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Personal and business networks within Chilean biotech[§]

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ABSTRACT

Agglomerations and proximities between firms are positively related to the creation of knowledge networks and the innovation performance of firms. Despite the long history of the study of proximities, only recently have interactions between multiple proximities and multiple networks been studied with respect to the economic performance of clustered firms. The role of personal relations in the creation of business relations between firms needs to be studied further. This study proposes a framework for the creation of business relations that combines the proximity framework, the strategic alliances literature, and multiplexity of social networks. The study uses a novel dataset on the *ego*-networks of personal relationships between owners or managers and the *ego*-networks of business relations of biotech firms in Chile. It is shown that the existence of previous personal relations between individuals from two organisations positively affects the probability of creating a business relationship between them.

KEYWORDS

Personal relations; business relations; multiplexity; biotech clusters; multiple proximities

1. Introduction

Collaborations between firms have different features depending on the objectives of the collaboration, sectoral factors, environmental features and types of partners. Firms will create formal agreements and collaborations with other firms for various reasons, such as to reduce costs and innovate (Hagedoorn, Link, and Vonortas 2000; Vonortas and Okamura 2009). Collaborations also depend on the types of partners and the objectives and strategic considerations involved in their collaboration, and will change according to the industry type and the level of competition that the partners experience (Gulati 1995; Uzzi 1997; Hagedoorn, Link, and Vonortas 2000; Vonortas and Okamura 2009).

A particular case of intense collaboration between firms is found in clusters. Firms within a cluster tend to collaborate, formally and informally, with one another at greater rates than they do with firms outside the cluster, achieving higher levels of productivity and innovation as a result (Audretsch and Feldman 1996). Different types of proximities between clustered firms have been identified as promoting innovation and knowledge networks in clusters (Boschma 2005; Bouba-Olga et al. 2015; Balland, Boschma, and Frenken 2015).

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Types of collaborations are intertwined within a cluster; there are several types of relations and different types of flows between firms – a process known as 'multiplexity' in Social Network Analysis (SNA) (Kadushin 2012). How different types of relations affect one another need to be studied further; 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; Lawton Smith 2008; Kadushin 2012). For example, personal relations between workers in a cluster are considered informal ties for the firms, while business relations among firms are thought to be formal relations between them.

This article explores the relationship between personal and business relations in the biotechnology[1] sector in four regions of Chile, contributing to the existing literature on the formation of business relations in a cluster. The purpose of this article is to identify how intra-cluster business relations emerge and to assess if the personal network structure in which the cluster is embedded determines the intra-cluster business network structure. In other words, is there a positive relationship between personal and business links? At the outset of this study, it is not clear whether the importance of personal relations in creating a business relation is positive and significant after controlling for other factors relevant to the decision to form a business link.

A cluster is a geographically bounded system with multiple interacting actors (Porter 1998). Collaborations can be studied with SNA because it allows for the identification of relations between actors in a system (Breschi and Malerba 2005; Lawton Smith 2008; Karlsson 2008a). A social network is represented by a set of actors – in this case, firms – and the relations between them (Wasserman and Faust 1994, 20). Relations between actors are defined as links. Through these links, material or non-material resources can be transferred. Social Network Analysis is also suitable to study the effects of different proximities in the generation of collaborations and networks of firms (Bouba-Olga et al. 2015).

Previous studies on biotech cluster relations have mainly used secondary data for the analysis of interactions between clustered firms (Casper 2007; D'Amore, Iorio, and Stawinoga 2010; D'Amore et al. 2013). Data to identify different types of relations between firms in a cluster, and particularly data that identify informal relations such as personal connections, is not publicly available; this gap remains a key problem in studying the interaction between types of relations in a cluster (Breschi and Malerba 2005; Lawton Smith 2008; Karlsson 2008b; Kadushin 2012). This study aims to tackle this issue using primary data to identify the effect of personal links between organisations in the creation and intensity of business links.

The biotechnology sector in Chile is an interesting case for studying the emergence and development of a high-tech sector in a country that mostly specialised in the exploitation of natural resources. The use of biotechnology can increase the productivity of sectors based on natural resources, contributing to higher value added in the products exported and promoting economic growth in emerging economies. The sector started developing in the 1980s; however, it is still in the early stages of development as defined by Feldman (2003). There are four regions in Chile with a higher concentration of companies that account for 90% of biotechnology firms in the country. Data was collected in these four clusters through face-to-face interviews and a survey distributed to CEOs and owners of

[1]Biotechnology is defined 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' (OECD 2009, 9).

biotechnology firms in 2011 and 2013. A multilevel logistic model was estimated to model the creation of business relations, taking the dependence of links within a firm into account (van Duijn, van Busschbach, and Snijders 1999; Snijders and Bosker 2012; Crossley et al. 2015). The probability that a personal relation leads to a business relation was analysed using a two-level multilevel model.

This article contributes to the literature on multiple proximities and multiple networks in clusters of firms. The case study selected, a high-tech cluster in an emerging economy, contributes to the literature on clusters broadening the analysis of proximities, networks and clusters to less researched examples. The results confirm what was suggested in previous research (Geldes et al. 2015; Hansen 2015; Werker, Ooms, and Caniëls 2016), that personal relations are positive and statistically significantly related to the probability of establishing a business relation.

The article is organised as follows: Section 2 summarises the relevant literature and develops the research hypothesis; Section 3 presents the model and the data; Section 4 presents descriptive analysis of the business and personal networks, whereas Section 5 presents the results of the multilevel model estimations, while Section 6 offers some conclusions.

2. The role of personal relations in networks of firms

The economic geography and regional economic literature suggests that a fundamental factor attracting firms to agglomerate, and a cause of success in innovative clusters, is interaction between firms, which generates networking among workers and leads to knowledge diffusion and learning (Audretsch 2003; Breschi and Malerba 2005; Boschma 2005). Recent literature on economic geography, social networks and clusters has provided new insights into the role of geographic closeness and networks in the exchange of resources, particularly knowledge, among clustered firms (Bathelt 2005; Boschma 2005; Giuliani and Bell 2005). Boschma (2005) specifies five types of proximities that are important for knowledge networks and innovation in clusters – geographic, institutional, organisational, cognitive and social – clarifying that it is not only geographic closeness that affects the level of innovation among clustered firms, but other proximities also positively affect collaboration and innovation. From this seminal work, a new stream of literature has emerged focusing on complementarities, substitution and the non-linear effects of proximities on innovation in firms (Huber 2012; Knoben and Oerlemans 2012; Mattes 2012; Hansen 2015). Also, SNA can be integrated into the proximity framework to explore the effects of different proximities and different networks on firms' performance (Massard and Mehier 2009; Balland, Boschma, and Frenken 2015).

In addition, the creation of research and development (R&D) collaborations or formal joint ventures is determined by the features of the partners, economic and strategic considerations, and the features of the industry (Hagedoorn, Link, and Vonortas 2000; Vonortas and Okamura 2009). Therefore, the creation of a business relation between two firms is determined by the specificities of the sector, the strategy of the firm, the effect of different proximities, and the multiple networks and relations in a cluster. Each part of this conceptual framework will be developed further below.

2.1. The determinants of business relations

The reasons why firms or organisations form business relations with others are diverse. Types of collaboration among actors in a cluster usually take many forms, such as user–producer relations, worker mobility, new firm spin-offs, and formal and informal relations (Breschi and Malerba 2005, 3). However, the objectives of these relations differ; for example, cooperation with universities or research centres usually focuses on knowledge creation and innovation, while cooperation with other firms might be used to increase productivity (Belderbos, Carree, and Lokshin 2004; Wolfe, Davis, and Lucas 2005). There are three types of networks between firms in a high-tech cluster: (1) production-oriented networks, where downstream and upstream connections exist; (2) innovation networks, where horizontal links with competitors, universities and research institutions are central; and (3) informal networks, where mainly horizontal social relations emerge (Lawton Smith 2008).

One reason to collaborate in high-tech clusters is to innovate, which usually translates in the creation of research partnerships between firms. Research partnerships are a particular case of strategic alliances (Hagedoorn, Link, and Vonortas 2000), and it is possible to use the theoretical reasons to form research collaborations to discuss the creation of business relationships in general.

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

The transaction cost perspective highlights, as the main driver for collaboration between firms, the role of minimising costs, achieving economies of scale or scope, and avoiding opportunistic market behaviour on the part of the potential partner (Kogut 1988; Hagedoorn, Link, and Vonortas 2000, 2003; Vonortas and Okamura 2009). In this case, geographic proximity reduces the transaction costs of interactions between firms and increases the capacity of each partner to check that the other part is fulfilling the contract, reducing opportunistic behaviour. Personal proximity and social proximity can also reduce the risk of opportunistic behaviour from partners, since there is a social cost of failing to fulfil a contract, including reputational effects or exclusion from certain networks.

Strategic management literature emphasises different reasons for the formation of collaborations. These reasons include entry deterrence, the accumulation of resources, complementary capabilities, the pooling of resources, minimising or sharing costs, transferring knowledge or technology, sharing sources of investment, and changing the positioning of a firm in a strategic network (Hagedoorn, Link, and Vonortas 2000; Vonortas and Okamura 2009). Strategic reasons for forming business relations are present in the case of high-tech clusters, where small firms access greater resources, especially in R&D expenditure, when collaborating with large firms, whereas large firms benefit from the specialised knowledge and technologies available in small firms (Dickson and Weaver 1997, 2011; Hagedoorn, Link, and Vonortas 2000; Stuart, Ozdemir, and Ding 2007). Biotechnology firms tend to collaborate with universities and pharmaceuticals, positioning themselves in a brokerage position between the two (Stuart, Ozdemir, and Ding 2007; Belderbos, Gilsing, and Lokshin 2012). Thus, the features of each partner will shape the type of relationship that two firms create.

The industrial organisation perspective focuses on the sector in which companies are embedded. The way firms compete affects the probability of forming collaborations. Firms competing on price reduction or product differentiation, or firms in a non-tournament setting, will cooperate if they have internalised the existence of positive knowledge spillovers. In tournament competition settings, when firms enter a race to develop a product or technology that might become the main product used in the market, cooperation is unlikely unless it is subsidised by public grants (Hagedoorn, Link, and Vonortas 2000). It has been observed that biotechnology firms in industrialised countries, particularly in biomedicine, compete in a tournament setting to develop new products (Owen-Smith and Powell 2004); the same applies to the Chilean case (Hernández-Cuevas 2007) since the industry is characterised by a 'winner-takes-all' type of competition and, given the small local market, the global market is the main objective for Chilean firms. This implies that collaborations between competitors would not emerge spontaneously, yet collaborations might be more frequent between biotechnology firms and research institutions, for example in order to reduce the cost of conducting research in the company (Stuart, Ozdemir, and Ding 2007; Li et al. 2008; Belderbos, Gilsing, and Lokshin 2012). Since the biotechnology sector in Chile is small and firms face international competition, they might generate business links and develop research collaborations between themselves to reach economies of scale or spread research costs.

Within this conceptualisation of the reasons for creating a relationship between organisations, the characteristics of the partners, the geographic closeness and the environment in which the firms operate are important. However, the relative importance of these different aspects for collaboration depends also on the objective, the timeframe, the environment, and the management of the collaboration (Street and Cameron 2007). Relations with operational purposes, such as sales or distribution, are routine within a firm's activities, and transaction cost determinants might prevail in the decision to create these types of relations. Cooperation in marketing (Geldes et al. 2015) and research and innovation (Hagedoorn, Link, and Vonortas 2003) have been considered strategic collaborations for firms. Although these two types of collaborations have different requirements concerning resources, procedures, timeframe and management of the relation, their long-term objectives are similar regarding the growth and positioning of firms. Social capital and trust have been found to be central to the formation and success of strategic alliances (Ireland, Hitt, and Vaidyanath 2002; Li et al. 2008); therefore, the role of proximities and personal relations on trust and formation of collaborations will be discussed below.

2.2. Multiple proximities

The central role of geographic proximity as a catalyst of innovation, knowledge spillovers and collaborative settings between firms located in the same region or district has been well established in the literature (Balland, Boschma, and Frenken 2015). Yet geographic proximity is not the only important factor in the emergence of business collaborations and shared innovation between firms (Boschma 2005; Knoben and Oerlemans 2006; Huber 2012; Werker, Ooms, and Caniëls 2016).

Boschma (2005) established five levels of proximity that are important for the innovation performance of firms: geographic; cognitive; institutional; organisational; and social. Definitions of these types of proximity have been developed and reformulated by different

Table 1. Definitions of proximities from the literature.

Proximity concept	Definition	Author(s)
Geographical	Spatial proximity. Geographical distance between two organizations.	Boschma (2005)
Institutional	Similar formal and informal institutions (law, norms) at a national or regional level	Boschma (2005)
Organizational	Structure, rules, regulations and culture of organizations	Werker, Ooms, and Caniëls (2016)
Cognitive	Knowledge base of an organization, determined by their absorptive capacities.	Boschma (2005)
Social	Embeddedness of an organization 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).

authors (Boschma 2005; Knoben and Oerlemans 2006; Caniëls, Kronenberg, and Werker 2014; Werker, Ooms, and Caniëls 2016). In some cases, differences between these definitions are significant and produce a lack of clarity about how these proximities can be measured.[2] This definitional ambiguity has led to the inclusion by authors of other forms of proximity to clarify previous concepts and incorporate 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 article are based on Werker, Ooms, and Caniëls (2016), as the most up-to-date research (see Table 1).

Social proximity and personal proximity are the focus of this article. In some studies, social proximity has also been represented as relational or personal proximity (Knoben and Oerlemans 2006), or associated with personal relationships between actors (Balland, Boschma, and Frenken 2015). However, in the definitions presented in Table 1, personal proximity is defined at the level of the individual and it is associated with personal likes and attributes, while social proximity is considered a meso-level dimension and is associated with relations based on trust that emerges from interactions in friendship or professional networks. 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; Crossley et al. 2015). As might be evident, homophily and personal proximity, as defined by Caniëls, Kronenberg, and Werker (2014), are closely related as noted by Werker, Ooms, and Caniëls (2016). The closeness in individual features (personal proximity) can generate a personal relationship between two individuals (through homophily), which in turn affects the social proximity of the two individuals and the social proximity between the two organisations to which they belong.

Several studies have estimated the effect of the different dimensions of proximity on innovation performance or research collaboration. In some studies, the definition of social proximity used refer to interactions between individuals in different organisations (Hansen 2015; Fitjar, Huber, and Rodríguez-Pose 2016), which is close to the definition of a personal relationship between them. In high-tech sectors, previous research has found

[2]It is not intended to provide a detailed review of this aspect of the literature. For detailed reviews on the subject, see Knoben and Oerlemans (2006) and Balland, Boschma, and Frenken (2015).

that personal proximity and social proximity are positively associated with the creation of research collaborations (Broekel and Boschma 2012; Huber 2012; Balland, De Vaan, and Boschma 2013; Boschma, Balland, and de Vaan 2014; Werker, Ooms, and Caniëls 2016). Also, personal and social proximity have a positive effect on innovation outputs (Balland, De Vaan, and Boschma 2013; Boschma, Balland, and de Vaan 2014; Fitjar, Huber, and Rodríguez-Pose 2016). A few other studies have found no statistical significance of social proximity or personal interactions on the emergence of collaborations between organizations (Weterings and Boschma 2009; Balland 2012).

The positive effect of proximities on innovation outputs is usually not linear. Many studies have found greater innovation returns at mid-levels of proximity (Broekel and Boschma 2012; Fitjar, Huber, and Rodríguez-Pose 2016), confirming the existence of a 'proximity paradox' (Balland, Boschma, and Frenken 2015). There might be negative effects at higher levels of proximity (Boschma 2005; Balland, Boschma, and Frenken 2015), like the creation of collaborations with the same partners, limiting generation of new knowledge and reducing innovation outputs (Boschma 2005); which relates to the negative effects of dense social networks in clusters identified by Uzzi (1997).

Personal and social proximities affect clusters in several ways. Ooms and Ebbekink (2015) studied the effect of personal proximities on the governance of three Dutch water clusters. The authors find that high levels of personal proximities in clusters are associated with better governance and growth of clusters. Werker, Ooms, and Caniëls (2016) show that both, personal and social proximity, increase collaboration between Dutch nanotechnology researchers. The authors also find that social proximity helps researchers to identify and develop personal proximity with other researchers, showing that there are high interactions between both types of proximities in the creation of research collaborations. In the case of Chile, a few articles have studied personal interactions and personal proximities in natural resource based clusters. Felzensztein (2008) and Felzensztein, Gimmon, and Carter (2010) studied social networks and collaborative marketing strategies in the salmon cluster in Chile and Scotland, identifying that informal social networking is more relevant than geographic closeness to collaborate in marketing between firms. Giuliani and Bell (2005) studied the Chilean wine cluster using SNA with data collected in surveys. They show that the social structure of the cluster determines knowledge flows, in particular, the informal interactions between oenologists and engineers generate the social structure of the knowledge network. Although these studies did not analyse the formation of relations in the cluster, they show that personal relations are a factor to consider for firms' interactions within clusters. Recently, Geldes et al. (2015) studied the role of different proximities in the generation of marketing cooperation between firms in an agribusiness cluster in Chile. They found that social proximity (identified as a factor of reputation, shared experiences and previous knowledge of partners) is the most relevant factor explaining non-technological collaboration between firms. They also found that geographic proximity did not affect collaborations directly nor did it mediate the effect of other types of proximities on collaboration.

Overall, personal and social proximities seem to positively impact the generation of different types of collaborations (research and marketing collaborations) between firms in different contexts (high-tech vs. low-tech). If we consider that personal proximity and social proximity contribute to the creation of a personal relation between individuals, but that these individuals are part of different firms, then a personal relation is likely to promote a business relation between the firms (Balland, Boschma, and Frenken 2015). This relation

between personal relations and business collaborations is the main argument in this article and will be developed further in the following sections.

2.3. Multiple networks

Previous analysis of relations between firms and actors in a cluster highlights the existence of multiple relations among the same set of actors in a cluster. This has been called 'multiplexity' in the SNA literature. Multiplexity indicates that there are complex simultaneous processes in a network. 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 (Kadushin 2012).

Similar to the analysis of proximities, 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, multiple links could create a conflict of interest in certain circumstances, such as unwanted knowledge leakage, or could even lead to collective action that could reduce benefits for the community. This last consequence is what Uzzi (1996, 1997) has described as the 'over-embeddedness' of a network and applies in particularly to firms embedded in a social structure that underlies the economic structure in which firms interact. The 'over-embeddedness' of a cluster can cause 'lock-in' of knowledge, reducing innovation and leading to the decline of a cluster (Uzzi 1996; Ter Wal and Boschma 2011; Fornahl, Hassink, and Menzel 2015).

It has been difficult to test hypotheses on multiplexity quantitatively given the data available (Kadushin 2012). Porter, 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 do not provide sufficient information to allow us to understand which type of relations sustain other relations over time.

2.4. The role of personal relations

Imagine an investor or a company choosing between two possible partners for a project, both of whom have the same features. If there were no market failures and complete contracts, the investor would have no grounds for a preference for one over the other. However, since there are incomplete contracts and market failures, such as asymmetries of information, the investor needs to take other factors into account to decide which firm to choose as a partner. Ultimately, the investor would decide to collaborate with the firm that has a greater chance of fulfilling the conditions of the contract. This decision might be based on other sources of information, such as personal relations. As Owen-Smith and Powell (2004) conclude in their study of the Boston biotechnology sector, 'formal partnerships between organisations represent the outcroppings of informal personal relationships in a community' (Owen-Smith and Powell 2004, 17). Personal relations can build trust because they give extra information – usually not observable – to each party.[3] Information from previous

[3]For example, many owners of the first generation of biotech firms in Chile continued to teach in different universities. Their former students later created their own companies. These interactions in the academic context would have been likely to inform both parties about the reliability of the other.

personal relations could be important only for initial interactions. Later, the experience of earlier interactions actualises the set of information available to firms.

From the analysis of the literature on proximities, it is possible to say that a personal relation can be observed when personal proximity and social proximity between two individuals is high, which allows us to use the observation of a personal relation as a proxy for the existence of personal and social proximity. In the debate of proximity dynamics between networks of firms presented by Balland, Boschma, and Frenken (2015), social proximity between organisations is generated by the emergence of interpersonal relations between workers. Also, as pointed out by Werker, Ooms, and Caniëls (2016), personal proximities and social proximities are highly related, since social proximity allows individuals to assess the levels of personal proximity that will promote a successful research collaboration. Therefore, the existence of a personal relation between two individuals in different organisations captures the existence of personal and social proximities between them.

This study contributes to the debate surrounding multiple proximities and multiple relations in clusters, by analysing the role of personal relations in the formation of business relations. 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? 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.

Personal relations build trust between owners or CEOs of different companies, which could be fundamental to new business relations (Ireland, Hitt, and Vaidyanath 2002). In biotech, the network of directors is a relevant source of knowledge transfer and diffusion between different biotech firms, facilitating innovation (Cantù, Corsaro, and Tunisini 2015; Crispeels, Willems, and Brugman 2015). Thus, the hypothesis that a personal relation between owners or managers of two organisations will lead to a business relation between those organisations in the case of the Chilean biotech clusters will be tested:

> *Hypothesis*: The presence of a personal relation between members of two different dedicated biotechnology firms (DBFs) increases the likelihood that a business relation will be created between those firms.

3. Methodology and data

3.1. Model specification

A business relation between two companies or organisations will be created and observed only when this relation is expected to generate benefits to both parties. 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 is 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 a business relation to be established between two organisations, this variable must be positive. van Duijn, van Busschbach, and Snijders (1999) show that the use of multilevel models was appropriate to study the frequency of contacts within the social networks in a sample of Dutch people. Based on the multilevel logistic regression threshold model presented in Snijders and Bosker (2012, chap. 17) and in Crossley et al. (2015), a multilevel logistic

model with fixed and random effects will be used, grouping observed 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.

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

Each observation represents a relationship between firm *i* and firm *j*. The sub-index *j* identifies the respondent firms (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 (called *alter* 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.[4] Coefficients of the first level of the model vary over respondent firms or *ego*, and therefore the model includes a random intercept and random slopes for each 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) into Equation (1), it is possible to identify the final multilevel model.

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

However, the variable y_{ij}^{*} is not observed, only a binary variable y_{ij} is observed and takes a value of 1 if a business relation exists between *i* and *j*, and 0 otherwise. Therefore, it is possible to observe a relationship between firms *i* and *j* if the value of y_{ij} is equal to 1, which implies that the net value of that relationship for both firms is positive ($y_{ij}^{*} > 0$). The probability of forming a business relation between two organisations in the cluster will be estimated by considering that links are not independent within a firm, since each relation can affect the probability of creating a new relation and is also affected by the past relations of each organisation (van Duijn, van Busschbach, and Snijders 1999). Assuming that r_{ij} has a logistic distribution, it is possible to write:

$$P\left(y_{ij} = 1\right) = P\left(y_{ij}^{*} > 0\right) \tag{5}$$

$$P\left(y_{ij} = 1\right) = P\left[\left(\gamma_{00} + X_{ij}'\gamma_{10} + Z_j'\gamma_{01} + Z_j'X_{ij}'\gamma_{11} + U_{0j} + X_{ij}'U_{1j} + r_{ij}\right) > 0\right] \tag{6}$$

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

$$P\left(y_{ij}=1\right)=P\left[-r_{ij}<\left(\gamma_{00}+X'_{ij}\gamma_{10}+Z'_{j}\gamma_{01}+Z'_{j}X'_{ij}\gamma_{11}+U_{0j}+X'_{ij}U_{1j}\right)\right] \quad (7)$$

$$P\left(y_{ij}=1\right)=logistic\left(\gamma_{00}+X'_{ij}\gamma_{10}+Z'_{j}\gamma_{01}+Z'_{j}X'_{ij}\gamma_{11}+U_{0j}+X'_{ij}U_{1j}\right) \quad (8)$$

$$logit\left(P\left(y_{ij}=1\right)\right)=\gamma_{00}+X'_{ij}\gamma_{10}+Z'_{j}\gamma_{01}+Z'_{j}X'_{ij}\gamma_{11}+U_{0j}+X'_{ij}U_{1j} \quad (9)$$

Equation (9) identifies the final model in which the log-odds of 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 is a dichotomous variable that takes a value of 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 that are not captured by variables of the *alter* or *ego* firms.

3.2. Case selected

This work follows a case study analysis of the biotechnology sector in four regions of Chile: Metropolitana, Valparaíso, Bío-Bío, and Los Lagos. In recent years, the Chilean government has established policies to promote innovation, cluster formation and growth to increase the productivity and competitiveness of Chilean products. Although these policies subsidise the collaborative projects of firms and research organisations, the policies do not directly consider the role of personal networks in the creation of collaborations. Within this context, biotechnology is considered a sector that could enhance technological upgrading in other areas if the economy, particularly in natural resource-based sectors, increasing the value added to an emerging economy's production and export matrices. It is therefore interesting to study how business relations between firms in knowledge-based sectors emerge in a non-industrialised country context.

Emerging economies have been associated with a large informal sector, low levels of social capital measured by general trust and civic engagement, high costs of starting a formal company, weak formal institutions and low levels of collaborations, which affect the entire economy and particularly the innovation process[5]. Given these features, business relations rely more heavily on trust and personal connections between partners in the context of emerging economies (Ahlstrom and Bruton 2006; Kwon and Arenius 2010; Ding, Au, and Chiang 2015).

[5]See, for example, data from The Enterprise Survey (http://www.enterprisesurveys.org/), the World Value Survey (http://www.worldvaluessurvey.org/), and the OECD Innovation Scoreboard (http://www.oecd.org/sti/scoreboard.htm).

Chile is a country that has reached the status of a high-income economy with a small percentage of the population living in poverty according to the World Bank. The country also has low proportion of informal enterprises in the economy, and the costs for creating a company are relatively low compared to other Latin American countries. The level of reliance in the rule of law is stable and the highest in the region. However, the levels of general trust are low and according to the latest results of the World Value Survey people tend to trust their closest family an friends' networks. Collaboration between firms for innovation is also low according to data from the OECD Innovation Scoreboard.

Therefore, in the case of Chile, there are two opposing visions regarding the importance of personal connections in the creation of business collaborations. On the one hand, given that there are low levels of general trust and low rates of collaboration between firms, it would be expected in the case of Chile that personal relations are highly relevant in the creation of business relations. On the other hand, it could be that personal relations do not have a role in the formation of business collaborations since the economic indicators and development of institutions are strong enough. According to the World Bank, the country experienced high rates of economic growth in the last decades and had stable levels and high reliance on the rule of law. Which effect will predominate is not clear, and therefore the case of Chile can help to identify the role of social institutions in the development of the economy in countries with high economic development but modest levels of social capital.

A clarification about the biotechnology sector is necessary. 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. I will focus on DBFs, since these firms are the core of the biotechnology industry. The relations these DBFs have with all other organisations in the cluster, whether the link is to another DBF or not, are included.

3.3. Data gathering

An original survey was conducted to compile data in four regions in Chile where biotechnology firms are concentrated. The list of firms was collected from the administrative data on biotechnology firms and research centres of the Chilean Economic Development Agency (CORFO), the Association of Biotechnology firms in Chile (ASEMBIO[6]), and web searches. This work generated a national directory of biotechnology and related firms for the Chilean biotechnology sector, identifying four regions where the firms are concentrated, considering these four biotech clusters in the country. All the companies in the directory were contacted for conducting the survey, therefore the rate of response reflects the proportion that declined to participate.

Definitions of personal relations and business relations are crucial to the analysis presented in this article. Business relations were broadly defined and included several types of interaction between firms[7]. The question to identify a business relationship between two

[6]Asociación Chilena de Empresas de Biotechnología.

[7]Some business relations show the direction of the link – supplier and client – yet other relations, such as research partners, could be thought of as undirected. In this study, all types of relations between firms will be considered undirected links.

organisations is: '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.)?' The next question on the survey asked respondents to 'Please specify the type of relationship with each institution', giving the following options for multiple choice: supplier; client; export partner; import partner; research partner; service provider; consultant; and member of a consortium or research centre. Other business relations frequently named were: subsidiary; capital partner for a research project; member of ASEMBIO; and ownership of the company. The survey also asked about the origin of business relations, such as: the personal connections of owners, directors, managers, CEOs or researchers; previous clients or suppliers; previous workers; previous partners in a research project; and partners in other companies. Relations can also have been formed through participation in ASEMBIO.

Information on personal relations between the owners or managers of companies was collected as well. The question to identify a personal relationship between two organisations is: '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?' The next question on the survey asked respondents 'Could you mention the kind of personal relationship?', giving the following options for multiple choice: former university classmates; former professors; former students; former school classmates; family connections; former co-workers; children attending school together; religious settings; political situations; professional relations; friendships; and others. These personal relations could have been created from a business relation or could have led to one. Partial information on the position of the acquaintance in the company mentioned (*alter*) was gathered as well. Summary statistics for the results are presented in the following section.

As stated earlier, the survey focused on four regions of Chile. It was possible to collect information for 90 out of 166 organisations working in the biotechnology field, and for 56 out of 92 DBFs in Chile (see Table 2). The rate of response to the survey was 54% in the biotechnology-related firms and 61% for DBFs (Table 2)[8].

3.4. Description of variables

3.4.1. 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 was 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 was no business relation between them. This variable is self-reported by the interviewee directly when asked about her or his personal relations with others in institutions related to biotechnology. This variable approximates the existence of personal and social proximities between organisations. The estimated coefficient associated

[8]This study focuses on DBFs since within this group the data has high nodal and relational response rates. Results will be representative of DBF firms, and their links with any organisation of the biotech sector in Chile for which I have full information will be considered for the analysis.

Table 2. Rate of responses of the directed and undirected network.

				Survey			
	Cluster	Total possible linkages (undirected)	Total possible linkages (directed)	*N*	Nodal response rate	Relational rate of response (undirected)	Relational rate of response (directed)
Non-biotech firms	16	1568	3136	9	56.3	82.5	56.3
Biotech firms	150	14,700	29,400	81	54.0	79.0	54.0
Non-DBFs	58	5684	11,368	26	44.8	70.0	44.8
DBFs	92	9016	18,032	56	60.9	84.9	60.9
Total	166	13,695	27,390	90	54.2	79.2	54.2

Source: Classification of firms is based on the information provided by ASEMBIO.

with this variable is expected to be positive and statistically significant, showing a strong and positive relation between personal and business relations.

The variable *geographic proximity* captures lower transaction costs when both organisations are geographically close. Relation management implies costs; close proximity could reduce these. The variable is measured as the inverse of the square root of distance in metres,[9] identifying geographic proximity, and is expected to have a positive and significant coefficient.

3.4.2. Features of ego and alter firms

3.4.2.1. Experience generating relations. From the literature on transaction costs, firms with previous experience in collaborations will generate new collaborations at a lower cost (Hagedoorn, Link, and Vonortas 2000; Li et al. 2008). Since the data is a cross-section of the cluster, 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 with previous collaborations, which will increase the probability of creating a business link.

3.4.2.2. Competitors. Additionally, from the discussion in Section 2, 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 (Hagedoorn, Link, and Vonortas 2000). However, in biotechnology there is a tournament research competition and therefore there will be a lower probability of two DBF firms cooperating (Owen-Smith and Powell 2006): 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 first firms established in the country, since the activity of reagent distribution provides 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.

3.4.2.3. Access to foreign markets. For the variables *Alter Exports* and *Ego Exports*, it is expected that if one of the partners exports, there will be a higher probability of generating a business link for strategic reasons to gain access to a new market (Hagedoorn 2002). Exporters might have access to greater markets as well as to newer technologies, frontier knowledge and products. This aspect could be crucial to high-tech firms operating far from the technological frontier in terms of geographic distance and technological capabilities. 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 both firms do not export. The expected sign of the coefficients is uncertain. The same applies to the variables *Alter Foreign* and *Ego Foreign*, which identify firms with at least 10% of foreign capital. Firms with foreign capital have directors or partner companies with access to foreign markets.

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

Nonetheless, multinational firms may have fewer relations with local companies and rely less on social interactions at the local level, 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.

3.4.2.4. Size of organisations. The size of organisations, measured by a categorical variable from 1 to 9 based on the firm's sales,[10] might influence business interactions. It might be the case that small firms prefer to create business relations with large firms for strategic reasons and to gain possible access to capital and knowledge (Dickson and Weaver 1997, 2011; Hagedoorn, Link, and Vonortas 2000; Owen-Smith and Powell 2006). In biotech, it is common to observe collaborations between smaller biotech firms and large pharmaceuticals, since large pharmaceuticals access frontier knowledge, while biotech firms gain access to capital and to possibilities to sell the technology created (Owen-Smith and Powell 2006; Belderbos, Gilsing, and Suzuki 2015). 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 (Cohen and Levinthal 1990). It is not clear which effect would dominate.

3.4.2.5. Knowledge bases. 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 (Cohen and Levinthal 1990) and foreign direct investment (Girma 2005; Girma and Görg 2007). At the moment, there are 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 the new knowledge transferred during the collaboration between firms. 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 between the technology gap and benefits of knowledge transfer. 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[11] 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 different areas within biotech in order

[10]Interviewees were asked directly for the level of sales in 2012. In cases where they did not respond, they were presented with nine categories of sales (with 1 the lowest level of sales, identifying micro-enterprises, and 9 the highest, identifying large firms, according to the classification of the National Statistics Institute in Chile). This categorical variable was selected to maximise the number of observations.

[11]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.

Table 3. Descriptive statistics for variables in the model.

Matrix	Variables	Description	Observations	Mean	SD	Min	Max
Dependent variable							
Y_{ij}	Business	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 R&D 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
$Pers_{ij}$	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 R&D Capacity	1 if ego conducts R&D, 0 otherwise	4488	0.82	0.39	0.0	1.0

Source: Author's survey.

Table 4. Descriptive statistics for firms in the model.

Variables	Observations	Mean	SD	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 R&D 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 R&D Capacity	44	0.82	0.39	0.0	1.0

Source: Author's survey.

to gain access to a wider knowledge base, or that they tend to work with more specialised firms in similar areas of biotech[12]. This is an empirical question to be tested.

3.4.2.6. 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 (Cohen and Levinthal 1990; Boschma 2005) and can be related to cognitive proximities between firms (Boschma 2005; Balland, Boschma, and Frenken 2015). The internal R&D capacities of a firm is proxied by a dummy variable that takes a value of 1 if the firm engages in R&D activities (in-house or outsourced), and 0 otherwise.[13] The significance and sign of these variables depend on the type of business relation. 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 relations.

As a summary, it is expected that variables related to personal relations (as a proxy for personal and social proximities), geographic, cognitive, and organizational proximities are positively related to the probability of generating a business relation, according to the literature on proximities (Boschma 2005; Balland, Boschma, and Frenken 2015). For variables identifying some strategic considerations for alliance formation, such as features of the partner firm, the expected effects are not that clear since they would depend on the industrial organization of the sector, the strategy of the firm, and the type of collaborations firms want to establish.

[12]Alternative variables were tested: a variable for the difference in biotech areas, and a binary variable indicating if the organisations are in the same biotech area. However, to include the areas for both organisations allows testing for different effects between internal and external knowledge bases.

[13]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 least missing values.

Table 5. Features of the business and personal networks.

Business network		Personal network	
Importance of the relation		*Importance of the relation*	
Low importance	27.3%	Low importance	58.8%
High importance	71.7%	High importance	41.2%
Length of the relation		*Length of the relation*	
Average years	8.4	Average years	11.9
Min	1	Min	1
Max	51	Max	44
Types of commercial relations		*Type of social relationship*	
Supplier	25.6%	Former university classmates	0.7%
Client	36.9%	Former school classmates	1.4%
Export partner	0.0%	Family ties	2.0%
Import partner	0.0%	Former co-workers	11.5%
Research partner	23.2%	Former professor	10.8%
Service provider	9.4%	Children go together to school	0.0%
Consultant	4.5%	Religious context	0.0%
Members in a consortium or research centre	0.5%	Political context	0.0%
Capitalist partner in the firm surveyed	0.3%	Trade/industrial association	9.5%
Firm surveyed is partner of firm named	0.9%	Conferences	12.8%
Business Partners of a third firm	0.7%	Professional	8.8%
Trade/industrial association member	0.3%	Friendship	8.8%
Other	3.1%	Former Student	0.0%
		Other	6.8%
How this commercial relationship started?		*The position in the company that your acquaintance has*	
Owner(s) or director personal connections	28.6%	Owner	20.9%
Manager or CEO's personal connections	15.0%	General manager/CEO	20.3%
A researcher's personal connection	6.1%	Commercial manager	4.1%
Previous clients	4.7%	Financial manager	0.7%
Previous partner in a research project	3.7%	Research manager	6.8%
Partner in another company	0.0%	Manager of another department	2.7%
Partner in a consortium	1.0%	Other administrative position	0.7%
Trade/industrial association	1.7%	Researcher	28.4%
They contacted the company	3.0%	Other	3.4%
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.

3.5. 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 3, which shows that just 1% of the observations are business relations, after including only observations for which both institutions, *ego* and *alter*, answered the survey. The low number of positive cases imposes additional challenges for estimation procedures,[14] and therefore estimations by different type of business relation (research versus supplier-client relations) cannot be performed. Table 3 also shows that *ego* variables have lower standard deviations in comparison to *alter* variables, although this analysis considered multiple observations per *ego* since each observation is a relation. Table 4 presents descriptive variables considering only

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

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 *alter*s is almost twice that of *ego*s[15].

4. Collaborations in Chilean biotechnology: descriptive analysis

Descriptive analysis of the relations between organisations in Chilean biotechnology is presented in this section (Table 5). 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 owners, managers or researchers. Similarly, the social network reported that 47% of social links led to a business relation, while 26% of business relations led to a personal relation. 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 personal links are important to understanding the connections made by companies in biotech. 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 biotech is relatively new in the country. In addition, 24% of links are related to research activities. Among the types of research relations are collaborations in publicly funded projects, bilateral and privately funded projects, and collaborations in research with private companies or consortia.

Relations with clients, suppliers and service providers account for 72% of total business relations. There are more client relations than supplier relations registered, given that some of the biotech companies provide reagents produced in 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 the participation in other firms; a total of 2.4% of business relations reported by the organisations involve a capitalist partner 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 (usually a director in a DBF company). The level of 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 reasons. Overall, personal relations between organisations' owners, managers, researchers and previous workers are the principal source (50%) of business links. Another 23% of links emerge as purely motivated by business reasons where one

[15]The correlation matrix (available upon request) shows that most *ego* variables are intercorrelated, as well as *alter* variables, while correlations between *ego* and *alter* variables are low, never higher than 0.47, ruling out a potentially serious problem of multicollinearity in the estimation.

of the parties contacted the other to buy or sell their products, and around 4% of business relations originated from previous research projects.

With respect to personal relations, professional and academic environments are highly important for the creation of such links in biotech. Table 5 shows that 13% of personal relationships started at academic and professional conferences, in line with previous findings of the relevance of scientific conferences for collaboration on nanotech (Werker, Ooms, and Caniëls 2016) and trade fairs in the manufacturing sector (Bathelt and Gibson 2015). Interviewees stressed the importance of national and international seminars and conferences for networking. 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 the latest knowledge in a particular area quickly, but also to assess potential partners for future collaboration (Werker, Ooms, and Caniëls 2016).

Other source of personal relations is university. Relations formed in the university context – with classmates, professors and students – represent 12% of the total. Relations with former co-workers make up 12% of total personal relations, identifying a source of knowledge spillovers within the sector through labour mobility similar to previous research (Broekel and Boschma 2012). These types of relationships are also part of the professional context. Other personal relationships, such as friendships and family ties, represent 11% of total personal relations. Personal relations formed in religious, political or other contexts are unimportant in this high-tech sector.

The majority of personal relations are with researchers (28%), CEOs (20%) or owners (21%) of other companies. The relative importance of researchers in the network reflects the knowledge-based nature of biotechnology. Additionally, this reinforces the weight of professional personal relations, since the network of researchers is closely related to the academic world. Also, the importance of relations between owners reflects a potential network where knowledge can be diffuse (Crispeels, Willems, and Brugman 2015).

In summary, personal relations seem to be 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 is related to the knowledge-based nature of biotechnology.

5. Determinants of collaborations

The previous description of personal and business networks in Chilean biotechnology indicates that it is possible for the personal relations of the sector to determine the business relations to a significant degree. To continue studying the role of personal relations in the creation of business relations in a cluster, a multilevel model was estimated as presented in equation (9). Estimation of the model was conducted in three stages, first the variables related to *alter* firms were included, then the variables of personal relation and geographic proximity were added, finally variables of *ego* firms were included. These estimations were first conducted for all the observations available (Models 1, 2 and 3), pooling the data for all the organisations surveyed in the four clusters studied which includes relations between *egos* and *alter* firms within each cluster and with *alter* firms outside the cluster (in other regions of the country). A second set of estimations were performed but with a restricted

Table 6. Determinants of business linkages in Chilean DBFs. Logistic multilevel model estimations.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Full sample		Full sample		Full sample		Restricted sample same cluster		Restricted sample same cluster		Restricted sample same cluster	
Variables	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Level-one explanatory variables												
Years of Alter	0.04***	0.01	0.04***	0.01	0.04***	0.01	0.05***	0.01	0.04***	0.01	0.04***	0.02
Alter DBF	1.73***	0.42	1.45***	0.50	1.56***	0.53	1.61***	0.41	1.33***	0.51	1.53***	0.54
Alter Foreign	−2.02***	0.48	−1.63***	0.56	−1.34**	0.57	−2.37***	0.57	−1.92***	0.66	−1.74***	0.68
Alter Exports	0.51	0.38	0.48	0.46	0.53	0.47	0.18	0.39	0.25	0.49	0.30	0.50
Alter Areas of Biotech	−0.05	0.09	−0.06	0.11	−0.10	0.11	0.00	0.10	−0.05	0.12	−0.10	0.12
Alter Size	0.22***	0.06	0.15**	0.07	0.12	0.08	0.17***	0.07	0.12	0.08	0.10	0.08
Alter Knowledge Capacity	−1.86***	0.48	−1.37**	0.60	−1.15*	0.63	−1.70***	0.47	−1.24**	0.60	−1.05*	0.63
Geographic Proximity			36.90***	8.89	37.27***	9.83			31.50***	9.25	33.23***	10.32
Personal Relation			3.87***	0.46	3.63***	0.46			3.68***	0.45	3.50***	0.46
Level-two explanatory variables												
Years of Ego					0.02	0.04					0.04	0.04
Ego Foreign					−0.66	0.95					−0.31	0.94
Ego Exports					0.74	0.66					0.58	0.67
Ego Areas of Biotech					0.02	0.17					0.04	0.17
Ego Size					−0.17	0.13					−0.28**	0.14
Ego Knowledge Capacity					0.25	1.23					0.55	1.22
Intercept	−7.16***	0.70	−7.46***	0.69	−7.22***	1.32	−6.10***	0.66	−6.69***	0.69	−6.92***	1.32
$\hat{\sigma}_u^2$	4.58	1.91	1.80	0.84	1.08	0.63	3.38	1.51	1.63	0.79	0.91	0.56
Number of observations	3940		3940		2529		2285		2285		1767	
Number of groups	56		56		39		55		55		38	
Average observations per group	70.4		70.40		64.80		41.50		41.50		46.50	
Deviance information criterion (DIC)	481.42		355.05		309.85		421.34		313.70		280.91	

(*Continued*)

Table 6. (*Continued*).

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Full sample		Full sample		Full sample		Restricted sample same cluster		Restricted sample same cluster		Restricted sample same cluster	
Variables	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Chi-square test (LR test vs. logistic regression)	86.05		28.49		13.75		63.29		25.34		10.91	

Note: Robust Standard Errors presented.
*Significant at 10%; **Significant at 5%; ***Significant at 1%.

sample (Models 4, 5 and 6), considering only the relations between *egos* and *alter* firms within each cluster[16].

Estimation results from different specifications (Table 6) indicate that there is a positive and significant relation between personal and business links for the general sample, and within each cluster.[17] Overall, results for the total sample and for the restricted sample of the clusters are highly similar, which suggest that relations within a cluster are the main source of business interactions.[18]

5.1. Strategic alliances

Strategic considerations, such as gaining access to new resources and complementarities, were tested by including dichotomic variables on the features of organisations. The results show that the experience of the *alter*, measured by the age of the firm, affects positively and significantly the probability of creating a business relation, as expected. This is not the case for the experience of the *ego* firm, however. Similarly, the size of *alter* firms is positively related to the probability of generating a business relation, while the size of *ego* firms is negatively, but not significantly, associated with the creation of a business link when considering all relations. When considering only relations within the cluster, the size of the ego firm becomes significant, indicating that within a cluster larger firms tend to generate fewer collaborations, while smaller firms tend to collaborate more within a cluster. These results confirm the idea of strategic complementarities for business relations (Hagedoorn, Link, and Vonortas 2000) where smaller firms tend to collaborate more in search of complementarities, while larger firms can conduct more activities within the firm. This is a behaviour observed in the biotech clusters in developed economies where smaller biotech firms tend to collaborate with bigger firms (Powell, Koput, and Smith-Doerr 1996; Owen-Smith and Powell 2006; Lawton Smith 2008; Belderbos, Gilsing, and Lokshin 2012).

Nevertheless, the variables age and size could be also capturing other features of the organisations, such as reputation effects. If older or bigger firms are considered more relevant players in the clusters, they can attract more potential collaborators. Reputation of firms can also be related to other variables as well, such as access to larger markets and the technology developed, for example. Reputation is a path dependence feature of actors and can be a relevant factor when considering potential collaborators, however, it is difficult to measure and can be related to several aspects of the firm. The cross-section nature of the data does not allow the inclusion of previous relations as a direct measure of experience in collaboration or reputation effect. Certainly, future research could advance the analysis including a direct measure of the reputation of firms.

There is no evidence that access to external markets, estimated by the export behaviour of the *alter* or *ego* firm, affects the probability of observing a business relation in the Chilean biotech clusters. The other variable related to access to foreign knowledge and markets is captured in the variables *Alter Foreign* and *Ego Foreign*. If the *alter* is a foreign company,

[16]It was not possible to compare estimations between intra-and extra-clusters relations, since the number of positive cases of business and personal relations outside the clusters were low for estimating a differentiated model.

[17]Several specifications were estimated, but only the most relevant models are presented. Other specifications with random slopes of *ego* variables were estimated, but these results and models did not perform better. The results of these models are available upon request.

[18]The results of a chi-squared test between the multilevel logistic model and a logistic regression (without considering the clustered nature of the data), show that multilevel estimations are preferable given the data structure.

there is a significantly lower probability that DBF firms in a cluster will generate a business relation with them. It is possible, as discussed above, that foreign firms could have fewer personal and business relations in the biotech sector in Chile. This result indicates that foreign firms might be relatively isolated in the business network of the clusters, or it can also be the case that foreign firms are relatively new in the clusters. Giuliani (2007) found that connections in the knowledge network of the wine cluster in Chile depend more on the age than on the foreignness of firms. Foreign firms established for a long time in a cluster could be as well connected as local firms.

In terms of the results for the variables of *ego* firms, none of these variables are significant at the national level, except for the size of the *ego* firm in clusters. This could be explained by the similar features of *ego* firms, all of them are DBF firms and they have less variability in their descriptive variables. This leads to the conclusion that for a DBF, the features of the partner are important when creating a business relation. It might also suggest that DBFs have similar strategies for business relations in the country and in the clusters.

5.2. Proximities

Analysing the results from the proximity framework, the results are varied. If the *alter* is a DBF, there is a higher probability of generating a business relation, identifying a potential positive effect of organisational proximity, similar to previous results (Balland 2012; Broekel and Boschma 2012; Werker, Ooms, and Caniëls 2016). However, if the *alter* organisation conducts R&D, this reduces the probability of a business relation. Both results combined may suggest that DBF firms tend to collaborate between them but not for research purposes. This is in line with the industrial organisation perspective that in certain sectors the way firms compete may not encourage collaboration between firms. In biotechnology, the tournament competition between DBFs (Owen-Smith and Powell 2004; Hernández-Cuevas 2007) makes collaboration for R&D purposes less likely, which is confirmed in the findings of this article. Within the clusters, there is suggestive evidence that collaboration between a DBF and a firm that does R&D could be relatively more probable, since the coefficients of the variable *Alter Knowledge Capacity* have a lower absolute value.

Also, the coefficient for the variable of number of biotechnology areas in which the *alter* firms work, as a proxy for cognitive proximity, is negative and non-significant. This result is similar to the results Balland (2012) found for the Global Satellite System industry in Europe. Also, Geldes et al. (2015) did not find a direct effect of cognitive or organisational proximities on the creation of marketing cooperation between firms in an agricultural cluster in Chile. *Ego* firms that work in more sub-areas of biotech tend to generate business collaborations (although results are not significant), but these firms may collaborate with other firms specialised in an area.

In terms of geographic proximity, since the variable is defined as the inverse of the square root of the linear 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, in line with the perspective that geographic proximity is important for collaboration between firms (Boschma 2005; Balland 2012; Broekel and Boschma 2012; Hansen 2015).

Finally, personal relations are positively and significantly associated with the probability of observing a business relation, confirming the results obtained in previous literature on personal and social proximities (Balland, Boschma, and Frenken 2015; Geldes et al. 2015;

Hansen 2015; Werker, Ooms, and Caniëls 2016). This result support the argument that personal and social proximities that lead to a personal relation between individuals in different organisations can, in turn, be the base for generating business relations in clusters, but questions arise regarding a potential differential effect depending on sector specifics and types of collaborations observed.

From this result, it is also possible to determine that different types of relations between firms in a cluster affect one another, as was expected by the multiplexity of networks in a system. Theoretically, personal relations and business relations could influence one another (Kadushin 2012; Borgatti, Everett, and Johnson 2013; Crossley et al. 2015). This can generate an endogeneity problem in the estimation procedure. The variable that identified personal relations was chosen to minimise any potential endogeneity since it only considers cases where the personal relation occurred before the formation of a business relation and cases where there is only a personal relation between firms. To verify this, an endogeneity exercise was conducted.[19] The results of this procedure, suggest that there is no strong evidence in favour of endogeneity between the variables used for business and personal relations. However, it is possible that endogeneity still exists between personal and business relations, although it cannot be tested using the available data.

Overall, there is evidence in favour of the hypothesis of this article, showing that personal relations are a significant factor for the creation of business relations, even when controlling for other proximities and partners' features.

6. Conclusion

This article studied the significance of personal connections in the formation of formal business relations between actors in four biotech clusters of Chile. 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, Link, and Vonortas 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; Balland, Boschma, and Frenken 2015; Bouba-Olga et al. 2015). In particular, personal and social proximities generate personal relations between individuals that affect research collaborations between them (Ooms and Ebbekink 2015; Werker, Ooms, and Caniëls 2016). Finally, from the SNA perspective, there are multiple relations that affect one another in a cluster (Giuliani and Bell 2005; Boschma and ter Wal 2007; Kadushin 2012). It is expected that personal relations between individuals will increase trust and reduce information asymmetries, increasing the probability that a formal business relation between firms will be generated. Although the literature acknowledges the importance of the interactions between different proximities and relations to the innovation outcomes of clustered firms, the effect of informal relations, such as personal connections, on the creation of formal business relations in a cluster has been considered a relevant venue of study (Boschma and Fornahl 2011).

This article contributes to the debate on multiple proximities and multiple relations within high-tech clusters in an emerging economy. By using a novel dataset of primary

[19]There is no direct way of testing endogeneity in the cases where the dependent variable and the endogenous variable are dichotomic. Following Nichols (2011), a bivariate probit was estimated and testing for endogeneity was approximated by testing for the significance of the covariance of the errors of both equations.

information about the relations between managers and owners of firms, it was possible to measure personal links directly and estimate their importance in formal collaborations between firms. To study the relationship between personal and business links, quantitative data was collected regarding the different relations between firms in four biotechnology clusters of Chile. By collecting primary data on personal relations in a cluster, the article uses information of relations between individuals that are usually not observable from secondary data. This allows the identification of more accurate information regarding personal relations. The probability of creating a business relationship was estimated using a multilevel logistic model suitable for assessing the non-independence of observations present in social network data. The results suggest a positive and highly significant relationship between personal and business relations in high-tech clusters in the context of an emerging economy, confirming the conclusions from previous studies on personal and social proximities in clusters (Caniëls, Kronenberg, and Werker 2014; Ooms and Ebbekink 2015; Werker, Ooms, and Caniëls 2016). Personal relations can overcome certain problems when generating new collaborations between firms – such as transaction costs, monitoring costs, or information asymmetries – generating trust between two organisations. Personal relations can therefore be considered an important resource in the creation of links between firms.

The study of a high-tech cluster in an emerging country like Chile provides an interesting case to analyse the importance of personal and social proximities for economic interactions, in a context where general levels of social capital, civic engagement and trust are relatively low compared to industrialised contexts. Compared to other countries in Latin America, Chile has high levels of income per capita and its institutions are highly grounded on the rule of law. Despite the relative stability of the economic indicators in the country, the evidence suggests that personal relations provide additional information of firms in the market that it is useful for the generation of business relations between organisations.

These results have a negative side. Given that personal relations within the cluster are important for the creation of business linkages between firms, it might be that clusters show a lock-in of knowledge in the long-term, which may lead to the creation of business cliques. If this is the case, firms not only face difficulties in terms of R&D uncertainties and financial restrictions, but also must access the 'right' social network if they are to grow. The long-term impacts of an over-reliance on personal and social proximities in clusters is described in Boschma (2005) and Ooms and Ebbekink (2015), showing that when personal and social proximities are too strong firms tend to generate cliques. These cliques get trapped in old strategies which are detrimental for the generation of new knowledge and the growth of clusters and their firms. These findings support the notion that there are drawbacks in terms of personal relations for cluster growth, in line with Uzzi (1996, 1997) and Boschma (2005). In countries where there are low levels of social capital and trust, there is a higher reliance on personal connections for the creation of business and business relations (Ahlstrom and Bruton 2006; Kwon and Arenius 2010; Ding, Au, and Chiang 2015). The evidence presented in this article suggests that clusters in these contexts may be more susceptible to negative effects of over-reliance in personal relations and knowledge lock-in.

Some limitations of this study allow for the identification of further research that will expand our knowledge of multiple proximities and multiple relations in clusters. This study has concentrated on the effect of one type of relation on the emergence of other type of

relation in clusters. Future studies can go further and estimate the multiple impacts of different types of relations on the growth of firms, clusters, and regions. Also, it was not possible to assess in this study the differential effect of personal relations on different types of business relations. For example, trust has usually played an important role in the creation of strategic collaborations such as research and marketing collaborations (Ireland, Hitt, and Vaidyanath 2002; Werker, Ooms, and Caniëls 2016; Geldes, Felzensztein, and Palacios-Fenech 2017); personal relations could therefore be more relevant in the emergence of these relations than in others. Also, the differential effect of personal and social proximities cannot be disentangled when using personal relations, since it contains the effects of both types of proximities. Further research should identify different indicators to be used in quantitative analysis of multiple proximities in clusters.

Additionally, the cross-section nature of the data does not allow the identification of dynamic features of collaboration that may emerge between firms, nor the potential differential effect of proximities through time. Longitudinal data would be required to conduct further analysis of the evolution of multiple relations and networks of firms and how this affects cluster evolution overall. There still scope to study the co-evolution of several networks of firms and their effects on local outcomes, such as innovation rates, productivity, and employment (Balland, Boschma, and Frenken 2015). Furthermore, longitudinal data would make it possible to test for changes in common institutions, such as the creation of firm associations, policies, and subsidies.

Implications for public policies regarding cluster development or regional economic development might consider these results when designing instruments to promote collaborations between firms. Policies promoting these collaborations should consider the importance of personal connections between individuals (entrepreneurs, CEOs, managers, scientists, etc.) and understand that these relations will shape, to a certain extent, the formal collaborative network. Therefore, if the policy objective is to increase collaborations and knowledge diffusion throughout a cluster, social activities to promote personal connections between the owners, managers and researchers in a cluster can be considered as a way of complementing traditional grants to enable new formal collaboration.

In Chile, as in many emerging and developed economies, there are public programmes that subsidise collaborative research and innovation projects among different organisations. Usually, the role of the public agencies is passive, in the sense that they receive the applications of associative projects presented by a group of firms and entities that usually known each other, but they do not actively promote the generation of new collaborations. Given the results provided in this article, previous literature on personal and social proximity, and literature on research collaboration in high-tech sectors (Huber 2012; Hansen 2015; Ooms and Ebbekink 2015; Werker, Ooms, and Caniëls 2016); there is a tendency to create collaborative projects with institutions previously known, where personal proximity, social proximity and trust between the partners already exists. 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 before. If governments want to promote the generation of new knowledge and the creation of disruptive innovations by promoting collaborative projects, then the design of public instruments needs to take into consideration the interplay between different types of proximities and previous relations since they can shape the outcome of these policies.

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