does he/she have participated in the creation of a new company before?**	**17. Was this company established abroad?**	**18. This company's main business was in an area related to biotechnology?**	**19. How many years has this company been active?**	**20. Does he/she have participated in the creation of a new company after the creation of this company?**	**21. Was this company established abroad?**	**22. This company's main business was in an area related to biotechnology?**	**23. How many years has this company been active?**
If no information is available or the interviewee does not know this information put **'not known'** response If the first CEO was one of the Founding Partners, indicate which row of the previous section is located and do not ask questions 13 onwards If the current CEO is the same as the first CEO,	YEARS	1. Complete Higher Education in a biotechnology related subject 2. Complete Higher Education in another subject 3. Master in a biotechnology related subject 4. Master in another subject 5. PhD in a biotechnology related subject 6. PhD in another subject	1. Yes. Diploma in General Management 2. Yes. Master in General Management 3. Yes. Doctorate in General Management 4. Yes. Diploma in Technology Management (or innovation) 5. Yes. Master of Technology Management (or innovation) 6. Yes. PhD in Technology Management (or innovation)	1. Yes. USA 2. Yes. Europe 3. Yes. Asia or Oceania 4. Yes. Latin America 5. No	1. Yes 2. No -> Go to Question 20	1. Yes. USA 2. Yes. Europe 3. Yes. Asia or Oceania 4. Yes. Latin America 5. No If the CEO has participated in the creation of more than one company indicate all relevant answers separated	1. Yes 2. No If the CEO has participated in the creation of more than one company indicate all relevant answers separated by the sign /	1. Between 0 and 2 years 2. Between 3 and 5 years 3. Between 6 and 10 years 4. Between 10 and 15 years 5. Between 15 and 20 years 6. More than 20 years If the CEO has participated in the	1. Yes 2. No -> Go to Next Person	1. Yes. USA 2. Yes. Europe 3. Yes. Asia or Oceania 4. Yes. Latin America 5. No. Entrepreneurship in Chile If the CEO has participated in the creation of more than one company indicate all relevant answers separated by the sign /	1. Yes 2. No If the CEO has participated in the creation of more than one company indicate all relevant answers separated by the sign /	1. Between 0 and 2 years 2. Between 3 and 5 years 3. Between 6 and 10 years 4. Between 10 and 15 years 5. Between 15 and 20 years 6. More than 20 years If the CEO has participated in the creation of more than one company indicate all

indicate this and only ask questions 12 to 23 once		7. Post-doctorate in a biotechnology related subject 8. Post-doctorate in another subject 9. Other (specify)	7. Yes. Other (specify) 8. No			by the sign /		creation of more than one company indicate all relevant answers separated by the sign /				relevant answers separated by the sign /
First CEO												
Current CEO												

III. OBSTACLES

1. What were the biggest challenges your organization faced during the creation of the company? How relevant were those difficulties?

		Importance			Not Applicable/It was not a difficulty
		High	**Average**	**Low**	NA
1	Lack of capital				
2	Difficulties getting capital from the financial sector				
3	Difficulties incorporating co-founders or partner companies				
4	Difficult access to venture capital companies or Angel Investors				
5	Lack of funding from government agencies				
6	Lack of guidance from government agencies				
7	Difficulties finding suppliers in the domestic market				
8	Difficulties finding foreign suppliers				
9	Difficulties finding customers in the domestic market				
10	Difficulties finding customers from abroad				
11	Legal procedures for starting and establishing the company				
12	Legal costs of establishing the company				
13	Other regulations (Health, Patents, International Standards, etc.)				
14	Difficulties finding qualified human resources or employees				
15	Difficulties accessing frontier knowledge and technologies				
16	Difficulties purchasing the latest equipment				
17	Other (please specify)				
18	Other (please specify)				

2. What have been the main difficulties that your institution has faced during the growth of your company? How relevant are these difficulties?

		Importance			Not Applicable/It was not a difficulty
		High	**Average**	**Low**	NA
1	Lack of capital				
2	Difficulties getting capital from the financial sector				
3	Difficulties incorporating new partners or partner companies				
4	Difficult access to venture capital companies or Angel Investors				
5	Lack of funding from government agencies				
6	Lack of guidance from government agencies				
7	Difficulties finding suppliers in the domestic market				
8	Difficulties finding foreign suppliers				
9	Difficulties finding customers in the domestic market				
10	Difficulties finding customers from abroad				
13	Regulations and legislations on the area of the company (Sanitary, Patents, International Standard, etc.)				
14	Difficulties finding qualified human resources or employees				
15	Difficulties accessing frontier knowledge and technologies				
16	Difficulties purchasing the latest equipment				
17	Other (please specify)				
18	Other (please specify)				

IV. TRADE RELATIONS

	1. Can you tell me the name of the companies and institutions with which your company has a business relationship (such as customer, supplier research partner, etc.)? Name all relevant domestic and foreign companies	2. Specify the type of relationship with each institution (multiple choice)	3. This company or institution is domestic or foreign?	4. Indicate the year this business relationship began	5. How important is this relationship to your company?	6. How important is this relationship to obtain technical information or to solve a technological problem in your company?	7. How this business relationship started? If answer is 4-8, or the contact is not through a person, go to the next company (next row)	8. Could you mention the type of social relationship that led to this business relationship? (Multiple choice)
	Type the name of all companies with which the company has a business relationship in different areas. If there are more than the specified rows, please include them at the end or insert a row where applicable Include more rows as necessary to annotate all the relations mentioned by type of firm and organisations	1. Supplier 2. Client 3. Exporter partner 4. Importer partner 5. Research Partner 6. Service Provider 7. Consultant Service 8. Members of a consortium 9. Capitalist Partner in respondent company 10. Respondent company is capitalist partner of the company mentioned 11. Other (Specify)	1. USA 2. Europe 3. Asia or Oceania 4. Latin America 5. Chilean	Year	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. Personal Connections of owners 2. Personal CEO Connections 3. Personal Connections from a researcher 4. Former Client -> Next row 5. Partners in previous research project-> Next row 6. Partners in another company -> Next row 7. Partners in a consortium -> Next row 8. Through a trade association (name) -> Next row 9. Other (Specify)	1. Former University/ college classmates 2. Former school classmates 3. Family Relationship 4. Former co-workers 5. Former university/ college professor 6. Children go to school together 7. Known in a religious context 8. Known in a political context 9. Known by the Trade Association 10. Known in Seminars and Conferences 11. Other (Specify)
	Production companies:							
1								
2								
3								
	Business Services:							
1								

	1. Can you tell me the name of the companies and institutions with which your company has a business relationship (such as customer, supplier research partner, etc.)? Name all relevant domestic and foreign companies	2. Specify the type of relationship with each institution (multiple choice)	3. This company or institution is domestic or foreign?	4. Indicate the year this business relationship began	5. How important is this relationship to your company?	6. How important is this relationship to obtain technical information or to solve a technological problem in your company?	7. How this business relationship started? If answer is 4-8, or the contact is not through a person, go to the next company (next row)	8. Could you mention the type of social relationship that led to this business relationship? (Multiple choice)
	Type the name of all companies with which the company has a business relationship in different areas. If there are more than the specified rows, please include them at the end or insert a row where applicable Include more rows as necessary to annotate all the relations mentioned by type of firm and organisations	1. Supplier 2. Client 3. Exporter partner 4. Importer partner 5. Research Partner 6. Service Provider 7. Consultant Service 8. Members of a consortium 9. Capitalist Partner in respondent company 10. Respondent company is capitalist partner of the company mentioned 11. Other (Specify)	1. USA 2. Europe 3. Asia or Oceania 4. Latin America 5. Chilean	Year	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. Personal Connections of owners 2. Personal CEO Connections 3. Personal Connections from a researcher 4. Former Client -> Next row 5. Partners in previous research project-> Next row 6. Partners in another company -> Next row 7. Partners in a consortium -> Next row 8. Through a trade association (name) -> Next row 9. Other (Specify)	1. Former University/ college classmates 2. Former school classmates 3. Family Relationship 4. Former co-workers 5. Former university/ college professor 6. Children go to school together 7. Known in a religious context 8. Known in a political context 9. Known by the Trade Association 10. Known in Seminars and Conferences 11. Other (Specify)
2								
3								
	Universities (Indicate the faculty or research center and the name of the researcher who collaborate to a later survey of scientists in biotechnology) :							
1								
2								
3								
	Institutes, foundations or private research centres:							

	1. Can you tell me the name of the companies and institutions with which your company has a business relationship (such as customer, supplier research partner, etc.)? Name all relevant domestic and foreign companies	2. Specify the type of relationship with each institution (multiple choice)	3. This company or institution is domestic or foreign?	4. Indicate the year this business relationship began	5. How important is this relationship to your company?	6. How important is this relationship to obtain technical information or to solve a technological problem in your company?	7. How this business relationship started? If answer is 4-8, or the contact is not through a person, go to the next company (next row)	8. Could you mention the type of social relationship that led to this business relationship? (Multiple choice)
	Type the name of all companies with which the company has a business relationship in different areas. If there are more than the specified rows, please include them at the end or insert a row where applicable Include more rows as necessary to annotate all the relations mentioned by type of firm and organisations	1. Supplier 2. Client 3. Exporter partner 4. Importer partner 5. Research Partner 6. Service Provider 7. Consultant Service 8. Members of a consortium 9. Capitalist Partner in respondent company 10. Respondent company is capitalist partner of the company mentioned 11. Other (Specify)	1. USA 2. Europe 3. Asia or Oceania 4. Latin America 5. Chilean	Year	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. Personal Connections of owners 2. Personal CEO Connections 3. Personal Connections from a researcher 4. Former Client -> Next row 5. Partners in previous research project-> Next row 6. Partners in another company -> Next row 7. Partners in a consortium -> Next row 8. Through a trade association (name) -> Next row 9. Other (Specify)	1. Former University/ college classmates 2. Former school classmates 3. Family Relationship 4. Former co-workers 5. Former university/ college professor 6. Children go to school together 7. Known in a religious context 8. Known in a political context 9. Known by the Trade Association 10. Known in Seminars and Conferences 11. Other (Specify)
1								
2								
3								
4								
	Technological Consortia:							
1								
2								

	1. Can you tell me the name of the companies and institutions with which your company has a business relationship (such as customer, supplier research partner, etc.)? Name all relevant domestic and foreign companies	2. Specify the type of relationship with each institution (multiple choice)	3. This company or institution is domestic or foreign?	4. Indicate the year this business relationship began	5. How important is this relationship to your company?	6. How important is this relationship to obtain technical information or to solve a technological problem in your company?	7. How this business relationship started? If answer is 4-8, or the contact is not through a person, go to the next company (next row)	8. Could you mention the type of social relationship that led to this business relationship? (Multiple choice)
	Type the name of all companies with which the company has a business relationship in different areas. If there are more than the specified rows, please include them at the end or insert a row where applicable Include more rows as necessary to annotate all the relations mentioned by type of firm and organisations	1. Supplier 2. Client 3. Exporter partner 4. Importer partner 5. Research Partner 6. Service Provider 7. Consultant Service 8. Members of a consortium 9. Capitalist Partner in respondent company 10. Respondent company is capitalist partner of the company mentioned 11. Other (Specify)	1. USA 2. Europe 3. Asia or Oceania 4. Latin America 5. Chilean	Year	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. Personal Connections of owners 2. Personal CEO Connections 3. Personal Connections from a researcher 4. Former Client -> Next row 5. Partners in previous research project-> Next row 6. Partners in another company -> Next row 7. Partners in a consortium -> Next row 8. Through a trade association (name) -> Next row 9. Other (Specify)	1. Former University/ college classmates 2. Former school classmates 3. Family Relationship 4. Former co-workers 5. Former university/ college professor 6. Children go to school together 7. Known in a religious context 8. Known in a political context 9. Known by the Trade Association 10. Known in Seminars and Conferences 11. Other (Specify)
	Associations:							
1								
2								
	Other: Is there any other company or institution with which your company has any bearing on trade issues and did not mention? Please specify the name below							

V. PERSONAL RELATIONSHIPS

	1. Could you name the companies or institutions involved in the field of biotechnology in Chile or abroad, where you or the owner(s) of the company have any personal relationship with any person working in them? Name all relevant domestic and foreign companies	2. This company or institution is domestic or foreign?	3. Could you mention the kind of personal relationship? (Multiple choice)	4. Can mention the year that this personal relationship started?	5. Can you mention the position that your acquaintance has in the company? (Multiple choice)	6. Some of these social relations started from an original business relationship?	7. Some of these social relations led to a subsequent commercial relationship?	8. (If yes in Q7) How important was the social relationship to build the business relationship?	9. How important, for your company, is to maintaining these social relations?
	Type the name of all companies in the field of biotechnology or related to biotechnology which there is a personal relationship in different areas Include more rows as necessary to annotate all the relations mentioned by type of firm and organisations	1. USA 2. Europe 3. Asia or Oceania 4. Latin America 5. Chilean	1. Former University/ college classmates 2. Former school classmates 3. Family Relationship 4. Former co-workers 5. Former university/ college professor 6. Children go to school together 7. Known in a religious context 8. Known in a political context 9. Known by the Trade Association 10. Known in Seminars and Conferences 11. Other (Specify)	Year	1. Owner 2. General Manager (CEO) 3. Commercial Manager 4. Finance Manager 5. Research or R&D Manager 6. Manager in another area 7. Other administrative position 8. Researcher 9. Other (Specify)	1. Yes 2. No	1. Yes 2. No -> Go to question 9	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important
	Production companies:								
1									
2									
3									
4									
	Business Services:								
1									
2									
3									
4									
	Institutes, foundations or private research centers:								

	1. Could you name the companies or institutions involved in the field of biotechnology in Chile or abroad, where you or the owner(s) of the company have any personal relationship with any person working in them? Name all relevant domestic and foreign companies	2. This company or institution is domestic or foreign?	3. Could you mention the kind of personal relationship? (Multiple choice)	4. Can mention the year that this personal relationship started?	5. Can you mention the position that your acquaintance has in the company? (Multiple choice)	6. Some of these social relations started from an original business relationship?	7. Some of these social relations led to a subsequent commercial relationship?	8. (If yes in Q7) How important was the social relationship to build the business relationship?	9. How important, for your company, is to maintaining these social relations?
	Type the name of all companies in the field of biotechnology or related to biotechnology which there is a personal relationship in different areas Include more rows as necessary to annotate all the relations mentioned by type of firm and organisations	1. USA 2. Europe 3. Asia or Oceania 4. Latin America 5. Chilean	1. Former University/ college classmates 2. Former school classmates 3. Family Relationship 4. Former co-workers 5. Former university/ college professor 6. Children go to school together 7. Known in a religious context 8. Known in a political context 9. Known by the Trade Association 10. Known in Seminars and Conferences 11. Other (Specify)	Year	1. Owner 2. General Manager (CEO) 3. Commercial Manager 4. Finance Manager 5. Research or R&D Manager 6. Manager in another area 7. Other administrative position 8. Researcher 9. Other (Specify)	1. Yes 2. No	1. Yes 2. No -> Go to question 9	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important
1									
2									
3									
4									
	Universities (Indicate the faculty or research center and the name of the researcher with whom they have a personal relationship to later survey) :								
1									
2									
3									
4									
5									
6									
	Technological Consortia:								

	1. Could you name the companies or institutions involved in the field of biotechnology in Chile or abroad, where you or the owner(s) of the company have any personal relationship with any person working in them? Name all relevant domestic and foreign companies	2. This company or institution is domestic or foreign?	3. Could you mention the kind of personal relationship? (Multiple choice)	4. Can mention the year that this personal relationship started?	5. Can you mention the position that your acquaintance has in the company? (Multiple choice)	6. Some of these social relations started from an original business relationship?	7. Some of these social relations led to a subsequent commercial relationship?	8. (If yes in Q7) How important was the social relationship to build the business relationship?	9. How important, for your company, is to maintaining these social relations?
	Type the name of all companies in the field of biotechnology or related to biotechnology which there is a personal relationship in different areas Include more rows as necessary to annotate all the relations mentioned by type of firm and organisations	1. USA 2. Europe 3. Asia or Oceania 4. Latin America 5. Chilean	1. Former University/ college classmates 2. Former school classmates 3. Family Relationship 4. Former co-workers 5. Former university/ college professor 6. Children go to school together 7. Known in a religious context 8. Known in a political context 9. Known by the Trade Association 10. Known in Seminars and Conferences 11. Other (Specify)	Year	1. Owner 2. General Manager (CEO) 3. Commercial Manager 4. Finance Manager 5. Research or R&D Manager 6. Manager in another area 7. Other administrative position 8. Researcher 9. Other (Specify)	1. Yes 2. No	1. Yes 2. No -> Go to question 9	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important	1. High Importance 2. Medium Importance 3. Low Importance 4. Not Important
1									
2									
	Associations:								
1									
2									
	Other: Is there any other company or institution with which you or your company has own social relations with someone of that institution who has not indicated before and is relevant to the company? Please specify the name below								

V. GENERAL OPINION

1. In your opinion, How relevant are Social/Personal relations to start a company in Chile?

2. In your opinion, How relevant are Social/Personal relations to start a company in the field of Biotechnology in Chile?

3. How social/personal relations of employees of your company have helped to the growth of your business? Please list any relevant social relationship that has generated a business relationship that has not been previously mentioned (e.g. social relations of researchers or other members of your company, etc.)

4. If you have any other comments, please let us know below

APPENDIX 2: IN-DEPTH SEMI-STRUCTURED INTERVIEWS QUESTIONNAIRE

Companies In-Depth Interview

The purpose of this interview is to gather information about the history of the institution, its decision to establish commercial ties with other companies and research institutions and their evolution, as well as the personal ties that exist between these companies and institutions. New questions may arise during the interview, depending on the topics mentioned by the interviewee.

1. Could you tell me how the company was established and created? How was the process? How relevant were the social relations of the owner (s) for this process?

2. In this context, Why and how it was decided to establish the company in this Region [name region where the company is located]? What were the advantages and disadvantages? How relevant were the social relations of the owners in this decision process?

3. In your opinion, how has been the growth of the company? What were the company's first objectives (regarding growth, markets, etc.)? Have they been reached?

4. How crucial for the growth of the company and the creation of commercial links with other institutions have been the social relations of the owners? What kind of business relationship is or are most important to your company?

5. In your opinion, how relevant is the labour mobility between companies and institutions in the Biotechnology sector in Chile? and your Region? (High, low) Why?

6. Is labour mobility an important source in the creation of social relations? Have social relations been relevant to the creation of business relationships in your company?

7. What kind of social relationships are most relevant to your institution? Are social relations with some worker (researcher, owner, general manager, commercial manager, etc.) more relevant to the creation of business relationships? Why?

8. Do you believe that social relations are relevant to the strengthening of the Biotechnology sector (or creation of a cluster) in your Region? and in Chile? In your opinion, have the Government and agencies such as CONICYT and CORFO promoted such relationships (directly or indirectly)?

APPENDIX 3: SURVEY RESPONSE RATES

Table: Surveyed firms in the Biotechnology Sector in Chile

Region	Non Surveyed					Surveyed					Rate of Response	Total Population
	Non-Biotech	Biotech			Total Non Surveyed	Non-Biotech	Biotech			Total Surveyed		
		Non-DBF*	DBF*	Total Biotech			Non-DBF*	DBF*	Total Biotech			
Arica y Parinacota			1	1	1							1
Tarapaca			2	2	2							2
Antofagasta		1	3	4	4							4
Coquimbo		1	1	2	2							2
Valparaíso		3	1	4	4		3	9	12	12	75.0%	16
Metropolitana	5	20	22	42	47	9	20	37	57	66	58.4%	113
Maule			1	1	1		1	1	2	2	66.7%	3
Biobío		1	1	2	2			6	6	6	75.0%	8
Araucanía	1				1							1
Los Ríos		2	2	4	4							4
Los Lagos	1	5	2	7	8		1	3	4	4	33.3%	12
Grand Total	**7**	**33**	**36**	**69**	**76**	**9**	**25**	**56**	**81**	**90**	**54.2%**	**166**

Source: Author's survey
Note: Regions from north to south of the country. The Capital is located in the Metropolitan Region
*: DBF corrseponds to Dedicated Biotechnology Firms, therefore, Non-DBF are non dedicated biotechnology firms

APPENDIX 4: CODING SCHEME FOR CONTENT ANALYSIS IN CHAPTER 5

Name of Coding	Description	Example in Spanish	Example (Translation to English)
1. Opportunity Recognition			
1.1 Biotech Specifics	Comments that mention the aspects of the biotechnology sector	Como se requieren personas con alto capital humano, como es un mundo muy chico, pueden haber más posibilidades de colaborar. Es mucho más complicado el producto, mucho mayor la inversión inicial. Explicar el producto es más complejo. Es difícil decidir cómo extender la red, hay mucho secreto.	As people with high human capital are required, as it is a very small world, there may be more possibilities to collaborate. The product is much more complicated, much greater the initial investment. Explaining the product is more complex. It is difficult to decide how to extend the network, there is a lot of secrecy.
1.2 Information Asymmetries	Comments that refer to Information Asymmetries	Es todavía peor. Es necesario emprender una empresa en el área, pues hay más riesgo y la sociedad tiene menos ideas y conocimientos de lo que se va a hacer. Por esto es fundamental tener contactos que te apoyen.	It is even worse. It is necessary to start a company in the area, because there is more risk and society has fewer ideas and knowledge of what is going to be done. Because of this, it is essential to have contacts that support you.
1.3 Reputation	Comments that mention aspects related to reputation of the firm or the owners.	Es lo mismo porque sí necesitas redes de contactos y formas de búsqueda de capital, darte a conocer y que te conozcan. Para relacionarse con otras áreas de conocimiento o sectores y detectar necesidades biotecnológicas y que el otro profesional no podría ver soluciones que se dan en un contexto de la conversación social, por ejemplo.	It is the same because you do need networks of contacts and forms of search of capital, to make known and to know you. To relate to other areas of knowledge or sectors and detect biotechnology needs and that the other professional could not see solutions that occur in a context of social conversation, for example.
1.4 Value Chain	Comments mentioning clients and suppliers	Sí, las relaciones tienen que tener muchos contactos con proveedores e investigadores. No saber todo hace necesario relacionarse.	Yes, relationships must have many contacts with providers and researchers. Not knowing everything makes it necessary to relate.

Name of Coding	Description	Example in Spanish	Example (Translation to English)
2. Resources for Creation of Company			
2.1 Financial Capital (including Lack of Funds)	Comments related to financial aspects	Es importante para elegir socios, para los fondos y para préstamos personales.	It is important to choose partners, for funds and for personal loans.
2.2 High Skilled Labour	Comments related to workers and high-skilled labour	Falta de incentivos o líneas de financiamiento para poder fortalecer el capital humano de empresas como las nuestras.	Lack of incentives or financing lines to be able to strengthen the human capital of companies like ours.
2.3 Scientific and Technological Knowledge	Comments related to scientific and technological knowledge	Todas las personas de la empresa son profesionales de las mejores universidades y siempre se han relacionado con los mejores investigadores del área.	All workers of the company are professionals from the best universities and have always been related to the best researchers in the area.
3. Social Capital Attitudes (Attitudes towards the importance of Social Relations for creation of firms in the country)			
3.1 Negative	Negative comments regarding Social Capital	Las relaciones sociales muchas veces son perjudiciales, en el sentido de que forman bloques y conglomerados y excluyen gente en vez de integrarla. Muchos intentos de emprendimientos han quedado en fase preliminares por el hecho de no ser parte de estas relaciones sociales. El país debe invertir en ética, para que estas cosas dejen de suceder.	Social relations are often detrimental, in the sense that they form blocks and conglomerates and exclude people instead of integrating them. Many attempts at entrepreneurship have been in preliminary stages because they are not part of these social relationships. The country must invest in ethics, so that these things stop happening.

Name of Coding	Description	Example in Spanish	Example (Translation to English)
3.2 No impact - Neutral	Neutral comments (not important) regarding Social Capital	Pienso que no es crucial o es poco relevante, eso de tener este tipo en relaciones para 'formar' una empresa. Distinto es para el éxito de la empresa, pues con más redes el camino se puede hacer más fácil, para negocios, clientes, tener conocidos en áreas comerciales.	I think that is not crucial or is not relevant, that of having this type in relationships to 'form' a company. Different is for the success of the company, because with more networks the road can be made easier, for businesses, clients, to have acquaintances in commercial areas.
3.3 Positive	Positive comments regarding Social Capital	Muchas veces, las relaciones sociales están por sobre las relaciones comerciales, por la disposición y confianza.	Many times, social relationships are above commercial relationships, by willingness and trust.
4. **Social Capital in Biotech** (Attitudes towards the importance of Social Relations for creation of biotechnology firms in the country)			
4.1 Less relevant	Comments indicating Social Capital is less relevant in Biotech than in other areas	No son tan relevantes, los conocimientos pesan más.	Not so relevant, knowledge weighs more.
4.2 More relevant	Comments indicating Social Capital is more relevant in Biotech than in other areas	En todas las industrias es igual, pero en el área científica es mayor.	In all industries it is the same, but in the scientific area it is greater.
4.3 Same relevance	Comments indicating Social Capital is has the sanme relevance in Biotech than in other areas	Son iguales que otros sectores. Este se basa en el conocimiento, pero igual no es muy diferente a otras industrias.	They are the same as other sectors. This is based on knowledge, but the same is not very different from other industries.

APPENDIX 5: DIFFERENCES BETWEEN SAMPLE GROUPS IN CHAPTER 7

This appendix shows test of means and test of proportions between the group of firms with complete information for the study in Chapter 7, the group of firms with incomplete information and also with the total sample.

The table below shows the number of observations, mean and standard deviation for each group of four variables: the proportion of biotechnology firms, the proportion of DBFs, the proportion of firms in the metropolitan region, the total number of publications and total number of patents. The tests presented are for the null hypothesis of equality of mean and equality of proportions between groups.

It is possible to conclude that the groups do not differ significantly from one another, except for the proportion of firms in the metropolitan region. The group of firms with complete information has a higher proportion of firms in the metropolitan region, therefore the conclusion of the analysis refer mainly to firms in this region of the country.

Table: Comparison of Groups of Firms with Complete Information, Firms with Incomplete Information and Total Sample

Variable	Total Surveyed Group (TS)			Incomplete Information Group (II)			Complete Information Group (CI)			Mean Test between CI and II	Mean Test between CI and TS	Proportion Test between CI and II	Proportion Test between CI and TS
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	P-value	P-value	P-value	P-value
Dummy Variable of Biotechnology Firms (BF)	103	0.81	0.40	37	0.86	0.35	66	0.77	0.42	0.24	0.53	0.04	0.53
Dummy Variable of Dedicated Biotechnology Firms (DBF)	103	0.54	0.50	37	0.57	0.50	66	0.53	0.50	0.72	0.83	0.54	0.90
Dummy Variabel of Firm in Metropolitan Region	103	0.75	0.44	37	0.54	0.51	66	0.86	0.35	0.00	0.01	0.00	0.03
Total Number of Publications	103	5.05	18.21	37	6.38	13.16	66	4.30	20.57	0.53	0.77	-	-
Total Number of Patents	103	7.42	41.17	37	2.46	5.12	66	10.20	51.22	0.23	0.66	-	-

Note: All test shown are for the null hypothesis (Ho) of equality of means or equality of proportions between the groups, thus all P-value evaluate a two-sided test

APPENDIX 6: CORRELATIONS AND MULTICOLLINEARITY TESTS BY CONDITION NUMBER ESTIMATION IN CHAPTER 7

This appendix shows the pearson correlation matrix and the condition number for each regression presented in Chapter 7. The condition number of the independent variables matrix is used to identify if there is a relevant multicollinearity problem in the regressions as susggested by Belsley, Kuh and Welsch (1980), explained by Greene (2000, p. 258). Values of the condition number higher than 20 are indicative of a multicollinearity problem. There is no condition number higher tan 9 in each equation estimated, indicating no relevant multicollienarity problem. Results are presented below.

1. Basic Regression for Knowledge Data (Total Publications and Patents)

Equations:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \varepsilon$$

Correlation Matrix 1:

	1	2	3	4	5	6
1 tot_publications	1					
2 large	0.3186*	1				
3 years	-0.0062	0.4331*	1			
4 areas	0.2959*	0.0839	0.0041	1		
5 ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1	
6 dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

	1	2	3	4	5	6
1 tot_patents	1					
2 large	-0.0302	1				
3 years	0.2627*	0.4331*	1			
4 areas	-0.0716	0.0839	0.0041	1		
5 ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1	
6 dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1

Note: * indicates significance of the relationship at 5% confidence level

The condition number and condition indexes only include the independent variables in the estimation; therefore, they are the same for the model with patent data or publication data.

Condition number using scaled variables: 4.67

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_emp	dbf
1	1.00	0.02	0.01	0.02	0.02	0.02	0.02
2	1.73	0.00	0.28	0.07	0.01	0.10	0.02
3	2.68	0.01	0.18	0.29	0.06	0.18	0.19
4	2.96	0.05	0.47	0.10	0.00	0.62	0.07
5	3.54	0.07	0.05	0.01	0.90	0.03	0.25
6	4.67	0.86	0.02	0.51	0.01	0.05	0.45

2. Regressions for Knowledge Data and Network Effects:

2.1. Regressions with Business Network Degree

Model 1:

$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 \text{deg_bus} + \varepsilon$

$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 \text{deg_bus} + \varepsilon$

Correlation Matrix 1:

		1	2	3	4	5	6	7
1	tot_publications	1						
2	large	0.3186*	1					
3	years	-0.0062	0.4331*	1				
4	areas	0.2959*	0.0839	0.0041	1			
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1		
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1	
7	deg_comm	0.4508*	0.2616*	0.1815	0.0834	-0.0014	-0.0526	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7
1	tot_patents	1						
2	large	-0.0302	1					
3	years	0.2627*	0.4331*	1				
4	areas	-0.0716	0.0839	0.0041	1			
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1		
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1	
7	deg_comm	0.063	0.2616*	0.1815	0.0834	-0.0014	-0.0526	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables: 6.28

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp _emp	dbf	deg_comm
1	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	1.89	0.00	0.25	0.06	0.01	0.11	0.03	0.00
3	2.91	0.01	0.25	0.20	0.09	0.09	0.18	0.03
4	3.20	0.03	0.34	0.01	0.00	0.72	0.08	0.03
5	3.68	0.02	0.10	0.34	0.43	0.02	0.01	0.21
6	4.11	0.00	0.01	0.21	0.45	0.04	0.48	0.19
7	6.28	0.94	0.05	0.16	0.00	0.01	0.21	0.53

Model 2:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_comm_nac + \beta_7 deg_comm_int + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_comm_nac + \beta_7 deg_comm_int + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8
1	tot_publications	1							
2	large	0.3186*	1						
3	years	-0.0062	0.4331*	1					
4	areas	0.2959*	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1			
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1		
7	deg_comm_nac	0.4508*	0.2553*	0.2627*	0.0628	-0.0371	-0.056	1	
8	deg_comm_int	0.113	0.0821	-0.1674	0.0749	0.0933	-0.0042	0.0715	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8
1	tot_patents	1							
2	large	-0.0302	1						
3	years	0.2627*	0.4331*	1					
4	areas	-0.0716	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1			
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1		
7	deg_comm_nac	0.069	0.2553*	0.2627*	0.0628	-0.0371	-0.056	1	
8	deg_comm_int	0.0001	0.0821	-0.1674	0.0749	0.0933	-0.0042	0.0715	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 6.43

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	deg_comm _nac	deg_comm _int
1	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	1.97	0.00	0.24	0.06	0.01	0.10	0.02	0.00	0.00
3	2.68	0.00	0.01	0.06	0.02	0.01	0.02	0.00	0.72
4	3.00	0.01	0.29	0.15	0.10	0.05	0.17	0.05	0.01
5	3.31	0.02	0.27	0.00	0.00	0.73	0.10	0.05	0.00
6	4.00	0.01	0.12	0.13	0.67	0.08	0.15	0.10	0.06
7	4.47	0.00	0.01	0.38	0.19	0.00	0.27	0.50	0.09
8	6.43	0.95	0.05	0.22	0.00	0.01	0.25	0.30	0.11

Model 3:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_comm_rdnet + \beta_7 deg_comm_others + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_comm_rdnet + \beta_7 deg_comm_others + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8
1	tot_publications	1							
2	large	0.3186*	1						
3	years	-0.0062	0.4331*	1					
4	areas	0.2959*	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1			
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1		
7	deg_comm_rdnet	0.6134*	0.2094	0.0268	0.3924*	0.0995	0.6226*	1	
8	deg_comm_others	0.0294	0.1292	0.1802	-0.208	-0.0777	-0.5345*	-0.2365	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8
1	tot_patents	1							
2	large	-0.0302	1						
3	years	0.2627*	0.4331*	1					
4	areas	-0.0716	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1			
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1		
7	deg_comm_rdnet	-0.0212	0.2094	0.0268	0.3924*	0.0995	0.6226*	1	
8	deg_comm_others	0.0859	0.1292	0.1802	-0.208	-0.0777	-0.5345*	-0.2365	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 8.14

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	deg_comm _rdnet	deg_comm _others
1	1.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	1.92	0.00	0.18	0.07	0.01	0.07	0.02	0.01	0.02
3	2.30	0.01	0.14	0.01	0.00	0.09	0.02	0.10	0.08
4	3.27	0.02	0.36	0.00	0.02	0.59	0.02	0.05	0.05
5	3.65	0.00	0.21	0.66	0.07	0.00	0.00	0.02	0.18
6	3.90	0.00	0.00	0.12	0.76	0.22	0.00	0.15	0.00
7	4.52	0.07	0.09	0.00	0.12	0.01	0.28	0.51	0.07
8	8.14	0.90	0.00	0.14	0.01	0.00	0.65	0.15	0.59

Model 4:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_comm_rdnet_nac + \beta_7 deg_comm_others_nac + \beta_8 deg_comm_rdnet_int + \beta_9 deg_comm_others_int + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_comm_rdnet_nac + \beta_7 deg_comm_others_nac + \beta_8 deg_comm_rdnet_int + \beta_9 deg_comm_others_int + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8	9	10
1	tot_publications	1									
2	large	0.3186*	1								
3	years	-0.0062	0.4331*	1							
4	areas	0.2959*	0.0839	0.0041	1						
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1					
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1				
7	deg_comm_rdnet_nac	0.5694*	0.1958	0.0443	0.3202*	0.0181	0.5728*	1			
8	deg_comm_others_nac	0.0652	0.142	0.2763*	-0.1906	-0.0592	-0.5415*	-0.1608	1		
9	deg_comm_rdnet_int	0.3448*	0.1128	-0.0526	0.3742*	0.3150*	0.3681*	0.1824	-0.2345	1	
10	deg_comm_others_int	-0.0738	0.0253	-0.1535	-0.1325	-0.0784	-0.2158	-0.1522	0.2674*	-0.1098	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8	9	10
1	tot_patents	1									
2	large	-0.0302	1								
3	years	0.2627*	0.4331*	1							
4	areas	-0.0716	0.0839	0.0041	1						
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1					
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1				
7	deg_comm_rdnet_nac	-0.018	0.1958	0.0443	0.3202*	0.0181	0.5728*	1			
8	deg_comm_others_nac	0.0971	0.142	0.2763*	-0.1906	-0.0592	-0.5415*	-0.1608	1		
9	deg_comm_rdnet_int	-0.0178	0.1128	-0.0526	0.3742*	0.3150*	0.3681*	0.1824	-0.2345	1	
10	deg_comm_others_int	0.0103	0.0253	-0.1535	-0.1325	-0.0784	-0.2158	-0.1522	0.2674*	-0.1098	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 8.43

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	deg_comm_ rdnet_nac	deg_comm_ others_nac	deg_comm_ rdnet_int	deg_comm_ others_int
1	1.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
2	1.88	0.00	0.05	0.03	0.01	0.03	0.01	0.01	0.03	0.08	0.05
3	2.18	0.00	0.22	0.02	0.00	0.07	0.00	0.03	0.01	0.01	0.14
4	2.66	0.00	0.06	0.00	0.00	0.04	0.03	0.17	0.00	0.41	0.00
5	2.77	0.00	0.06	0.11	0.00	0.09	0.00	0.02	0.02	0.05	0.43
6	3.76	0.01	0.50	0.11	0.00	0.53	0.00	0.00	0.01	0.32	0.00
7	3.97	0.00	0.00	0.00	0.68	0.11	0.00	0.23	0.05	0.09	0.01
8	4.49	0.02	0.00	0.24	0.24	0.02	0.15	0.14	0.27	0.02	0.07
9	4.78	0.09	0.11	0.37	0.05	0.10	0.12	0.23	0.12	0.00	0.27
10	8.43	0.88	0.00	0.09	0.00	0.00	0.67	0.16	0.48	0.01	0.02

2.2. Regressions with Weighted Business Network Degree

Model 1:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 \text{wdeg_bus} + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 \text{wdeg_bus} + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7
1	tot_publications	1						
2	large	0.3186*	1					
3	years	-0.0062	0.4331*	1				
4	areas	0.2959*	0.0839	0.0041	1			
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1		
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1	
7	wdeg_comm	0.4239*	0.2490*	0.1233	0.0912	-0.0023	-0.0641	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7
1	tot_patents	1						
2	large	-0.0302	1					
3	years	0.2627*	0.4331*	1				
4	areas	-0.0716	0.0839	0.0041	1			
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1		
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1	
7	wdeg_comm	0.0683	0.2490*	0.1233	0.0912	-0.0023	-0.0641	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables: 6.37

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	wdeg_comm
1	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	1.89	0.00	0.25	0.06	0.01	0.11	0.03	0.00
3	2.91	0.01	0.24	0.21	0.09	0.10	0.19	0.02
4	3.20	0.03	0.34	0.01	0.00	0.71	0.07	0.04
5	3.60	0.01	0.09	0.39	0.28	0.02	0.00	0.27
6	4.02	0.00	0.01	0.10	0.60	0.05	0.46	0.12
7	6.37	0.94	0.05	0.21	0.00	0.01	0.24	0.53

Model 2:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_comm_nac + \beta_7 wdeg_comm_int + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_comm_nac + \beta_7 wdeg_comm_int + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8
1	tot_publications	1							
2	large	0.3186*	1						
3	years	-0.0062	0.4331*	1					
4	areas	0.2959*	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1			
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1		
7	wdeg_comm_nac	0.3873*	0.2145	0.2586*	0.0356	-0.0562	-0.0936	1	
8	wdeg_comm_int	0.1316	0.09	-0.1599	0.0938	0.1115	0.0113	0.0807	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8
1	tot_patents	1							
2	large	-0.0302	1						
3	years	0.2627*	0.4331*	1					
4	areas	-0.0716	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1			
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1		
7	wdeg_comm_nac	0.0759	0.2145	0.2586*	0.0356	-0.0562	-0.0936	1	
8	wdeg_comm_int	0.0104	0.09	-0.1599	0.0938	0.1115	0.0113	0.0807	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 6.46

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	wdeg_comm _nac	wdeg_comm _int
1	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	1.97	0.00	0.24	0.06	0.01	0.10	0.02	0.00	0.00
3	2.73	0.00	0.02	0.07	0.02	0.01	0.02	0.00	0.71
4	2.97	0.01	0.31	0.12	0.10	0.03	0.16	0.07	0.01
5	3.30	0.02	0.21	0.00	0.00	0.74	0.12	0.05	0.00
6	4.02	0.01	0.15	0.12	0.68	0.09	0.17	0.08	0.06
7	4.45	0.00	0.03	0.42	0.18	0.00	0.24	0.48	0.11
8	6.46	0.95	0.04	0.20	0.00	0.02	0.26	0.31	0.09

Model 3:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_comm_rdnet + \beta_7 wdeg_comm_others + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_comm_rdnet + \beta_7 wdeg_comm_others + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8
1	tot_publications	1							
2	large	0.3186*	1						
3	years	-0.0062	0.4331*	1					
4	areas	0.2959*	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1			
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1		
7	wdeg_comm_rdnet	0.5813*	0.1905	0.0251	0.4071*	0.0958	0.6390*	1	
8	wdeg_comm_others	0.0415	0.1439	0.1567	-0.1786	-0.0754	-0.4968*	-0.2317	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8
1	tot_patents	1							
2	large	-0.0302	1						
3	years	0.2627*	0.4331*	1					
4	areas	-0.0716	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1			
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1		
7	wdeg_comm_rdnet	-0.0194	0.1905	0.0251	0.4071*	0.0958	0.6390*	1	
8	wdeg_comm_others	0.0661	0.1439	0.1567	-0.1786	-0.0754	-0.4968*	-0.2317	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 7.87

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	wdeg_comm _rdnet	wdeg_comm _others
1	1.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	1.92	0.00	0.18	0.07	0.01	0.07	0.02	0.01	0.02
3	2.33	0.01	0.14	0.00	0.00	0.10	0.02	0.09	0.09
4	3.26	0.02	0.36	0.00	0.02	0.59	0.02	0.05	0.07
5	3.59	0.00	0.23	0.70	0.01	0.00	0.00	0.00	0.19
6	3.93	0.00	0.00	0.04	0.88	0.21	0.01	0.12	0.00
7	4.59	0.09	0.08	0.01	0.05	0.03	0.27	0.56	0.08
8	7.87	0.88	0.00	0.18	0.00	0.00	0.66	0.17	0.53

Model 4:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_comm_rdnet_nac + \beta_7 wdeg_comm_others_nac + \beta_8 wdeg_comm_rdnet_int + \beta_9 dweg_comm_others_int + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_comm_rdnet_nac + \beta_7 wdeg_comm_others_nac + \beta_8 wdeg_comm_rdnet_int + \beta_9 wdeg_comm_others_int + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8	9	10
1	tot_publications	1									
2	large	0.3186*	1								
3	years	-0.0062	0.4331*	1							
4	areas	0.2959*	0.0839	0.0041	1						
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1					
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1				
7	wdeg_comm_rdnet_nac	0.5556*	0.1916	0.0399	0.3121*	0.0062	0.5636*	1			
8	wdeg_comm_others_nac	0.0544	0.11	0.2526*	-0.1572	-0.0431	-0.5481*	-0.1854	1		
9	wdeg_comm_rdnet_int	0.3507*	0.1167	-0.0494	0.3799*	0.2924*	0.3679*	0.1829	-0.2425*	1	
10	wdeg_comm_others_int	-0.0729	0.0095	-0.1514	-0.1321	-0.0827	-0.2082	-0.1405	0.2600*	-0.107	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8	9	10
1	tot_patents	1									
2	large	-0.0302	1								
3	years	0.2627*	0.4331*	1							
4	areas	-0.0716	0.0839	0.0041	1						
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1					
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1				
7	wdeg_comm_rdnet_nac	-0.0248	0.1916	0.0399	0.3121*	0.0062	0.5636*	1			
8	wdeg_comm_others_nac	0.1284	0.11	0.2526*	-0.1572	-0.0431	-0.5481*	-0.1854	1		
9	wdeg_comm_rdnet_int	-0.0169	0.1167	-0.0494	0.3799*	0.2924*	0.3679*	0.1829	-0.2425*	1	
10	wdeg_comm_others_int	0.0177	0.0095	-0.1514	-0.1321	-0.0827	-0.2082	-0.1405	0.2600*	-0.107	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 8.48

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	wdeg_comm _rdnet_nac	wdeg_comm _others_nac	wdeg_comm _rdnet_int	wdeg_comm _others_int
1	1.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
2	1.89	0.00	0.05	0.03	0.01	0.03	0.02	0.01	0.03	0.09	0.06
3	2.16	0.00	0.23	0.02	0.00	0.07	0.00	0.03	0.01	0.01	0.12
4	2.67	0.00	0.04	0.01	0.00	0.05	0.03	0.20	0.00	0.36	0.00
5	2.75	0.00	0.06	0.10	0.00	0.08	0.00	0.01	0.01	0.11	0.46
6	3.72	0.01	0.53	0.13	0.00	0.51	0.00	0.00	0.01	0.28	0.00
7	4.03	0.00	0.00	0.01	0.74	0.13	0.00	0.23	0.02	0.11	0.00
8	4.43	0.01	0.00	0.27	0.13	0.02	0.14	0.18	0.29	0.03	0.08
9	4.75	0.09	0.09	0.34	0.10	0.11	0.14	0.20	0.11	0.00	0.25
10	8.48	0.88	0.00	0.10	0.00	0.00	0.67	0.13	0.50	0.00	0.02

2.3. Regressions with Social Network Degree

Model 1:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 \text{deg_per} + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 \text{deg_per} + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7
1	tot_publications	1						
2	large	0.3186*	1					
3	years	-0.0062	0.4331*	1				
4	areas	0.2959*	0.0839	0.0041	1			
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1		
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1	
7	deg_soc	0.5029*	0.0743	-0.0593	0.0069	0.1111	0.0564	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7
1	tot_patents	1						
2	large	-0.0302	1					
3	years	0.2627*	0.4331*	1				
4	areas	-0.0716	0.0839	0.0041	1			
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1		
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1	
7	deg_soc	0.0053	0.0743	-0.0593	0.0069	0.1111	0.0564	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables: 4.96

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	deg_soc
1	1.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02
2	1.80	0.00	0.28	0.07	0.01	0.09	0.02	0.00
3	2.30	0.00	0.00	0.01	0.04	0.00	0.01	0.86
4	2.79	0.01	0.18	0.29	0.06	0.18	0.19	0.00
5	3.09	0.05	0.45	0.09	0.00	0.62	0.07	0.01
6	3.76	0.04	0.06	0.00	0.88	0.06	0.30	0.05
7	4.96	0.88	0.03	0.52	0.00	0.03	0.39	0.05

Model 2:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_soc_nac + \beta_7 deg_soc_int + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_soc_nac + \beta_7 deg_soc_int + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8
1	tot_publications	1							
2	large	0.3186*	1						
3	years	-0.0062	0.4331*	1					
4	areas	0.2959*	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1			
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1		
7	deg_soc_nac	0.4563*	0.064	-0.0552	-0.032	0.0695	0.0418	1	
8	deg_soc_int	0.6090*	0.1125	-0.0626	0.2570*	0.3376*	0.1294	0.5606*	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8
1	tot_patents	1							
2	large	-0.0302	1						
3	years	0.2627*	0.4331*	1					
4	areas	-0.0716	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1			
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1		
7	deg_soc_nac	-0.0036	0.064	-0.0552	-0.032	0.0695	0.0418	1	
8	deg_soc_int	0.0611	0.1125	-0.0626	0.2570*	0.3376*	0.1294	0.5606*	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 5.29

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	deg_soc_nac	deg_soc_int
1	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	1.83	0.00	0.20	0.09	0.00	0.05	0.00	0.02	0.06
3	1.99	0.01	0.08	0.00	0.02	0.03	0.04	0.14	0.14
4	2.82	0.04	0.28	0.10	0.07	0.01	0.00	0.25	0.12
5	2.92	0.00	0.01	0.16	0.01	0.35	0.25	0.07	0.03
6	3.62	0.00	0.38	0.13	0.32	0.41	0.03	0.04	0.17
7	4.34	0.00	0.04	0.14	0.53	0.04	0.43	0.29	0.37
8	5.29	0.93	0.00	0.37	0.02	0.08	0.23	0.18	0.10

Model 3:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_soc_rdnet + \beta_7 deg_soc_others + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_soc_rdnet + \beta_7 deg_soc_others + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8
1	tot_publications	1							
2	large	0.3186*	1						
3	years	-0.0062	0.4331*	1					
4	areas	0.2959*	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1			
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1		
7	deg_soc_rdnet	0.6606*	0.1002	-0.125	0.1334	0.1949	0.3918*	1	
8	deg_soc_others	0.3398*	0.0491	-0.0194	-0.0498	0.0536	-0.101	0.4259*	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8
1	tot_patents	1							
2	large	-0.0302	1						
3	years	0.2627*	0.4331*	1					
4	areas	-0.0716	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1			
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1		
7	deg_soc_rdnet	0.0152	0.1002	-0.125	0.1334	0.1949	0.3918*	1	
8	deg_soc_others	0	0.0491	-0.0194	-0.0498	0.0536	-0.101	0.4259*	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 5.54

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_emp	dbf	deg_soc_rdnet	deg_soc_others
1	1.00	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01
2	1.84	0.00	0.24	0.09	0.00	0.06	0.01	0.03	0.00
3	2.04	0.00	0.02	0.01	0.04	0.03	0.01	0.15	0.26
4	2.55	0.01	0.15	0.07	0.01	0.06	0.07	0.16	0.22
5	3.17	0.04	0.27	0.01	0.01	0.75	0.09	0.01	0.03
6	3.44	0.01	0.15	0.34	0.33	0.01	0.00	0.26	0.22
7	4.07	0.12	0.16	0.17	0.58	0.03	0.20	0.21	0.02
8	5.54	0.81	0.00	0.30	0.02	0.04	0.59	0.17	0.23

Model 4:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_soc_rdnet_nac + \beta_7 deg_soc_others_nac + \beta_8 deg_soc_rdnet_int + \beta_9 deg_soc_others_int + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 deg_soc_rdnet_nac + \beta_7 deg_soc_others_nac + \beta_8 deg_soc_rdnet_int + \beta_9 deg_soc_others_int + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8	9	10
1	tot_publications	1									
2	large	0.3186*	1								
3	years	-0.006	0.4331*	1							
4	areas	0.2959*	0.0839	0.0041	1						
5	ln_rdexp_emp	0.0879	-0.239	-0.177	0.2863*	1					
6	dbf	0.1806	-0.068	-0.2566*	0.4098*	0.235	1				
7	deg_soc_rdnet_nac	0.6612*	0.1039	-0.119	0.1261	0.1808	0.3823*	1			
8	deg_soc_others_nac	0.2511*	0.0299	-0.012	-0.1	0.0003	-0.13	0.3246*	1		
9	deg_soc_rdnet_int	-0.024	-0.067	-0.107	0.1259	0.2424*	0.1576	-0.05	-0.0525	1	
10	deg_soc_others_int	0.6298*	0.1255	-0.049	0.2458*	0.3117*	0.1101	0.7428*	0.3723*	0.123	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8	9	10
1	tot_patents	1									
2	large	-0.03	1								
3	years	0.2627*	0.4331*	1							
4	areas	-0.072	0.0839	0.0041	1						
5	ln_rdexp_emp	0.0808	-0.239	-0.177	0.2863*	1					
6	dbf	-0.076	-0.068	-0.2566*	0.4098*	0.235	1				
7	deg_soc_rdnet_nac	0.0164	0.1039	-0.119	0.1261	0.1808	0.3823*	1			
8	deg_soc_others_nac	-0.012	0.0299	-0.012	-0.1	0.0003	-0.13	0.3246*	1		
9	deg_soc_rdnet_int	-0.02	-0.067	-0.107	0.1259	0.2424*	0.1576	-0.05	-0.0525	1	
10	deg_soc_others_int	0.0658	0.1255	-0.049	0.2458*	0.3117*	0.1101	0.7428*	0.3723*	0.123	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 6.66

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	deg_soc_ rdnet_nac	deg_soc_ others_nac	deg_soc_ rdnet_int	deg_soc_ others_int
1	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
2	1.79	0.01	0.08	0.07	0.00	0.01	0.00	0.03	0.02	0.01	0.04
3	1.85	0.00	0.08	0.01	0.01	0.05	0.01	0.02	0.06	0.19	0.01
4	2.29	0.01	0.15	0.00	0.01	0.02	0.02	0.00	0.00	0.58	0.02
5	2.48	0.01	0.10	0.02	0.01	0.01	0.02	0.03	0.50	0.01	0.01
6	3.02	0.00	0.00	0.07	0.00	0.36	0.14	0.01	0.10	0.06	0.06
7	3.57	0.02	0.30	0.38	0.21	0.04	0.01	0.08	0.14	0.04	0.00
8	3.76	0.00	0.28	0.05	0.41	0.40	0.03	0.01	0.00	0.00	0.08
9	5.45	0.88	0.00	0.34	0.06	0.09	0.07	0.04	0.16	0.00	0.13
10	6.66	0.06	0.00	0.04	0.26	0.01	0.70	0.76	0.01	0.10	0.64

2.4. Regressions with Weighted Social Network Degree

Model 1:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 \text{wdeg_per} + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 \text{wdeg_per} + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7
1	tot_publications	1						
2	large	0.3186*	1					
3	years	-0.0062	0.4331*	1				
4	areas	0.2959*	0.0839	0.0041	1			
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1		
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1	
7	wdeg_soc	0.5168*	0.0787	-0.0339	0.0045	0.1388	0.0458	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7
1	tot_patents	1						
2	large	-0.0302	1					
3	years	0.2627*	0.4331*	1				
4	areas	-0.0716	0.0839	0.0041	1			
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1		
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1	
7	wdeg_soc	0.0222	0.0787	-0.0339	0.0045	0.1388	0.0458	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables: 5.00

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	wdeg_soc
1	1.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02
2	1.81	0.00	0.28	0.07	0.01	0.09	0.02	0.00
3	2.38	0.00	0.00	0.01	0.06	0.00	0.03	0.82
4	2.82	0.01	0.20	0.32	0.04	0.16	0.17	0.02
5	3.11	0.05	0.43	0.07	0.00	0.64	0.08	0.02
6	3.80	0.04	0.06	0.00	0.88	0.07	0.30	0.07
7	5.00	0.89	0.03	0.51	0.00	0.02	0.39	0.05

Model 2:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_soc_nac + \beta_7 wdeg_soc_int + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_soc_nac + \beta_7 wdeg_soc_int + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8
1	tot_publications	1							
2	large	0.3186*	1						
3	years	-0.0062	0.4331*	1					
4	areas	0.2959*	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1			
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1		
7	wdeg_soc_nac	0.5039*	0.0934	-0.036	0.0011	0.0755	0.0703	1	
8	wdeg_soc_int	0.5257*	0.0859	-0.0883	0.2371	0.3393*	0.1142	0.5933*	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8
1	tot_patents	1							
2	large	-0.0302	1						
3	years	0.2627*	0.4331*	1					
4	areas	-0.0716	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1			
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1		
7	wdeg_soc_nac	-0.0024	0.0934	-0.036	0.0011	0.0755	0.0703	1	
8	wdeg_soc_int	0.0364	0.0859	-0.0883	0.2371	0.3393*	0.1142	0.5933*	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 5.21

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	wdeg_soc_ nac	wdeg_soc_ int
1	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	1.81	0.00	0.18	0.09	0.00	0.05	0.00	0.02	0.07
3	1.99	0.01	0.09	0.00	0.02	0.04	0.04	0.11	0.13
4	2.89	0.03	0.30	0.26	0.09	0.04	0.10	0.06	0.02
5	2.93	0.02	0.06	0.02	0.00	0.34	0.15	0.23	0.10
6	3.65	0.00	0.32	0.11	0.40	0.39	0.04	0.04	0.15
7	4.42	0.00	0.03	0.13	0.46	0.06	0.41	0.38	0.45
8	5.21	0.93	0.01	0.39	0.01	0.08	0.25	0.14	0.07

Model 3:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_soc_rdnet + \beta_7 wdeg_soc_others + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_soc_rdnet + \beta_7 wdeg_soc_others + \varepsilon$$

Correlation Matrix 1:

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	tot_publications	1							
2	large	0.3186*	1						
3	years	-0.0062	0.4331*	1					
4	areas	0.2959*	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1			
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1		
7	wdeg_soc_rdnet	0.6186*	0.0805	-0.1331	0.1255	0.1872	0.3979*	1	
8	wdeg_soc_others	0.3587*	0.0629	-0.0198	-0.0487	0.0477	-0.0976	0.3998*	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	tot_patents	1							
2	large	-0.0302	1						
3	years	0.2627*	0.4331*	1					
4	areas	-0.0716	0.0839	0.0041	1				
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1			
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1		
7	wdeg_soc_rdnet	0.0133	0.0805	-0.1331	0.1255	0.1872	0.3979*	1	
8	wdeg_soc_others	0.0017	0.0629	-0.0198	-0.0487	0.0477	-0.0976	0.3998*	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 5.44

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	wdeg_soc_ rdnet	wdeg_soc_ others
1	1.00	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01
2	1.83	0.00	0.24	0.09	0.00	0.06	0.01	0.03	0.00
3	2.02	0.00	0.02	0.01	0.03	0.03	0.01	0.14	0.30
4	2.54	0.01	0.14	0.06	0.00	0.08	0.07	0.19	0.24
5	3.17	0.04	0.33	0.02	0.01	0.73	0.08	0.01	0.02
6	3.35	0.01	0.12	0.32	0.31	0.02	0.00	0.27	0.22
7	4.06	0.12	0.14	0.14	0.61	0.02	0.23	0.20	0.02
8	5.44	0.80	0.00	0.34	0.02	0.04	0.59	0.14	0.19

Model 4:

$$tot_publications = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_soc_rdnet_nac + \beta_7 wdeg_soc_others_nac + \beta_8 wdeg_soc_rdnet_int + \beta_9 wdeg_soc_others_int + \varepsilon$$

$$tot_patents = \beta_0 + \beta_1 large + \beta_2 year + \beta_3 areas + \beta_4 \ln_rdexp_emp + \beta_5 dbf + \beta_6 wdeg_soc_rdnet_nac + \beta_7 wdeg_soc_others_nac + \beta_8 wdeg_soc_rdnet_int + \beta_9 wdeg_soc_others_int + \varepsilon$$

Correlation Matrix 1:

		1	2	3	4	5	6	7	8	9	10
1	tot_publications	1									
2	large	0.3186*	1								
3	years	-0.0062	0.4331*	1							
4	areas	0.2959*	0.0839	0.0041	1						
5	ln_rdexp_emp	0.0879	-0.2393	-0.1766	0.2863*	1					
6	dbf	0.1806	-0.0684	-0.2566*	0.4098*	0.235	1				
7	wdeg_soc_rdnet_nac	0.5735*	0.0642	-0.1371	0.0883	0.1781	0.4009*	1			
8	wdeg_soc_others_nac	0.2476*	0.0173	-0.007	-0.1018	0.0065	-0.1458	0.3201*	1		
9	wdeg_soc_rdnet_int	-0.0244	-0.0665	-0.1065	0.1259	0.2424*	0.1576	-0.0599	-0.0556	1	
10	wdeg_soc_others_int	0.5792*	0.1165	-0.0782	0.2247	0.3249*	0.1377	0.7050*	0.3974*	0.141	1

Note: * indicates significance of the relationship at 5% confidence level

Correlation Matrix 2:

		1	2	3	4	5	6	7	8	9	10
1	tot_patents	1									
2	large	-0.0302	1								
3	years	0.2627*	0.4331*	1							
4	areas	-0.0716	0.0839	0.0041	1						
5	ln_rdexp_emp	0.0808	-0.2393	-0.1766	0.2863*	1					
6	dbf	-0.0764	-0.0684	-0.2566*	0.4098*	0.235	1				
7	wdeg_soc_rdnet_nac	0.0121	0.0642	-0.1371	0.0883	0.1781	0.4009*	1			
8	wdeg_soc_others_nac	-0.0149	0.0173	-0.007	-0.1018	0.0065	-0.1458	0.3201*	1		
9	wdeg_soc_rdnet_int	-0.0204	-0.0665	-0.1065	0.1259	0.2424*	0.1576	-0.0599	-0.0556	1	
10	wdeg_soc_others_int	0.0441	0.1165	-0.0782	0.2247	0.3249*	0.1377	0.7050*	0.3974*	0.141	1

Note: * indicates significance of the relationship at 5% confidence level

Condition number using scaled variables = 6.32

Condition Indexes and Variance-Decomposition Proportions:

	condition index	constant	large	years	areas biotech	ln_rdexp_ emp	dbf	wdeg_soc_ rdnet_nac	wdeg_soc_ others_nac	wdeg_soc_ rdnet_int	wdeg_soc_ others_int
1	1.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
2	1.78	0.01	0.10	0.08	0.00	0.01	0.00	0.03	0.01	0.02	0.04
3	1.87	0.00	0.05	0.00	0.01	0.04	0.01	0.02	0.07	0.20	0.02
4	2.29	0.01	0.14	0.00	0.01	0.01	0.02	0.00	0.00	0.54	0.02
5	2.50	0.01	0.13	0.02	0.01	0.01	0.03	0.04	0.43	0.01	0.01
6	3.05	0.01	0.00	0.03	0.00	0.41	0.12	0.02	0.10	0.09	0.07
7	3.52	0.01	0.15	0.34	0.31	0.00	0.00	0.11	0.15	0.03	0.00
8	3.83	0.00	0.41	0.16	0.29	0.39	0.03	0.00	0.03	0.00	0.11
9	5.50	0.86	0.00	0.26	0.09	0.10	0.04	0.08	0.19	0.01	0.20
10	6.32	0.09	0.01	0.08	0.26	0.01	0.74	0.69	0.01	0.10	0.51

APPENDIX 7: ENDOGENEITY TESTS IN CHAPTER 7

This section presents the endogeneity tests carried out for equations of Chapter 7. Following Durbin-Wu-Hausman test, (in Greene, 2000 p.383) a two-step test was conducted to estimate endogeneity in each variable. First a linear estimation was conducted with the endougenous variable as dependent variable. Then the estimated residuals were included in the initial equation as a regressor. If the coefficient associated to the estimated errors is significant different from zero, then there is evidence of endogeneity.

Results for endogeneity test for R&D expenditures does not indicate the presence of endogeneity for this variable. This test was conducted using a Heckman selection model, given the selection to invest on R&D or not. Since the result of the Heckman selection model for R&D does not support the hypothesis of selection bias for R&D, an endogeneity test with linear regression for R&D expenditures was also conducted. Results from both procedures were the same, discarding endogeneity from R&D.

Results for the endogeneyty test of business relations does not support the hypothesis of endogeneity in this variable. In the case of personal relations there is some evidence to indicate that there is endogeneity of this variable. Finally, a correction for this endogeneity is proposed. Unfortunately, there is no command in STATA to implement an instrumental variable regression with negative binomial models, only poisson. Therefore, a second-best correction is presented. A negative binomial model was estimated with the instrumental variable been the estimated prediction of the variable for social relations.

First, the test for endogeneity of R&D is presented, followed by the endogeneity test for business relations, and then by the endogeneity test for personal relations.

Finally, the proposed correction for endogenenity of personal relations variables is presented.

1. Test for Endogeneity of R&D Expenditures

1.1. Test for endogeneity of R&D expenditures on Publications Model

1.1.1. Test for endogeneity of R&D expenditures with Selection Model for R&D activities

Heckman Selection Model for R&D Expenditures

Variables	Coefficient	Robust Std. Error	P-value
Equation for ln_rdexp_emp			
years_ego	-0.026	0.014	0.071
areas_ego	0.212	0.154	0.169
dbf	-0.046	0.733	0.950
_cons	1.749	0.737	0.018
Equation for R&D Selection			
ln_ventas	0.087	0.176	0.620
years_ego	0.075	0.034	0.027
areas_ego	1.182	0.703	0.093
dbf	-0.412	1.023	0.687
_cons	-1.103	1.202	0.359
Coefficients of the model			
/athrho	-0.212	0.370	0.567
/lnsigma	0.725	0.197	0.000
rho	-0.209	0.354	
sigma	2.066	0.406	
lambda	-0.431	0.739	
Model Information			
Number of obs	62		
Censored obs	8		
Uncensored obs	54		
Wald chi2(3)	8.15		
Prob > chi2	0.0429		
Log pseudolikelihood	-130.153		
Wald test of indep. eqns. (rho = 0):			
chi2(1)	0.33		
Prob > chi2	0.5667		

After this estimation with selection bias for R&D expenditures, the residuals of this model were estimated and included in the regressions of Publications and Patents. If the variable of the residual is significant, then there is evidence of endogeneity.

Endogeneity Test for R&D Expenditures with Total Publications as Dependent Variable and Selection Model for R&D

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Model Basic	Model 1 with R&D resid,	Model with business degree	Model 3 with R&D resid,	Model with weighted business degree	Model 5 with R&D resid,	Model with personal degree	Model 7 with R&D resid,	Model with weighted personal degree	Model 9 with R&D resid,
Independent Variables										
large	2.2755***	2.2764***	1.6191**	1.6506**	1.6492**	1.6817**	1.8975***	1.8891***	1.8649***	1.8593***
	(0.4826)	(0.4813)	(0.6639)	(0.6750)	(0.6864)	(0.6953)	(0.5609)	(0.5597)	(0.5671)	(0.5659)
years_ego	-0.0402***	-0.0414***	-0.0325**	-0.0332**	-0.0292**	-0.0303**	-0.0358**	-0.0362***	-0.0355**	-0.0359***
	(0.0144)	(0.0145)	(0.0137)	(0.0139)	(0.0146)	(0.0149)	(0.0142)	(0.0139)	(0.0143)	(0.0139)
areas_ego	0.3925***	0.3832***	0.3299***	0.3297***	0.3178***	0.3187***	0.3827***	0.3758***	0.3797***	0.3735***
	(0.1147)	(0.1161)	(0.1093)	(0.1122)	(0.1084)	(0.1120)	(0.1190)	(0.1188)	(0.1199)	(0.1191)
ln_rdexp_emp	0.3681**	0.3687**	0.4097**	0.4035**	0.4216**	0.4145**	0.2773	0.2712	0.2598	0.2535
	(0.1596)	(0.1559)	(0.1689)	(0.1673)	(0.1686)	(0.1672)	(0.1700)	(0.1650)	(0.1679)	(0.1614)
dbf	1.7793***	1.5583***	1.7247***	1.5859***	1.7830***	1.6351***	1.7057***	1.4205**	1.7509***	1.4633**
	(0.5071)	(0.5786)	(0.5376)	(0.6085)	(0.5404)	(0.6046)	(0.5116)	(0.6022)	(0.5030)	(0.5911)
rd_res		**-1.8992**		**-1.1130**		**-1.1548**		**-2.3192**		**-2.3435**
		(2.8601)		**(2.9862)**		**(2.9649)**		**(2.8584)**		**(2.8206)**
deg_bus_tot			0.0614**	0.0582*						
			(0.0300)	(0.0305)						
w4deg_bus_tot					0.0161*	0.0152*				
					(0.0085)	(0.0087)				
deg_per_tot							0.0229*	0.0247**		
							(0.0117)	(0.0117)		
w4deg_per_tot									0.0106**	0.0114**
									(0.0051)	(0.0051)
_cons	-2.2604***	-0.9856	-2.9490***	-2.1591	-2.9755***	-2.1533	-2.2453***	-0.7074	-2.2794***	-0.7298
	(0.5204)	(2.0188)	(0.6917)	(2.2159)	(0.7144)	(2.2266)	(0.5007)	(1.9622)	(0.4950)	(1.9208)
lnalpha	1.0718***	1.0518***	0.9883***	0.9756***	0.9954***	0.9823***	0.9948***	0.9585***	0.9848***	0.9475***
	(0.2928)	(0.2901)	(0.2923)	(0.2905)	(0.2920)	(0.2900)	(0.3069)	(0.3071)	(0.3042)	(0.3042)
N	66	66	66	66	66	66	66	66	66	66
ll	-95.2163	-95.0261	-94.2056	-94.1387	-94.2925	-94.2206	-94.6214	-94.3163	-94.4943	-94.1769

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

1.1.2. Test for endogeneity of R&D expenditures with Linear Model for R&D activities

Linear Model for R&D Expenditures

Variables	Coefficient	Robust Std. Error	P-value
ln_ventas	-0.191	0.144	0.190
years_ego	-0.007	0.011	0.513
areas_ego	0.283	0.149	0.062
dbf	0.060	0.664	0.928
_cons	2.069	0.951	0.034
Model Information			
Number of obs	62		
F(4,57)	3.05		
Prob > F	0.024		
R-squared	0.158		
Root MSE	2.019		

Endogeneity Test for R&D Expenditures with Total Publications as dependent variable and Linear Model for R&D

	(1) Model Basic	(2) Model 1 with R&D resid,	(3) Model with business degree	(4) Model 3 with R&D resid,	(5) Model with weighted business degree	(6) Model 5 with R&D resid,	(7) Model with personal degree	(8) Model 7 with R&D resid,	(9) Model with weighted personal degree	(10) Model 9 with R&D resid,
Independent Variables										
large	2.2755***	1.8842***	1.6191**	1.4748*	1.6492**	1.5659**	1.8975***	1.4186*	1.8649***	1.3763*
	(0.4826)	(0.6249)	(0.6639)	(0.7644)	(0.6864)	(0.7527)	(0.5609)	(0.7542)	(0.5671)	(0.7562)
years_ego	-0.0402***	-0.0545***	-0.0325**	-0.0460**	-0.0292**	-0.0435**	-0.0358**	-0.0504***	-0.0355**	-0.0502***
	(0.0144)	(0.0176)	(0.0137)	(0.0179)	(0.0146)	(0.0187)	(0.0142)	(0.0163)	(0.0143)	(0.0162)
areas_ego	0.3925***	0.7126***	0.3299***	0.5525**	0.3178***	0.5414**	0.3827***	0.6933***	0.3797***	0.6910***
	(0.1147)	(0.2710)	(0.1093)	(0.2562)	(0.1084)	(0.2703)	(0.1190)	(0.2620)	(0.1199)	(0.2616)
ln_rdexp_emp	0.3681**	-0.6368	0.4097**	-0.2961	0.4216**	-0.2643	0.2773	-0.7370	0.2598	-0.7605
	(0.1596)	(0.6728)	(0.1689)	(0.6678)	(0.1686)	(0.6887)	(0.1700)	(0.6605)	(0.1679)	(0.6654)
dbf	1.7793***	1.8718***	1.7247***	1.8432***	1.7830***	1.8789***	1.7057***	1.8780***	1.7509***	1.9414***
	(0.5071)	(0.5375)	(0.5376)	(0.5526)	(0.5404)	(0.5527)	(0.5116)	(0.5287)	(0.5030)	(0.5165)
rd_res2		**1.1108**		**0.7769**		**0.7451**		**1.1204**		**1.1237**
		(0.7408)		**(0.7162)**		**(0.7374)**		**(0.7010)**		**(0.7023)**
deg_bus_tot			0.0614**	0.0495						
			(0.0300)	(0.0306)						
w4deg_bus_tot					0.0161*	0.0116				
					(0.0085)	(0.0090)				
deg_per_tot							0.0229*	0.0276		
							(0.0117)	(0.0170)		
w4deg_per_tot									0.0106**	0.0129*
									(0.0051)	(0.0074)
_cons	-2.2604***	-1.2610*	-2.9490***	-2.0754**	-2.9755***	-2.0629**	-2.2453***	-1.2706*	-2.2794***	-1.3178*
	(0.5204)	(0.7401)	(0.6917)	(0.9093)	(0.7144)	(0.9580)	(0.5007)	(0.7334)	(0.4950)	(0.7326)
lnalpha	1.0718***	1.1312***	0.9883***	1.0757***	0.9954***	1.0886***	0.9948***	1.0523***	0.9848***	1.0407***
	(0.2928)	(0.2926)	(0.2923)	(0.2917)	(0.2920)	(0.2911)	(0.3069)	(0.3065)	(0.3042)	(0.3041)
N	66	62	66	62	66	62	66	62	66	62
ll	-95.2163	-87.9047	-94.2056	-87.3870	-94.2925	-87.5563	-94.6214	-87.2950	-94.4943	-87.1542

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

1.2. Test for endogeneity of R&D expenditures on Patents Model

1.2.1. Test for endogeneity of R&D expenditures with Selection Model for R&D activities

Results for the selection model for R&D expenditures presented above.

Endogeneity Test for R&D Expenditures with Total Patents as dependent variable and Selection Model for R&D

	(1) Model Basic	(2) Model 1 with R&D resid,	(3) Model with business degree	(4) Model 3 with R&D resid,	(5) Model with weighted business degree	(6) Model 5 with R&D resid,	(7) Model with personal degree	(8) Model 7 with R&D resid,	(9) Model with weighted personal degree	(10) Model 9 with R&D resid,
Variables										
large	-1.1794	-1.1381	-1.0676	-1.0518	-1.1572	-1.1322	-1.7761**	-1.7654**	-1.7373**	-1.7145**
	(0.8323)	(0.8662)	(0.8300)	(0.8531)	(0.8008)	(0.8325)	(0.8633)	(0.8775)	(0.8550)	(0.8699)
years_ego	0.1022***	0.1055***	0.1036***	0.1062***	0.1025***	0.1056***	0.1053***	0.1059***	0.1041***	0.1056***
	(0.0235)	(0.0352)	(0.0239)	(0.0354)	(0.0241)	(0.0352)	(0.0237)	(0.0319)	(0.0236)	(0.0323)
areas_ego	-0.0074	-0.0069	0.0089	0.0074	-0.0033	-0.0056	-0.0095	-0.0094	-0.0077	-0.0077
	(0.1530)	(0.1551)	(0.1706)	(0.1734)	(0.1759)	(0.1787)	(0.1557)	(0.1559)	(0.1556)	(0.1560)
ln_rdexp_emp	0.2920*	0.2803	0.3055*	0.2940	0.2951*	0.2814	0.2184	0.2161	0.2177	0.2125
	(0.1712)	(0.2027)	(0.1761)	(0.2158)	(0.1722)	(0.2093)	(0.1766)	(0.1963)	(0.1786)	(0.1986)
dbf	2.5379***	2.5997***	2.5610***	2.6084***	2.5428***	2.6002***	2.4028***	2.4180***	2.4195***	2.4524***
	(0.6618)	(0.8569)	(0.6644)	(0.8529)	(0.6652)	(0.8550)	(0.6752)	(0.8762)	(0.6744)	(0.8715)
rd_res		**0.6127**		**0.5059**		**0.6033**		**0.1275**		**0.2825**
		(3.4922)		**(3.5716)**		**(3.5087)**		**(2.9491)**		**(2.9822)**
deg_bus_tot			-0.0098	-0.0084						
			(0.0366)	(0.0361)						
w4deg_bus_tot					-0.0006	-0.0002				
					(0.0100)	(0.0099)				
deg_per_tot							0.0237	0.0236		
							(0.0150)	(0.0153)		
w4deg_per_tot									0.0089	0.0088
									(0.0059)	(0.0059)
_cons	-2.2589***	-2.6955	-2.2510***	-2.6129	-2.2566***	-2.6882	-2.2772***	-2.3680	-2.2640***	-2.4652
	(0.7592)	(2.7333)	(0.7520)	(2.7919)	(0.7597)	(2.7580)	(0.7930)	(2.3823)	(0.7893)	(2.4025)
lnalpha	1.7943***	1.7935***	1.7967***	1.7957***	1.7951***	1.7937***	1.7608***	1.7607***	1.7651***	1.7650***
	(0.2306)	(0.2302)	(0.2310)	(0.2307)	(0.2317)	(0.2313)	(0.2365)	(0.2364)	(0.2357)	(0.2355)
N	66	66	66	66	66	66	66	66	66	66
ll	-123.2761	-123.2640	-123.2599	-123.2522	-123.2752	-123.2640	-122.8059	-122.8053	-122.8816	-122.8785

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

1.2.2. Test for endogeneity of R&D expenditures with Linear Model for R&D activities

Endogeneity Test for R&D Expenditures with Total Patents as dependent variable and Linear Model for R&D

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Model Basic	Model 1 with R&D resid,	Model with business degree	Model 3 with R&D resid,	Model with weighted business degree	Model 5 with R&D resid,	Model with personal degree	Model 7 with R&D resid,	Model with weighted personal degree	Model 9 with R&D resid,
Variables										
large	-1.1794	-1.3142	-1.0676	-1.1076	-1.1572	-1.2089	-1.7761**	-2.1090**	-1.7373**	-2.0296**
	(0.8323)	(0.8919)	(0.8300)	(0.8980)	(0.8008)	(0.8571)	(0.8633)	(1.0237)	(0.8550)	(1.0079)
years_ego	0.1022***	0.0986***	0.1036***	0.1007***	0.1025***	0.0996***	0.1053***	0.0949***	0.1041***	0.0948***
	(0.0235)	(0.0267)	(0.0239)	(0.0274)	(0.0241)	(0.0271)	(0.0237)	(0.0266)	(0.0236)	(0.0267)
areas_ego	-0.0074	0.0830	0.0089	0.1406	-0.0033	0.1295	-0.0095	0.1692	-0.0077	0.1551
	(0.1530)	(0.3307)	(0.1706)	(0.3654)	(0.1759)	(0.3842)	(0.1557)	(0.3409)	(0.1556)	(0.3457)
ln_rdexp_emp	0.2920*	0.0160	0.3055*	-0.0351	0.2951*	-0.0386	0.2184	-0.3523	0.2177	-0.2989
	(0.1712)	(0.9565)	(0.1761)	(0.9574)	(0.1722)	(0.9836)	(0.1766)	(1.0883)	(0.1786)	(1.0852)
dbf	2.5379***	2.4846***	2.5610***	2.5154***	2.5428***	2.4986***	2.4028***	2.2405***	2.4195***	2.2830***
	(0.6618)	(0.6636)	(0.6644)	(0.6620)	(0.6652)	(0.6618)	(0.6752)	(0.7010)	(0.6744)	(0.6995)
rd_res2		**0.2218**		**0.2840**		**0.2825**		**0.5082**		**0.4568**
		(0.8398)		**(0.8449)**		**(0.8688)**		**(0.9465)**		**(0.9401)**
deg_bus_tot			-0.0098	-0.0186						
			(0.0366)	(0.0422)						
w4deg_bus_tot					-0.0006	-0.0034				
					(0.0100)	(0.0115)				
deg_per_tot							0.0237	0.0283		
							(0.0150)	(0.0220)		
w4deg_per_tot									0.0089	0.0102
									(0.0059)	(0.0084)
_cons	-2.2589***	-1.9138	-2.2510***	-1.8280	-2.2566***	-1.8296	-2.2772***	-1.5115	-2.2640***	-1.5709
	(0.7592)	(1.2351)	(0.7520)	(1.2231)	(0.7597)	(1.2533)	(0.7930)	(1.4083)	(0.7893)	(1.3943)
lnalpha	1.7943***	1.8572***	1.7967***	1.8600***	1.7951***	1.8597***	1.7608***	1.8199***	1.7651***	1.8263***
	(0.2306)	(0.2348)	(0.2310)	(0.2346)	(0.2317)	(0.2352)	(0.2365)	(0.2439)	(0.2357)	(0.2423)
N	66	62	66	62	66	62	66	62	66	62
ll	-123.2761	-113.6499	-123.2599	-113.6036	-123.2752	-113.6299	-122.8059	-113.2015	-122.8816	-113.2952

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

2. Test for Endogeneity of Business Relations

2.1. Test for endogeneity of Business Relations on Publications Model

2.1.1. Test for endogeneity of Business Degree

Linear Model for Commercial Degree

Variables	Coefficient	Robust Std. Error	P-value
ln_ventas	1.092	0.429	0.014
years_ego	0.004	0.054	0.936
areas_ego	0.463	0.532	0.387
dbf	-0.897	1.544	0.564
rd	1.122	2.845	0.695
_cons	4.161	3.079	0.182

Model Information

Number of obs	62
F(4,57)	2.56
Prob > F	0.038
R-squared	0.141
Root MSE	7.148

Endogeneity Test for Business Relations Degree with Total Publications as dependent variable

	(1) Model with business degree	(2) Model 1 with business degree residuals
Variables		
large	1.6191**	1.4470*
	(0.6639)	(0.7686)
years_ego	-0.0325**	-0.0423***
	(0.0137)	(0.0159)
areas_ego	0.3299***	0.2596**
	(0.1093)	(0.1149)
ln_rdexp_emp	0.4097**	0.4843**
	(0.1689)	(0.1952)
dbf	1.7247***	1.9283***
	(0.5376)	(0.5661)
deg_bus_tot	0.0614**	0.2036*
	(0.0300)	(0.1214)
dbus_res		**-0.1559**
		(0.1200)
_cons	-2.9490***	-4.5772***
	(0.6917)	(1.6053)
lnalpha	0.9883***	1.0724***
	(0.2923)	(0.2914)
N	66	62
ll	-94.2056	-87.2669

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

2.1.2. Test for endogeneity of Weighted Business Degree

Linear Model for Weighted Commercial Degree

Variables	Coefficient	Robust Std. Error	P-value
ln_ventas	4.294	1.658	0.012
years_ego	-0.098	0.201	0.629
areas_ego	1.940	1.814	0.290
dbf	-4.160	5.795	0.476
rd	2.289	11.068	0.837
_cons	15.705	12.081	0.199
Model Information			
Number of obs	62		
F(4,57)	2.22		
Prob > F	0.065		
R-squared	0.140		
Root MSE	25.821		

Endogeneity Test for Business Relations Weighted Degree with Total Publications as dependent variable

	(1) Model with business weighted degree	(2) Model 1 with business weighted degree residuals
Variables		
large	1.6492**	1.5528**
	(0.6864)	(0.7553)
years_ego	-0.0292**	-0.0354**
	(0.0146)	(0.0155)
areas_ego	0.3178***	0.2610**
	(0.1084)	(0.1164)
ln_rdexp_emp	0.4216**	0.4834**
	(0.1686)	(0.1962)
dbf	1.7830***	1.9801***
	(0.5404)	(0.5713)
w4deg_bus_tot	0.0161*	0.0475
	(0.0085)	(0.0314)
w4dbus_res		**-0.0363**
		(0.0321)
_cons	-2.9755***	-4.3044***
	(0.7144)	(1.5875)
lnalpha	0.9954***	1.0874***
	(0.2920)	(0.2909)
N	66	62
ll	-94.2925	-87.4963

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

2.2. Test for endogeneity of Business Relations on Patents Model

2.2.1. Test for endogeneity of Business Degree

Endogeneity Test for Business Relations Degree with Total Patents as dependent variable

	(1) Model with business degree	(2) Model 1 with business degree residuals
Variables		
large	-1.0676	-1.0519
	(0.8300)	(0.8834)
years_ego	0.1036***	0.1038***
	(0.0239)	(0.0264)
areas_ego	0.0089	0.0267
	(0.1706)	(0.1957)
ln_rdexp_emp	0.3055*	0.2667
	(0.1761)	(0.2326)
dbf	2.5610***	2.5511***
	(0.6644)	(0.6570)
deg_bus_tot	-0.0098	0.0002
	(0.0366)	(0.1371)
dbus_res		**-0.0163**
		(0.1391)
_cons	-2.2510***	-2.3344
	(0.7520)	(1.5393)
lnalpha	1.7967***	1.8625***
	(0.2310)	(0.2346)
N	66	62
ll	-123.2599	-113.6381

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

2.2.2. Test for endogeneity of Weighted Business Degree

Endogeneity Test for Business Relations Weighted Degree with Total Patents as dependent variable

	(1) Model with business weighted degree	(2) Model 1 with business weighted degree residuals
main		
large	-1.1572	-1.1778
	(0.8008)	(0.8524)
years_ego	0.1025***	0.1029***
	(0.0241)	(0.0259)
areas_ego	-0.0033	0.0184
	(0.1759)	(0.2009)
ln_rdexp_emp	0.2951*	0.2525
	(0.1722)	(0.2324)
dbf	2.5428***	2.5348***
	(0.6652)	(0.6604)
w4deg_bus_to t	-0.0006	0.0049
	(0.0100)	(0.0359)
w4dbus_res		**-0.0078**
		(0.0376)
_cons	-2.2566***	-2.4574
	(0.7597)	(1.5652)
lnalpha	1.7951***	1.8611***
	(0.2317)	(0.2352)
N	66	62
ll	-123.2752	-113.6519

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3. Test for Endogeneity of Personal Relations

3.1. Test for endogeneity of Personal Relations on Publications Model

3.1.1. Test for endogeneity of Personal degree

Linear Model for Social Degree

Variables	Coefficient	Robust Std. Error	P-value
ln_ventas	0.425	0.567	0.456
years_ego	0.008	0.052	0.876
areas_ego	0.881	0.905	0.335
dbf	0.864	2.290	0.707
rd	-13.705	7.994	0.092
_cons	14.357	7.732	0.069

Model Information

Number of (	62
F(4,57)	1.21
Prob > F	0.314
R-squared	0.120
Root MSE	12.265

Endogeneity Test for Personal Relations Degree with Total Publications as dependent variable

	(1) Model with personal degree	(2) Model 1 with personal degree residuals
Variables		
large	1.8975***	1.8509***
	(0.5609)	(0.5487)
years_ego	-0.0358**	-0.0359**
	(0.0142)	(0.0141)
areas_ego	0.3827***	0.4842***
	(0.1190)	(0.1219)
ln_rdexp_emp	0.2773	0.1422
	(0.1700)	(0.1628)
dbf	1.7057***	1.9085***
	(0.5116)	(0.5017)
deg_per_tot	0.0229*	-0.1688**
	(0.0117)	(0.0691)
dper_res		**0.2066*** **
		(0.0772)
_cons	-2.2453***	-1.0958
	(0.5007)	(0.7059)
lnalpha	0.9948***	1.0130***
	(0.3069)	(0.3131)
N	66	62
ll	-94.6214	-86.9202

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.1.2. Test for endogeneity of Weighted Personal degree

Linear Model for Weighted Social Degree

Variables	Coefficient	Robust Std. Error	P-value
ln_ventas	0.719	1.406	0.611
years_ego	0.060	0.131	0.647
areas_ego	1.831	2.248	0.419
dbf	1.443	5.788	0.804
rd	-28.503	17.358	0.106
_cons	34.485	17.114	0.049

Model Information

Number of (	62
F(4,57)	0.98
Prob > F	0.439
R-squared	0.092
Root MSE	29.203

Endogeneity Test for Personal Relations Weighted Degree with Total Publications as dependent variable

	(1) Model with social weighted degree	(2) Model 1 with social weighted degree residuals
Variables		
large	1.8649***	1.7949***
	(0.5671)	(0.5622)
years_ego	-0.0355**	-0.0313**
	(0.0143)	(0.0143)
areas_ego	0.3797***	0.4951***
	(0.1199)	(0.1213)
ln_rdexp_emp	0.2598	0.1205
	(0.1679)	(0.1619)
dbf	1.7509***	1.9569***
	(0.5030)	(0.4980)
w4deg_per_tot	0.0106**	-0.0911***
	(0.0051)	(0.0325)
w4dper_res		**0.1082*** **
		(0.0367)
_cons	-2.2794***	-0.6820
	(0.4950)	(0.7807)
lnalpha	0.9848***	0.9983***
	(0.3042)	(0.3098)
N	66	62
ll	-94.4943	-86.6526

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.2. Test for endogeneity of Personal Relations on Patents Model

3.2.1. Test for endogeneity of Personal degree

Endogeneity Test for Personal Relations Degree with Total Patents as dependent variable

	(1) Model with personal degree	(2) Model 1 with personal degree residuals
Variables		
large	-1.7761**	-1.6288*
	(0.8633)	(0.8697)
years_ego	0.1053***	0.1057***
	(0.0237)	(0.0246)
areas_ego	-0.0095	-0.0176
	(0.1557)	(0.1796)
ln_rdexp_emp	0.2184	0.3425
	(0.1766)	(0.2408)
dbf	2.4028***	2.3509***
	(0.6752)	(0.7126)
deg_per_tot	0.0237	0.0985
	(0.0150)	(0.0629)
dper_res		-0.0832
		(0.0641)
_cons	-2.2772***	-3.0147***
	(0.7930)	(1.0567)
lnalpha	1.7608***	1.8118***
	(0.2365)	(0.2455)
N	66	62
ll	-122.8059	-112.9243

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.2.2. Test for endogeneity of Weighted Personal degree

Endogeneity Test for Personal Relations Weighted Degree with Total Patents as dependent variable

	(1) Model with social weighted degree	(2) Model 1 with social weighted degree residuals
Variables		
large	-1.7373**	1.7949***
	(0.8550)	(0.5622)
years_ego	0.1041***	-0.0313**
	(0.0236)	(0.0143)
areas_ego	-0.0077	0.4951***
	(0.1556)	(0.1213)
ln_rdexp_emp	0.2177	0.1205
	(0.1786)	(0.1619)
dbf	2.4195***	1.9569***
	(0.6744)	(0.4980)
w4deg_per_to t	0.0089	-0.0911***
	(0.0059)	(0.0325)
w4dper_res		0.1082***
		(0.0367)
_cons	-2.2640***	-0.6820
	(0.7893)	(0.7807)
lnalpha	1.7651***	0.9983***
	(0.2357)	(0.3098)
N	66	62
ll	-122.8816	-86.6526

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4. Correction for Endogeneity of Personal Relations

4.1. Correction for endogeneity of Personal Relations on Publications Model

Correction for Endogeneity of Personal Relations with Total Publications as dependent variable

	(1) Model with personal degree	(2) Model with personal degree estimated	(3) Model with social weighted degree	(4) Model with social weighted degree estimated
Variables				
large	1.8975***	2.3644***	1.8649***	2.3494***
	(0.5609)	(0.4886)	(0.5671)	(0.4900)
years_ego	-0.0358**	-0.0421***	-0.0355**	-0.0382***
	(0.0142)	(0.0138)	(0.0143)	(0.0138)
areas_ego	0.3827***	0.4910***	0.3797***	0.5083***
	(0.1190)	(0.1198)	(0.1199)	(0.1189)
ln_rdexp_emp	0.2773	0.2763	0.2598	0.2757
	(0.1700)	(0.1754)	(0.1679)	(0.1746)
dbf	1.7057***	1.9268***	1.7509***	1.9097***
	(0.5116)	(0.5244)	(0.5030)	(0.5262)
deg_per_tot	0.0229*			
	(0.0117)			
dper_mill		**-0.1747****		
		(0.0764)		
w4deg_per_tot			0.0106**	
			(0.0051)	
w4dper_mill				**-0.0947*****
				(0.0366)
_cons	-2.2453***	-1.2662*	-2.2794***	-0.8310
	(0.5007)	(0.7589)	(0.4950)	(0.8560)
lnalpha	0.9948***	1.1188***	0.9848***	1.1137***
	(0.3069)	(0.3007)	(0.3042)	(0.3008)
N	66	62	66	62
ll	-94.6214	-87.8632	-94.4943	-87.7585

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.2. Correction for endogeneity of Personal Relations on Patents Model

Correction for Endogeneity of Personal Relations with Total Patents as dependent variable

	(1)	(2)	(3)	(4)
	Model with personal degree	Model with personal degree estimated	Model with social weighted degree	Model with social weighted degree estimated
main				
large	-1.7761**	-1.2793	-1.7373**	-1.2628
	(0.8633)	(0.8040)	(0.8550)	(0.8049)
years_ego	0.1053***	0.1050***	0.1041***	0.1034***
	(0.0237)	(0.0249)	(0.0236)	(0.0248)
areas_ego	-0.0095	-0.0041	-0.0077	-0.0082
	(0.1557)	(0.1817)	(0.1556)	(0.1809)
ln_rdexp_emp	0.2184	0.4052	0.2177	0.4070
	(0.1766)	(0.2488)	(0.1786)	(0.2478)
dbf	2.4028***	2.4067***	2.4195***	2.4409***
	(0.6752)	(0.7000)	(0.6744)	(0.7000)
deg_per_tot	0.0237			
	(0.0150)			
dper_mill		**0.0985**		
		(0.0614)		
w4deg_per_tot			0.0089	
			(0.0059)	
w4dper_mill				**0.0470**
				(0.0294)
_cons	-2.2772***	-3.1896***	-2.2640***	-3.3681***
	(0.7930)	(1.0159)	(0.7893)	(1.0944)
lnalpha	1.7608***	1.8242***	1.7651***	1.8254***
	(0.2365)	(0.2415)	(0.2357)	(0.2414)
N	66	62	66	62
ll	-122.8059	-113.0525	-122.8816	-113.0632

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$