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The micro-determinants of meso-level learning and innovation: evidence from a Chilean wine cluster

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Abstract

Most analyses of the relationship between spatial clustering and the technological learning of firms have emphasised the influence of the former on the latter, and have focused on intra-cluster learning as the driver of innovative performance. This paper reverses those perspectives. It examines the influence of individual firms' absorptive capacities on both the functioning of the intra-cluster knowledge system and its interconnection with extra-cluster knowledge. It applies social network analysis to identify different cognitive roles played by cluster firms and the overall structure of the knowledge system of a wine cluster in Chile. The results show that knowledge is not diffused evenly 'in the air', but flows within a core group of firms characterised by advanced absorptive capacities. Firms' different cognitive roles include some—as in the case of technological gatekeepers—that contribute actively to the acquisition, creation and diffusion of knowledge. Others remain cognitively isolated from the cluster, though in some cases strongly linked to extra-cluster knowledge. Possible implications for policy are noted.

Keywords: Clusters; Absorptive capacity; Knowledge communities; Technological gatekeepers

1. Introduction

Over the years, the literature on industrial clusters has emphasised their capacity as loci for knowledge diffusion and generation. Industrial clusters, which are defined here as geographic agglomerations of economic activities that operate in the same or interconnected sectors,[1] have for this reason been considered a source of dynamic endogenous development and have received increased attention in both the academic and

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[1] This definition both differs from and overlaps with the numerous expressions adopted in the literature to analyse similar economic phenomena, such as industrial districts, localised production systems, technology districts, milieux, etc. (for different definitions, see among others Becattini, 1989; Humphrey and Schmitz, 1996; Markusen, 1996; Porter, 1998; Capello, 1999; Altenburg and Meyer-Stamer, 1999; Cassiolato et al., 2003).

policy arenas. The importance of clustering for knowledge diffusion and generation was seminally stressed by Alfred Marshall, who introduced the concept of 'industrial atmosphere' (Marshall, 1919) and described the district as a place where "mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them, unconsciously" (Marshall, 1920, p. 225).

Following this seminal contribution, later scholars have emphasised the importance of localised knowledge spillovers for innovation, due primarily to the fact that firms in industrial clusters benefit from the availability of a pool of skilled labour and that, mainly due to geographical and social proximity, new ideas circulate easily from one firm to another promoting processes of incremental and collective innovation (see among many others: Becattini, 1989; Asheim, 1994; Saxenian, 1994; Audretsch and Feldman, 1996; Maskell and Malmberg, 1999; Belussi and Gottardi, 2000; Baptista, 2000).

At the same time, other contributions have stressed the importance of extra-cluster networking, since the mere reliance on localised knowledge can result in the 'entropic death' of the cluster that remains locked-in to an increasingly obsolete technological trajectory (Camagni, 1991; Grabher, 1993; Becattini and Rullani, 1993; Guerrieri et al., 2001; Cantwell and Iammarino, 2003).

Increasing attention has been given to the influence of clustering on industry learning and competitive performance in developing countries, the context of this study (Humphrey and Schmitz, 1996; Nadvi and Schmitz, 1999; Rabellotti, 1999; Cassiolato et al., 2003). Within this, emphasis has been given to the internal characteristics of clusters: the spatial agglomeration of firms and the derived external economies, together with various forms of 'joint action'. However, the 'openness' of cluster knowledge systems and their capacity to interconnect with extra-cluster sources of knowledge seems especially important in such technologically lagging regions, industries or countries (Bell and Albu, 1999).

This paper contributes to this field of study by considering, on the one hand, the linkages that clusters establish with extra-cluster sources of knowledge; on the other, by trying to go beyond the received Marshallian 'knowledge in the air' idea of intra-cluster learning processes. In addressing these two issues, the paper joins other recent work in questioning the emphasis on spatial proximity that has come to characterise much of the literature about knowledge flows and technological learning in clustered production activities.

With respect to the first issue, extra-cluster linkages, the paper shares with recent work a sceptical view of the commonly presumed close relationship between functional, relational and geographical proximity. As emphasised by Malmberg (2003), for instance, there is no reason why learning processes should be territorially bounded, and both "local and global circuits of interactive learning" are likely to be important (p. 157). More broadly, Amin and Cohendet (2004) have recently highlighted the distinction between relational and spatial proximity as different contexts for learning, with the latter no more likely than the former to shape learning processes: ". . . relational or social proximity involves much more than 'being there' in terms of physical co-location . . . Crucially, if the sociology of learning is not reducible to territorial ties, there is no compelling reason to assume that 'community' implies spatially contiguous communities, or that local ties are stronger than interaction at a distance" (p. 93).

On the second issue, intra-cluster learning, we share with recent literature a scepticism about the role of fuzzy social relationships and ill-defined spillover mechanisms as the basis of knowledge flows and learning processes within territory-bounded communities. Consequently, like several others (e.g. Dicken and Malmberg, 2001; Malmberg and Maskell, 2002; Amin and Cohendet, 2004), we search for more structured mechanisms that shape these flows and processes. However, we pursue this search in somewhat different directions. We do not examine meso-level structures (e.g. cluster labour markets, as suggested by Malmberg, 2003). Instead, like Owen-Smith and Powell (2004), we focus on characteristics of the nodes in networks as influences on the structure of knowledge flows. But rather than the organisational and institutional characteristics of network nodes, we examine their cognitive characteristics. In particular, the paper focuses on micro-level (firm-centred) knowledge endowments and analyse how these influence the formation of intra- and extra-cluster knowledge networks.

The study has been based on empirical evidence collected at firm level in a wine cluster in Chile (Colchagua Valley). Inter-firm cognitive linkages and relational data have been processed through social network analysis (Wasserman and Faust, 1994) and graph theoretical indicators.

The paper is structured as follows: in Section 1, we review some of the outstanding questions in this field, outline the theoretical framework and formulate the hypotheses for research. Section 2 introduces the case study cluster in Chile in the context of recent developments in the international wine industry. Section 3 explains the methodology applied in the research; and Section 4 presents the empirical evidence. A concluding discussion is provided in Section 5, with comment on the possible policy implications.

2. Research questions and theoretical framework

2.1. External openness and the concept of cluster absorptive capacity

The degree of openness of a cluster is inevitably tied to the degree of extra-cluster openness of its member firms and institutions. At a meso level of analysis, we define *cluster absorptive capacity* as the capacity of a cluster to absorb, diffuse and exploit extra-cluster knowledge (Giuliani, 2002).[2] The focus of this study is specifically on firms' abilities to access and absorb external knowledge. However, external knowledge lies not merely outside the firm, as with Cohen and Levinthal (1990) absorptive capacity, but it lies outside both the firm *and* the Colchagua cluster. Consequently, we use external knowledge and extra-cluster knowledge interchangeably.

It is argued here that firms are heterogeneous in their capabilities and knowledge bases (Dosi, 1997) and, therefore, they are likely to play different roles in interfacing between extra- and intra-cluster knowledge systems. At the micro level, absorptive capacity is considered a function of the firm's level of prior knowledge (Cohen and Levinthal, 1990). It, therefore, reflects the stock of knowledge accumulated within the firm, embodied in skilled human resources and accrued through in-house learning efforts. Consequently, it is defined here independently of any linkages with external sources of knowledge.[3] So, following the argument of Cohen and Levinthal, it is firms with higher absorptive capacities in a cluster that are more likely to establish linkages with external sources of knowledge. This is explained on the basis of cognitive distances between firms and extra-cluster knowledge, so that firms with higher absorptive capacities are considered more cognitively proximate to extra-cluster knowledge than firms with lower absorptive capacities. From this, the first hypothesis is elaborated:

Hypothesis 1. Firms with higher absorptive capacity are more likely to establish knowledge linkages with extra-cluster sources of knowledge.

From this, it would follow that a cluster does not absorb external knowledge *uniformly* through all its constituent firms, but selectively through only those firms with a low cognitive distance from the technological frontier. Interestingly enough, firms with high external openness could be potentially fruitful at local level if they contribute to the diffusion of acquired knowledge to other firms in the cluster, and perform as technological *gatekeepers* (Allen, 1977; Rogers, 1983; Gambardella, 1993). Accordingly, we expect that firms perform different cognitive roles, according to their knowledge bases, in interfacing with extra- and intra-cluster knowledge.

2.2. Firms' absorptive capacity and the intra-cluster knowledge system

Several contributions in the economics of innovation literature have emphasised that the propensity of firms to establish knowledge linkages with other firms is associated with the degree of similarity/dissimilarity in their knowledge bases (see e.g. Rogers, 1983; Lane and Lubatkin, 1998). We draw on this body of literature and claim that, even within a cluster context, firms will exchange knowledge depending on: (i) the amount of knowledge they have accumulated over time and can, therefore, release to others and (ii) their capacity to

[2] This definition draws on the concept of the absorptive capacity of firms, defined by Cohen and Levinthal (1990) as "the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128).

[3] The operational measure of absorptive capacity is discussed in Section 3.

decode and absorb knowledge that is potentially transferable from other cluster firms.

In particular, and in contrast to the conventional knowledge-spillover story, the exchange of knowledge follows some structured rules of behaviour which are determined by the relative values of firms' absorptive capacities (i.e. by the cognitive distances between them). So, while on one hand, when firms have very similar absorptive capacities the exchange of knowledge is more likely to occur on a mutual basis (Coleman, 1990), as "reciprocity appears to be one of the fundamental rules governing information trading" (Schrader, 1991, p. 154);[4] on the other, it seems likely that differences between the knowledge bases of firms will lead them to play differing, sometimes asymmetric roles within the cluster knowledge system. Hence, firms with particularly advanced knowledge bases are likely to be perceived by other cluster firms as 'technological leaders' or 'early adopters' of technologies in the local area, leading to them being sought out as sources of advice and knowledge more often than firms with less advanced knowledge bases. This is also likely to lead to a degree of imbalance in the knowledge interactions of the leading firms since they are less likely to seek out useful knowledge from firms with 'lower' knowledge bases (Schrader, 1991). Some firms may, therefore, *transfer* more knowledge than they receive from other local firms, so acting as net 'sources' within the cluster knowledge system. At the same time, firms have more incentives to *ask* for technical advice when they know that they will be able to decode and apply the received knowledge (Carter, 1989). Consequently, while the similar levels of their knowledge bases may lead some firms into balanced exchange, other firms with lower but still significant capacities are likely to absorb more knowledge than they release, so acting as net 'absorbers' within the cluster knowledge system. Finally, however, the knowledge base of some firms may be so low that it neither offers anything of value to other firms nor provides a capacity to acquire and exploit knowledge that others may have. Such firms are likely to be isolated within the cluster knowledge system—a position that is not considered significant within perspectives on cluster dynamism that emphasise the importance of homogeneous meso characteristics leading to the pervasive availability of knowledge and learning opportunities 'in the air'.

These considerations lead to the formulation of the following hypotheses:

Hypothesis 2(a). Links between local firms are more likely to develop among firms with higher absorptive capacity.

Hypothesis 2(b). Firms with differing levels of capacity are likely to establish different kinds of cognitive positions within the cluster knowledge system.

Underlying this argument about the differentiation of roles is a more general set of issues about how communication within a cluster knowledge system is structured. These are now explored.

2.3. Knowledge communities and the structure of the intra-cluster knowledge system

Beside inter-firm cognitive distances, the structure of the intra-cluster knowledge system is likely to be influenced by the formation of local communities of knowledge workers,[5] who share common language and technical background, seek advice from other peers of the same community and in so doing develop spontaneous (but not random) networking practices, which boost processes of knowledge exchange and generation (Von Hippel, 1987; Haas, 1992; Wenger and Snyder, 2000; Lissoni, 2001).[6]

The formation of these communities is driven by the existence of a certain degree of intra-community homophily (Rogers, 1983; McPherson et al., 2001), based upon the similarity of the members' personal

[4] Although we recognise the well-known distinction between information and knowledge, we use the terms interchangeably here. This is consistent with the contributions we discuss in this section (i.e. Von Hippel, 1987; Carter, 1989; Schrader, 1991), in which a variety of terms are used interchangeably: e.g. 'know how', 'technical information' and 'technical advice'.

[5] Knowledge workers are defined by the literature as individuals with high education and training in a particular profession. These characteristics are normally combined with a high capability in problem solving (Drucker, 1993; Creplet et al., 2001).

[6] Such communities have been variously defined in the literature e.g. as 'communities of practice' (Brown and Duguid, 1991; Wenger and Snyder, 2000) or 'epistemic communities' (Haas, 1992). For an insight into the differences between these two types of communities see Creplet et al. (2001).

technical background, which is inevitably entangled with the professional experience followed within the firm where they work. At the same time, such knowledge workers seek advice from other community members in search of complementary, different solutions to their specific technical problems, or simply interconnect to exchange experiences and improve their technical knowledge accordingly. It is conceivable that such networks tend to be structured by a local homophily-diversity trade-off. On the basis of this, we do expect that local knowledge flows within 'cognitive subgroups' of professionals (and, therefore, firms) rather than randomly in the 'air' (Breschi and Lissoni, 2001). Hence the third hypothesis is formulated as follows:

Hypothesis 3. The knowledge system within a cluster will be structured and differentiated, reflecting the existence of distinct 'cognitive subgroups'.

We test each of these hypotheses in Sections 5.1–5.3, aiming to shed light on the relationships between firms' absorptive capacities and their patterns of extra- and intra-cluster knowledge acquisition and diffusion. In Section 5.4, we examine the connection between external linkages and intra-cluster communication patterns, the technological gatekeeper' role as well as other cognitive roles taken by firms in the cluster.

3. The wine cluster in Colchagua Valley

3.1. The context: the Chilean wine industry

In the past decade, the international wine industry has been characterised by a very rapid growth of exports and by the emergence of new wine producing countries and their entry into the global market. Besides traditional producers, such as France and Italy, 'new world' exporters (primarily Argentina, Chile, New Zealand, South Africa and the US) have increased their share of global exports and upgraded the quality of their wines (Anderson and Norman, 2001a,b).

The case of Chile is an interesting example. Despite its long-standing tradition in the production of wines (Del Pozo, 1998), it is only since the 1980s that sustained growth in the production and export of wine has been achieved. In the 1990s, the country's participation in the global wine trade increased at a rate of 27 per cent per year, and the quality of the product was substantially improved, attaining widespread positive appraisal from international experts.

Chile presents ideal conditions for wine production because of the country's excellent natural endowments that result in numerous wine regions characterised by favourable *terroir*.[7] In addition wineries have made considerable efforts to modernise their technologies and adopt novel productive practices. Old methods have been replaced and firms have deepened their commitment to experimentation and upgrading of the production process. This rapid and pervasive transition has been described as a 'wine revolution' (Crowley, 2000).

Considerable investment at an institutional level in Chile has supported the firm-level efforts to upgrade and expand the Chilean industry. With respect to technology, co-financing through competitive funding schemes has sustained applied research in viticulture and oenology and the interaction between wine producers and various research institutes and universities (e.g. Universidad Catolica, Universidad de Talca and Universidad de Chile). With respect to marketing, the export of wines has been supported through the advice and intermediation of specific institutions, such as PROCHILE.

The Colchagua Valley is one of the promising emerging wine clusters of the country (Tapia, 2001). It is located in the VIth Region, about 180 km south-west of Santiago and is closed off to the east by the Andes and approximately 80 km to the west by the Coastal Range mountains. The area, is traditionally rural, with a history of wine production dating back to the XIXth century. It has recently increased its specialisation in wine production and since the 1990s the cluster has experienced a period of growth and prosperity, tied, mainly, to the success of the wine industry (Schachner, 2002).

3.2. Key features of the Colchagua wine cluster

Being traditionally a wine producing area, the cluster is populated by a myriad of predominantly micro and small grape growers and wine producers. In many

[7] *Terroir* is a French term that refers to the combination of soil and climatic conditions of a specific wine area.

cases, these produce for personal consumption or sell grapes or processed bulk wine at the local level. In addition to them, the cluster has been characterised by the development of firms that produce wine for the domestic and foreign market with an orientation towards quality. Together with long established firms, domestic and foreign investors have been attracted by the favourable *terroir* and have, therefore, established new production plants in the cluster.

During the 1990s, the favourable market conditions boosted the planting of new vineyards, which doubled in size in the second half of the 1990s (S.A.G., 2000). Accordingly, in the same period, the local production of wine tripled (S.A.G., 2000).[8] Most of the firms in the cluster have invested in new technologies. The cellar is usually the first step made towards modernisation: French steel tanks for fermentation, French or American *barriques*, Italian bottling lines are not difficult to find in the cluster. Firms are also very dynamic in introducing new methods and techniques in pruning, irrigation and canopy management. More recently, starting from the end of the 1990s, the sustained growth trend culminated in an overproduction crisis. Wine producers are currently affected by a global slow down of wine consumption and by increased competition (Anderson and Norman, 2001a,b), and this has spurred them to intensify their efforts to improve product quality and to enter higher value niches in international markets.

A critical role in the recent innovation process of the wine industry has been played by specialised knowledge workers, such as oenologists and agronomists employed in firms. Having university qualifications in technical fields, these professionals have the scientific understanding of the wine making process, which allow new methods of production to be applied and more intense experimentation to be carried out in firms. Besides, such knowledge workers boost technological change in firms also as external consultants. Also known as 'flying winemakers', consultants represent a vehicle of national and international transfer of both tacit and codified knowledge, spreading frontier knowledge on grape growing and wine making processes across many different places.

One can distinguish between four types of firm in the cluster:

(a) Firms that are vertically integrated at the local level, producing bottled wines, usually for quality markets. They undertake all phases of the production chain, from the vineyard to the market, growing their own grapes, processing them and bottling their own branded wines at the local level. These can be either domestic or foreign-owned.
(b) Firms that are vertically disintegrated at the local level: the local vineyard 'subsidiaries' of large national firms that own properties in different areas of the country and perform the final steps of the process (vinification, bottling, branding and marketing) in their headquarters outside the cluster.
(c) Vertically integrated grape growers and producers of bulk wine, usually at low quality.
(d) Non-integrated small-scale growers selling grapes directly to one of the three groups above.

A firm's commitment to producing higher quality products reinforces its need to exercise control over the process of grape-growing and viticulture, and this has stimulated a trend towards the vertical integration of wine producers via either of the first two firm categories noted above. Correspondingly, it has also progressively reduced the importance of subcontracting to independent grape-growers.

4. Methodology

4.1. The sample and data collection

The study has been based on the collection of primary data at firm level. This was done via interviews in a sample of firms in the cluster. As summarised in Table 1 below, the sample was determined in the following way. From the total population of wine producers in the cluster (approximately 100[9]), we first selected the total population of producers that bottle wine and sell under their brand names—28 firms, including the subsidiaries of national wineries that normally perform within this cluster only a part

[8] These data refer to the VI Region and not specifically to the Colchagua Valley. Nonetheless, it is believed that this trend is representative of this area.

[9] This is an estimate kindly provided by the Servicio Agricola y Ganadero, Santa Cruz. The number includes all producers of wine, including those that produce for personal consumption.

Table 1
The sample

	Wine producers		
	Branded		Not branded
	Locally based, vertically integrated firms	Subsidiaries, vertically disintegrated firms	Vertically integrated, bulk suppliers
Population ($N = 100$)	21	7	72 (Estimate including all other types of firm)
Sample ($n = 32$)	21	7	4
Of which:			
National	15	7	4
Foreign	6	0	0

of the value chain, typically grape-growing. Then, following the guidance of an expert informant, we selected four other firms that produce and sell bulk wine, normally to the first two groups of firms. No independent grape-growers were selected.

A number of pilot interviews in the cluster indicated that technical people in the firms were usually the best informants about the history and current characteristics of the firms. More important, they were also key nodes in the cognitive interconnections between firms.[10] The interviews, based on a structured questionnaire, were, therefore, held with the chief oenologist or the cellarman of each of the sampled firms.

Apart from general background and contextual information, the interviews sought information that would permit the development of quantitative indicators in three key areas: (a) the 'absorptive capacity' of the firms, (b) their intra-cluster knowledge communication patterns, and (c) their acquisition of knowledge from extra-cluster sources.

4.1.1. Firm-level absorptive capacity

In the literature this concept, a key element in the analysis here, is described in terms of the knowledge base of the firm. This is usually identified not only in terms of human resources (skills, training, experience, etc.) but also in terms of in-house knowledge-creation effort (usually R&D) as in Cohen and Levinthal (1989, 1990). Correspondingly, the structured interviews sought detailed information about (i) the number of technically qualified personnel in the firm and their level of education and training, (ii) the experience of professional staff—in terms of time in the industry and the number of other firms in which they had been employed, and (iii) the intensity and nature of the firms' experimentation activities—an appropriate proxy for knowledge creation efforts, since information about expenditure on formal R&D would have been both too narrowly defined and too difficult to obtain systematically. This information was transformed into a scalar value via Principal Component Analysis as explained in Section 3.2.

4.1.2. Intra-cluster knowledge communication patterns

In the questionnaire-based interview, these kinds of relational data were collected through a 'roster recall' method: each firm was presented with a complete list (roster) of the other firms in the cluster, and they were asked the following questions:

Q1: Technical support received [inbound]

If you are in a critical situation and need technical advice, to which of the local firms mentioned in the roster do you turn? [Please indicate the importance you attach to the information obtained in each case by marking the identified firms on the following scale: 0 = none; 1 = low; 2 = medium; 3 = high].

[10] This role of the oenologist was consistent with the behaviour stressed by Von Hippel (1987): "When required know-how is not available in-house, an engineer typically cannot find what he needs in publications either: much is very specialised and not published anywhere. He must either develop it himself or learn what he needs to know by talking to other specialists" (Von Hippel, 1987, p. 292).

Q2: Transfer of technical knowledge (problem solving and technical advice) [outbound]

Which of the following firms do you think have benefited from technical support provided from this firm? [Please indicate the importance you attach to the information provided to each of the firms according to the following scale: 0 = none; 1 = low; 2 = medium; 3 = high].

These questions specifically address *problem solving* and *technical assistance* because they involve some effort in producing improvements and change within the economic activity of a firm. This is meant to go beyond the mere transfer of information, whose access can be easily attained through other channels (e.g. trade fairs, the internet, specialised reviews, etc.). Instead, our interest here is to investigate whether local stocks of contextualised complex knowledge are not only accessible but also eventually absorbed by localised firms. So, for example, knowledge is transferred by providing a suggestion on how to treat a new pest or how to deal with high levels of wine acidity during fermentation. Accordingly, the knowledge transferred is normally the reply to a query on a complex problem that has emerged and that the firm seeks to solve.

The ways in which the responses to questions have been operationalised into a set of relational variables are indicated in Section 3.2.

4.1.3. The acquisition of knowledge from extra-cluster sources

The interview also asked about the firms' acquisition of knowledge from sources outside the cluster, both at national and international level. Specifically, respondents were asked to name on a roster of possible extra-cluster sources of knowledge (universities, suppliers, consultants, business associations, etc.) those which had contributed to the technical enhancement of firms[11]. They were also asked to indicate whether the firm had co-operated with any of those sources for joint research and experimentation. More specifically two different questions were formulated:

Q3: Technical support received [inbound]

Question Q3: Could you mark, among the actors included in the roster, those that have transferred relevant technical knowledge to this firm? [Please indicate the importance you attach to the information obtained in each case by marking the identified firms on the following scale: 0 = none; 1 = low; 2 = medium; 3 = high].

Q4: Joint experimentation

Question Q4: Could you mark, among the actors included in the roster, those with whom this firm has collaborated in research projects in the last 2 years? [Please indicate the importance you attach to the information obtained in each case by marking the identified firms on the following scale: 0 = none; 1 = low; 2 = medium; 3 = high].

4.2. Operationalising key indicators

Testing our hypotheses required operationalisation of the following firm-level concepts: absorptive capacity, external openness, and intra-cluster knowledge linkages. It also required operational indicators of the extent to which, and the most important ways in which, the cluster knowledge system was structured into 'cognitive subgroups'. Table 2 summarises the basis of the measures and indicators used. Further information is provided in the Appendix.

5. Main empirical findings

5.1. Absorptive capacity and external openness

In general terms, the Colchagua Valley cluster can be described as an 'open' knowledge system (Bell and Albu, 1999) as many of its constituent firms have established linkages with external sources of knowledge. Firms tend to establish frequent knowledge linkages with many of the leading research and technology transfer institutions and with universities (see Table 3). Suppliers of materials and machinery, jointly with consultants, are also important sources of knowledge and seem to be the main drivers of technical change in the firms. The cluster firms are also well connected with international sources of knowledge—in particular with foreign consultant oenologists ('flying winemakers') that play an important role in the transfer of frontier knowledge and techniques in the field. How-

[11] The list also contains open lines to permit the respondent to mention extra-cluster sources which were not included in the pre-defined roster.

Table 2
Key concepts and their measurement

Hypotheses and concepts	Explanation/elaboration of concepts	Measure adopted
Hypothesis 1 Association between firms' (i) ***Absorptive capacity*** and	(i) *Absorptive capacity* has four components: (a) the level of education of the technical personnel employed in the firm, (b) each professional's months of experience in the industry, (c) the number of firms in which each professional has been previously employed, and (d) the type and intensity of R&D undertaken by the firm	**Absorptive capacity**: an index derived from the application of Principal Component Analysis to the data about the four component indicators (see Appendix Section A for more detail).
(ii) ***External openness***	(ii) *External openness:* reflects the firm's propensity to acquire extra-cluster knowledge	**External openness**: the number of linkages with extra-cluster sources of knowledge (see Appendix Section C)
Hypothesis 2	Indicators of three key features of individual firms' intra-cluster knowledge linkage are developed.	Graph theoretical methods were adopted to measure different dimensions of the 'centrality' of firms communication patterns, and more generally their cognitive positions in the cluster. For further details see Appendix Section B.
Association between firms' (i) ***Absorptive capacity*** and	(i) The propensity of a firm to be a local 'source' of knowledge	**Out-degree centrality index**: measures the extent to which technical knowledge *originates from* a firm to be used by other local firms. The indicator is computed on two alternative bases *dichotomous:* reflects the presence/absence of such a linkage *valued:* analyses the value given to each linkage by the knowledge-user (a 0–3 range)
(ii) ***Intra-cluster knowledge linkages*** and	(ii) The propensity of a firm to absorb knowledge from intra-cluster sources	**In-degree centrality index**: measures the extent to which technical knowledge is acquired by/*transferred to* a firm from other local firms. Again the indicator is computed on two alternative bases: *dichotomous* and *valued*.
(iii) ***Different cognitive positions in the cluster knowledge system***	(iii) A firm's degree of interconnection with the intra-cluster knowledge system	**Betweenness**: measures the degree of cognitive interconnectedness of a firm on the basis of its propensity to be in-between of other firms' knowledge linkages.
	Indicators of the different roles of a firm in the local knowledge system combine (i) and (ii) above in order to assess the balance between a firm's role as source and absorber of knowledge flows within the cluster.	**In-degree/Out-degree centrality index (I/O C.I.)**: measures the ratio between the knowledge received and that transferred by each firm If I/O C.I is >1: the firm is a net 'absorber' of knowledge If I/O C.I is <1: the firm is a net 'source' of knowledge If I/O C.I is about 1, the firm engages in the mutual exchange of knowledge

Table 2 (*Continued*)

Hypotheses and concepts	Explanation/elaboration of concepts	Measure adopted
Hypotheses 3 The structuring of the cluster knowledge system in ways reflecting distinct '***cognitive sub-groups***'	In order to identify the extent to which knowledge interactions in the cluster are structured within subgroups of highly interconnected firms, three graph-theoretic indicators are used. See, Appendix Section B.II. for further detail.	**Core and peripheral groups**: core-periphery analysis allows the identification of a cohesive subgroup of core firms and a set of peripheral firms that are loosely interconnected with the core. **k–core (k = 4)**: a cohesive subgroup in which each firm is connected to at least four other firms in the subgroup

Source: Authors' own specification of indicators, with sociometric indexes taken from Wasserman and Faust (1994) and Borgatti et al. (2002).

ever, as shown in Table 3, the degree of external openness is not homogeneous across the cluster firms, as some firms tend to establish more linkages than others.

Given this heterogeneity, a non-parametric correlation test was run between the level of firms' absorptive capacity and their degree of external openness (Hypothesis 1). The test shows a significant correlation between those two variables: the Kendall tau_b correlation coefficient is 0.45 with $p < 0.01$. This result confirms Hypothesis 1: firms with higher absorptive capacity tend to interconnect more to external sources of knowledge than other firms (see Table 4).

According to our results, the existing knowledge base of the cluster firms appears to shape the heterogeneous propensity to interconnect with extra-cluster sources of knowledge. This seems consistent with the idea that firms with higher levels of absorptive capacity

Table 3
Linkages with extra-cluster sources of knowledge (number of firms with at least one knowledge link to the knowledge sources indicated)

Extra-cluster sources	Among the firms with overall 'openness' to external sources that was		
	Above the average	On the average	Below the average
Research institutes	9	9	4
Ceviuc (University Catolica)			
Knowledge transfer	8	6	3
Joint research projects	5	1	0
Centro Tec. Vid Y Vino (University Talca)			
Knowledge transfer	7	8	3
Joint research projects	1	2	1
Fac. CC. Agronomicas (University Chile)			
Knowledge transfer	6	2	0
Joint research projects	2	1	0
INIA			
Knowledge transfer	2	0	1
Joint research projects	4	1	0
Business associations	8	7	2
Vinas de Chile			
Knowledge transfer	6	3	0
Chilevid			
Knowledge transfer	3	4	1
Corporacion Chilena de Vino			
Knowledge transfer	4	4	1
Private firms: consultants and suppliers	10	10	6
Domestic knowledge transfer	10	10	6
Foreign knowledge transfer	9	4	4

Source: Authors' own data.

Table 4
Correlation between external openness and absorptive capacity (non-parametric correlation: Kendall tau_b coefficient)

	Average absorptive capacity
External openness (above the average) ($n = 10$)	0.74
External openness (on the average) ($n = 10$)	0.07
External openness (below the average) ($n = 12$)	−0.67
Kendall tau_b correlation between external openness and absorptive capacity	0.45**

Source: Authors' own data.
** Coefficient is significant with $p < 0.01$.

are cognitively closer to extra-cluster knowledge and can, therefore, operate more easily than other firms as interfaces or nodes of connection of the cluster with the external environment.

5.2. Local inter-firm knowledge exchange: how cognitive positions vary in the cluster

It is also evident that firms do not participate in the local knowledge system in an even and homogeneous way. Visual inspection (see Fig. 1) suggests that firms tend to interconnect differently to one another: in particular one group of firms (centre of the figure) are linked, transferring and receiving knowledge from each other. In contrast, another group of firms (top left) remain cognitively isolated.

In order to test whether firms that were more cognitively interconnected in the cluster knowledge system also had higher absorptive capacities (Hypothesis 2(a)), we ran a second correlation test. As indicated in Table 5, this indicated statistically significant relationships between the absorptive capacity and the different centrality indexes.

The variation between the different correlation statistics is also illuminating. We observe that among these the highest correlations are between absorptive capacity and Out-degree centrality, with both dichotomous and valued data (Kendall tau_b = 0.523 and 0.532). This suggests that absorptive capacity influences the propensity of firms to *transfer* knowledge to other local firms and hence to be net 'sources' of technical knowledge within the cluster system. For the In-degree centrality and betweenness indexes, the correlations are weaker, but still significant. This suggests that even at lower levels of absorptive capacity, firms might be linked to the local knowledge system, provided that a *minimum* absorptive capacity threshold is reached.

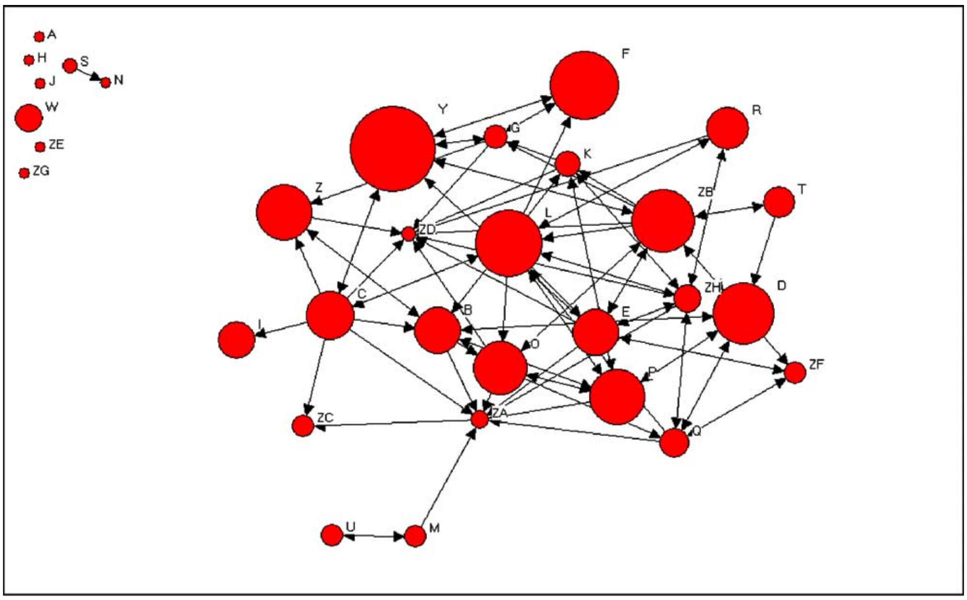

Fig. 1. The local knowledge system in the Colchagua Valley: a graphical representation source: UCINET 6 on author's own data. Note: An arrow from i to j indicates that i transfers knowledge to j. The diameter of the nodes is proportional to firms' absorptive capacity.

Table 5
Correlation between absorptive capacity and centrality indexes

	Indexes of different communication patterns				
	Out-degree C. (dichotomous)	Out-degree C. (valued)	In-degree C. (dichotomous)	In-degree C. (valued)	Betweenness
Absorptive capacity	0.523**	0.532**	0.399**	0.323*	0.291*

Source: Authors' own data (non-parametric correlation: Kendall tau_b coefficient), see Appendix Section B for definitions of the indexes.
* Correlation is significant with $p < 0.05$.
** Correlation is significant with $p < 0.01$.

This association between firms' absorptive capacities and their propensity to take different cognitive positions in the cluster knowledge system (Hypothesis 2(b)) is shown more directly in Table 6. This introduces a set of classifications of the firms' cognitive positions in the cluster—knowledge transferers, mutual exchangers, absorbers or isolates—as described in the first column in the Table.

The Table shows clearly that average absorptive capacity varies considerably across the different cognitive positions. Particularly interesting is the difference observable between the first three groups: sources, mutual exchangers and absorbers and the last one, which is characterised by isolated firms. This result supports the idea that a threshold for inter-firm knowledge exchange exists, so that when firms' absorptive capacity is very low, the cognitive distance with other firms' knowledge bases becomes too high (i.e. infinite) and the firms tend to be isolated. Correspondingly, those firms that are sufficiently above the minimum threshold have a higher probability of being interconnected with other local firms. Given the way the questions were centred on problem-solving and performance improvement, these linked firms, in contrast to the isolated firms, are likely to improve the quality of their production by virtue of such linkages. On the basis of these results we accept Hypothesis 2(b).

Table 6
Firms' absorptive capacities and cluster cognitive positions

Cognitive positions in the cluster	Absorptive capacity measure
Sources ($n = 5$) firms with an In/Out degree centrality ratio >1	1.00
Absorbers ($n = 5$) firms with an In/Out degree centrality ratio <1	0.65
Mutual exchangers ($n = 8$) firms with an In/Out degree centrality ratio = 1	0.07
Isolates ($n = 14$) firms with In and Out centralities approximating to 0	−0.88

Source: Authors' own data.

5.3. Structure of the intra-cluster knowledge system

In order to analyse how knowledge flows were structured within the cluster knowledge system, we adopted graph theoretical measures for identifying cognitive subgroups within the cluster, by which we mean subgroups of firms that have established more relations with members internal to the subgroup than with non-members (Alba, 1973). In particular, we applied core/periphery models to our data (Borgatti and Everett, 1999). These allow the identification of central and peripheral poles within cluster knowledge systems.

In the case of the Colchagua cluster we observe the formation of a clear core-peripheral knowledge structure where (a) firms in the *core* tend to be highly interconnected among themselves, whereas (b) peripheral firms tend to establish loose linkages with the core firms and virtually no interconnections with other peripheral firms. More specifically, we show in Table 7, the density of the four types of relations namely: core-to-core (top left), core-to-periphery (top right), periphery to core (bottom left) and periphery to periphery (bottom right).[12] Density is highest for core-to-core relations (0.571), which means that core firms tend to transfer knowledge more often within the core. As expected, they are also identified as sources of knowledge by peripheral firms (core-to-periphery density is 0.155), but this relation is much looser than the previous one. At the

[12] For core/periphery analysis we adopted a directional dataset.

Table 7
Density of linkages within and between core and peripheral groups

	The density of linkages (knowledge transfer from row to column)		Average absorptive capacity
	Core	Periphery	
Core ($n_C = 14$)	0.571	0.155	0.58
Periphery ($n_P = 18$)	0.083	0.026	−0.45

Source: UCINET 6 applied to author's own data. *Note:* The density of a network is the total number of ties divided by the total number of possible ties.

same time core firms do not mention peripheral firms as sources of technical advice (periphery-to-core density is very low 0.083) and even less do peripheral firms transfer or receive knowledge from other peripherals (periphery-to- periphery density is 0.026).

The association between these core/periphery positions and the absorptive capacity of the constituent firms is interesting. Core firms have an average absorptive capacity of 0.58, while the same data for peripheral firms is 0.45. This seems consistent with the idea that core firms, having higher absorptive capacities, boost local processes of incremental learning and stimulate some peripheral firms to ask for technical advice, although these relations are not nearly as intense as those within the core group itself.

To improve understanding of this core sub-group, we undertook a further step in the analysis, the identification of 4-cores within the cluster. This identifies firms that have established at least four knowledge linkages with other firms of the sub-group. This is carried out by taking into account the whole set of knowledge links, independently of their estimated importance. As shown in Fig. 2, we find a complete network of interrelated firms, which correspond to the core identified above.

These results support Hypothesis 3. In particular, the local knowledge system has the structural characteristics of a core/periphery set where knowledge interactions are clearly concentrated within a subset of core firms. Furthermore, consistent with previous sections, this core group is formed by firms that have, on average, higher absorptive capacities than the firms in the periphery. The data are consistent with the existence of a single community of fairly well connected, skilled knowledge workers who tend to exchange more knowledge within the community (i.e. within the core) than outside it. In contrast, with their relatively weak knowledge base, peripheral firms are not part of the core knowledge community in the cluster. In other words, we observe that firms' absorptive capacities and the participation of their professional personnel in knowledge communities are interwoven elements which shape the structure of the local knowledge system.

5.4. Linking intra- and extra-cluster knowledge systems: the role of technological gatekeepers

In this section, we bring together the data about (a) the external openness of firms and (b) the 'cognitive position' of firms within the local knowledge system. Combining these parameters we identified five main learning patterns within the cluster, corresponding to the following five types of 'cognitive role', as indicated

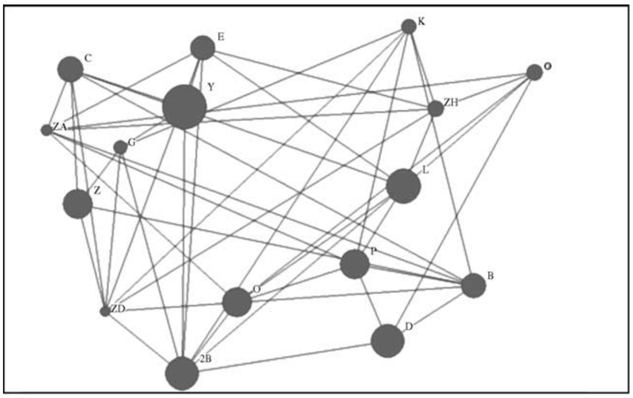

Fig. 2. The core group: an analysis of 4-cores Source: UCINET 6 on author's own data. Note: The linkages are undirected as we adopted a symmetrised version of the original dataset. The diameter of the nodes is proportional to firms' absorptive capacity.

Table 8
Differing firm-centred cognitive roles in cluster learning

Intra-Cluster Cognitive Position	External Openness: Low (Below the average)	External Openness: Medium (Average)	External Openness: High (above the average)
Source *In/Out Degree centrality <1*	-	-	**TG** **Technological gatekeepers** **(n=5)**
Mutual Exchanger *In/Out Degree centrality → 1*	Intra-cluster mutual exchanger (n=1)	**AME** **Active Mutual Exchangers** **(n=4)** **WME** **Weak mutual exchangers,** **(n=3)**	
Absorber *In/Out-Degree centrality > 1*	Intra-cluster absorber (n=1)	Local absorber (n=1)	**ES** **External stars** (n=3)
Isolated **(or poorly interconnected)** *In = Out and →0*	**IF** **Isolated firms** (n=10)	Locally isolated (n=2)	Locally isolated (n=2)

Source: Authors' own data.

in the cells in Table 8 that are highlighted inside the heavy broken lines. More detailed characteristics of the firms playing these five types of role are indicated in Table 8.

(a) *Technological gatekeepers (TGs):* firms that have a central position in the network in terms of knowledge transfer to other local firms and that are also strongly connected with external sources of knowledge.
(b) *Active mutual exchangers (AMEs):* firms that form a central part of the local knowledge system with balanced source/absorber positions within the cluster. They also have relatively strong external links. Although they are less strongly connected to external sources than the TG firms, they behave in a similar way to 'technological gatekeepers' by bridging between external sources and local absorbers of knowledge.
(c) *Weak mutual exchangers (WMEs)* consist of firms that are similar to AMEs in that they are well linked to external knowledge sources and play a relatively balanced source and absorber role within the cluster. However, compared with AMEs, they are less well connected to other firms in the cluster.
(d) *External Stars (ES):*[13] firms that have established strong linkages with external sources, but have limited links with the intra-cluster knowledge system. These weak intra-cluster links are primarily inward and absorption–centred.
(e) *Isolated firms (IFs):* are poorly linked at both the local and extra-cluster levels.

Tables 8 and 9 indicate that firms playing three of the five cognitive roles (TGs, AMEs and WMEs) are connected actively into the cluster knowledge system and contribute positively to its learning processes. They constitute the core of the absorptive capacity of the cluster. The other two groups' cognitive links with the cluster system are much more marginal.

All the firms contributing to the cluster's absorptive capacity engage in a combination of three key activities: acquiring knowledge from outside the cluster, generating new knowledge through their own intra-cluster experimentation, and contributing to intra-cluster diffusion. The strength of this combination of positive roles differs between the groups and is

[13] This term is taken from Allen (1977) where it describes individuals having similar positions within firms i.e. with strong links to external sources of knowledge plus weak links to the internal knowledge system.

Table 9
Heterogeneity in the cluster knowledge system

	Characteristics of firms' differing cognitive roles in the cluster knowledge system						
	ES ($n=3$)	TG ($n=5$)	AME ($n=4$)	WME ($n=3$)	IF ($n=10$)	Others ($n=7$)	Total ($n=32$)
1. Absorptive capacity							
Composite index	1.7	1.00	0.16	0.04	−0.70	–	0
Within which							
Intensity of experimentation	3.0	3.0	1.75	1.66	0.7	–	1.59
2. Openness							
External openness	10.33	11.0	8.5	8.9	3.1	–	7.12
3. Intra-cluster cognitive positions							
Average Out-degree centrality							
Dicot	3.0	7.2	6.0	3.0	0.36	–	2.90
Valued	5.3	12.8	11.5	7.3	0.73	–	5.37
Average In-degree centrality							
Dicot	4.3	4.0	5.0	3.0	0.5	–	2.90
Valued	8.3	6.6	10.25	7.6	1.1	–	5.37
Ratio In/Out degree centrality							
Dicot	1.44	0.58	0.8	1.0	1.5	–	0.85
Valued	1.56	0.51	0.9	1.0	1.6	–	0.86
Betweenness	20.0	43.2	26.75	8.0	0.2	–	13.90

Source: Authors' own data.

most evident in the case of the TGs and AMEs. They have relatively high Out-degree centrality indexes, and this is particularly so with respect to the valued data indexes, reflecting the qualitative importance attached to the knowledge they transfer to other firms. There are nevertheless substantial differences between these two groups. The TG firms play a striking role as net sources of knowledge for the cluster system (with In/Out degree indexes of only about 0.5), while the AMEs act only marginally as net sources (with In/Out degree indexes around 0.8–0.9). Behind this difference lie differing firm-level capacities. Compared to the TGs, the AMEs undertake more modest local experimentation and have more limited intra-firm knowledge resources. In contrast, the TGs are not just well connected to external knowledge sources. They are also significant creators of knowledge in their own right, demonstrating a high intensity of local experimentation; and this is backed by relatively strong intra-firm knowledge resources. These are typically 'advanced' firms that operate very close to the technological frontier[14] and whose production is oriented towards the exportation of premium wines.

These TG firms, therefore, tend to be local depositories of technical novelties, which they apply and contextualise in their economic practice. Their technologically advanced position is normally acknowledged by the rest of the firms in the cluster[15] and this spurs the latter to ask for advice. This explains their asymmetric position as substantial net sources of knowledge in the cluster. It is pertinent to note that these TG firms in the majority of the cases have vertically integrated operations located within the cluster and are, therefore, well embedded in the local area.[16] Their willingness to engage in unreciprocated knowledge transfer to other local firms, may reflect the positive externalities associated with this. In a wine area, such as Colchagua, which is currently investing in achieving international acknowledgement for the production of high quality wines, the improvement of every producer in the area is likely to generate positive marketing-related exter-

[14] The wine industry has gone through substantial scientific and technological changes over recent decades. Both old world producers (e.g. France) and new world producers (e.g. California, Australia, South Africa, etc.) have contributed to define a widely accepted frontier of technology in this industry (see Paul, 2002).

[15] A question specifically addressed this issue. Respondents were asked to provide three names of firms that they considered advanced in the cluster, with respect to their degree of technical modernisation and the quality of wine produced.

[16] This does not mean that such firms are all locally-owned. Indeed in three of the five cases the ownership is wholly or partially foreign.

nalities for the whole area, and these may outweigh the possible cost to these firms associated with imbalanced knowledge transfer relationships with competing firms.

Among the relatively active participants in the cluster knowledge system, the WME group has some similar attributes to the AME firms (moderate levels of openness and experimentation). However, with a very low level of absorptive capacity, the WME firms have much more modest knowledge resources to draw on. It is perhaps not surprising, therefore, that they seem to be sought out only infrequently to contribute knowledge to other firms, as reflected in the low Out-degree centrality indexes (3.0 and 7.3 for the dichotomous and valued data respectively). At the same time they have, similarly, low levels of In-degree centrality. Consequently, although they have a balanced exchange of knowledge with other firms (an In/Out degree ratio of 1.0), those interactions take place at a much lower level than in the case of the AME firms.

The two marginal groups of firms differ widely. The IFs have extremely low scores on almost all the indicators. They have very low absorptive capacity; they undertake almost no experimentation; and they acquire almost no knowledge from extra-cluster sources. Not surprisingly, they are rarely sought out as knowledge sources by other firms. But it is striking that they also rarely seek out knowledge from other cluster firms (demonstrating by far the lowest In-degree centrality indexes in the sample: 0.5 and 1.1). These firms, accounting for nearly one-third of the sample, are barely connected to the cluster knowledge system at all.[17]

The External Stars are marginally connected to the knowledge system in a different way. They have by far the highest index of firm-level absorptive capacity among all the firms in the cluster (1.7), and this includes a high intensity of experimentation carried out in the cluster. This suggests they face a low cognitive distance from extra-cluster sources of knowledge, enabling them to draw heavily on those sources for their own learning and innovation (as reflected in the high openness index of 10.3). At the same time, though, they play a highly imbalanced cognitive role inside the cluster. On the one hand, they pass on very little of their knowledge to other cluster firms (reflected in very low Out-degree indexes: 3.0 and 5.3). On the other, as reflected in their high In-degree centrality values, they seek out advice from the 'advanced' firms inside the cluster, particularly the technological gatekeepers, although they tend not to reciprocate the transfer of knowledge.

In other words, although these external star firms are perhaps best positioned of all the cluster firms to make positive contributions to the cluster knowledge system, they rarely do so. To the extent that they engage with the intra-cluster knowledge system, this is primarily about extracting and absorbing cluster knowledge, not about contributing to it. This pattern appears not to reflect the ownership status of the firm,[18] but may reflect the production structure of the firms. They are mainly vertically disintegrated subsidiaries of large national wine producers that base their main operations elsewhere, and are, therefore, not well embedded in the local area. This might partially explain why their behaviour contrasts so sharply with that of the other advanced firms that do operate as local technological gatekeepers.

In summary, then, because of the limited role played by these two groups of firms, the overall technological dynamism of the cluster as a whole seems to be driven by less than half of the sample firms—the TGs, AMEs and, to a lesser extent, the WMEs (12 out of 32). Although this is a relatively dynamic cluster that is moving 'upwards' in international markets, its technological dynamism is not driven by a widespread community of technologically dynamic firms operating, similarly, and pervasively across the cluster. Instead, it is driven by a relatively small group of firms that is organised within a core interacting knowledge community, surrounded by greater number of largely passive firms that occasionally absorb elements of knowledge from the core group or, in a small number of cases, directly from external sources. Moreover, that

[17] In addition, there are four other isolated firms, not included in any of the selected groups of firms. These have, similarly, low levels of connection to other firms in the cluster, though stronger links with extra cluster sources of knowledge.

[18] The small number of observations precludes meaningful analysis. However, it may be pertinent to note that, while two of the three stars were subsidiaries of large national (not foreign) firms, the remaining five of the seven nationally-owned subsidiaries were as follows: one TG, one WME, one IF and two in the 'Other' categories. Similarly, clear conclusions cannot be drawn about the six foreign firms in the cluster. Half of them were technological gatekeepers and the others fell into more isolated categories. Ongoing research by the first author in other wine clusters suggests that the cognitive roles of foreign companies depends more on the duration of the location in the cluster than on their foreignness.

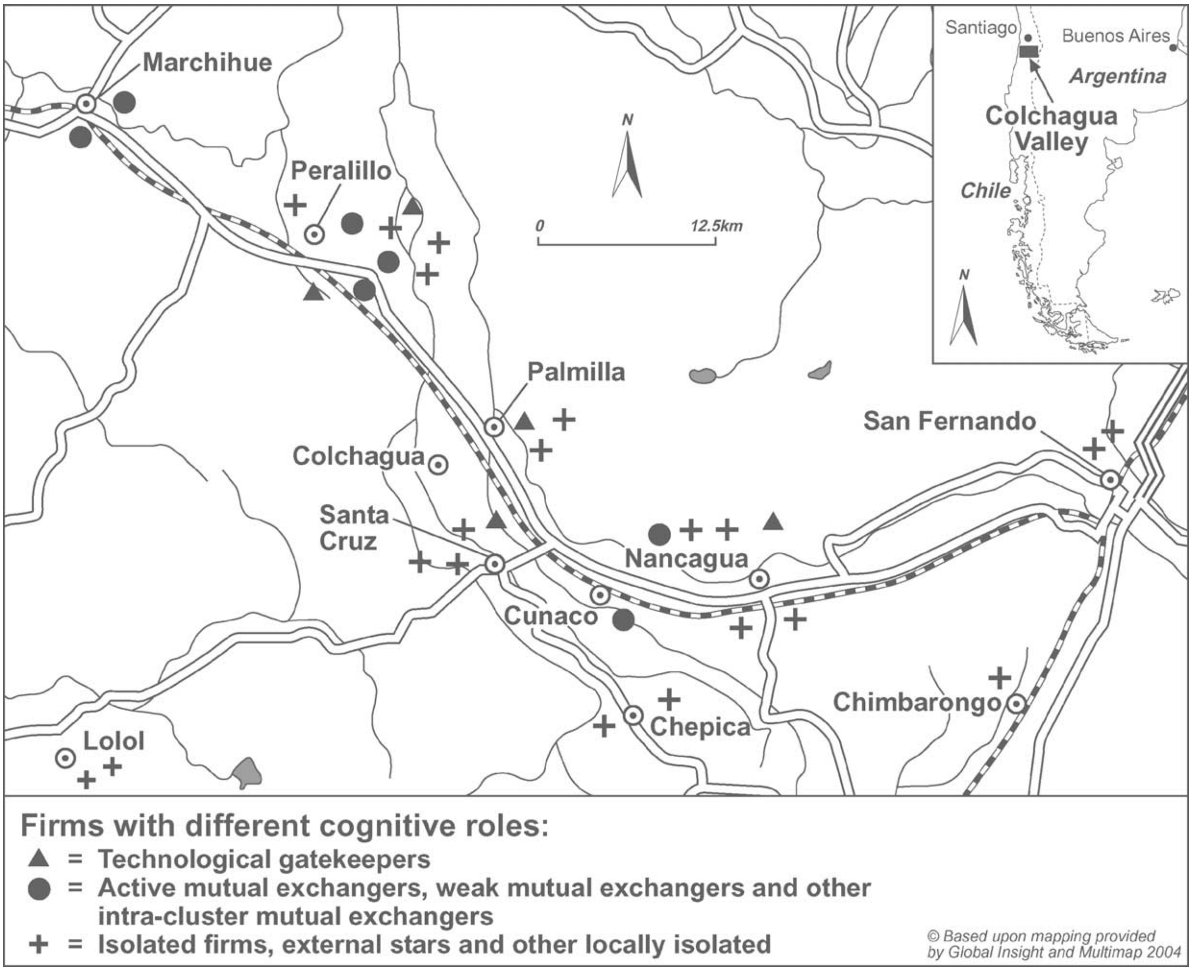

Fig. 3. Approximate location of wine cluster firms with differing cognitive roles, Colchagua Valley, Chile.

core group is itself organised in a hierarchical knowledge structure that has a few very capable, knowledge-creating, and external knowledge-acquiring firms at the 'top', acting as the main sources of new knowledge for the cluster. Below that, firms with progressively lower levels of these qualities shift from being net contributors into the cluster knowledge system to being net absorbers of that circulating knowledge.

It is interesting to note also that this hierarchy does not seem to be influenced in any way by geography. Fig. 3 indicates the physical location of firms in the cluster, distinguished by their cognitive roles. All the firms are distributed along the valley running from San Fernando in the East to Marchihue and Lolol in the West and their spatial propinquity and cognitive roles seem unrelated. Indeed, in the subcluster of firms around Perallillo technological gatekeepers are closely located with all the other types of firms. Similarly, in the subclusters around Santa Cruz and Nancagua, the closest neighbours to the technological gatekeepers are cognitively isolated at the local level.

6. Conclusions

The results of the analysis in this paper call into question the extent to which clustering *per se* influences the learning behaviour of cluster firms. In Colchagua at least, the spatially clustered wine producers demonstrated a wide range of different communication and learning behaviours. For some, learning links with other organisations ran strongly outside the valley, almost exclusively so in some cases; and a substantial number of other firms were almost totally isolated from any learning processes at all whether within the cluster or outside. Among the firms that did demonstrate cluster-centred learning relationships, the cognitive positions and roles varied widely. This heterogeneity, associated with the differences in firms' absorptive capacities, suggests that a cluster is a complex economic and cognitive space where firms establish knowledge linkages not simply because of their spatial proximity but in ways that are shaped by their own particular knowledge bases.

Consequently, the results shed light on the relationship between meso and micro within the cluster. Instead of the common emphasis given to ways in which the meso-level characteristics of clusters influence micro behaviour, this study highlights the importance of the opposite direction of influence. It was the capacities of individual firms to absorb, diffuse and creatively exploit knowledge that shaped the learning dynamics of the cluster as a whole.

This direction of relationship was exemplified particularly clearly in the case of one meso characteristic that has been suggested as important for the longer run growth of a cluster: its openness to external knowledge, or more specifically its capacity to acquire external knowledge and absorb it into its production activities. In the Colchagua cluster, this meso-level absorptive capacity was determined by the knowledge bases of the firms. This was not simply a matter of the cluster capacity being an aggregation of the individual firms' capacities, since the channels of knowledge acquisition and diffusion *between* the firms were also key components of the overall cluster absorptive capacity. However, the density and structure of those channels into and within the cluster, and hence their impact on the extent of learning in the cluster, were strongly shaped by the knowledge bases of the individual firms.

These conclusions align with the distinction between relational and spatial proximity highlighted by Amin and Cohendet (2004). However, in several respects they differ from other recent contributions in this field. In particular, although spatially bounded knowledge interactions within the cluster were important in the learning process, instead of being "unstructured and unplanned", arising "by chance" (Malmberg, 2003, pp. 157–158), they were highly structured. Also, although, like Owen-Smith and Powell (2004), we have highlighted the importance of networks nodes in shaping the structure of interactions, we have shown the significance of their cognitive rather than organisational and institutional characteristics. This leads into, but leaves open, questions about why firms with these characteristics behaved in the ways we describe. In particular, why did firms with very similar cognitive characteristics behave as differently as the Technological Gatekeepers and the External Stars? Also, what factors drive the interactions among the members of the knowledge community? These questions are not pursued here but are being examined in further research by the first author.

Our conclusions also prompt speculative questions about the long term evolution of cluster cognitive systems of this type. Our cross sectional data do not throw light directly on that dynamic, but the indirect illumination they provide does prompt reflection about the circumstances that might underpin it. Recall key features of the current situation: one group of firms with the strongest knowledge bases, the most intensive in-house experimentation and the strongest links to external knowledge sources were the External Stars which contributed very little to the intra-cluster learning system. At the same time, a relatively small number of other firms played strong positive roles in acquiring or developing new knowledge and diffusing it more widely in the cluster; and finally nearly one-third of the sample firms were disconnected from the system. From that base, several directions of evolution can be envisaged. Two seem particularly interesting.

One would be towards a much more pervasive and less polarised knowledge and learning system. A greater number of firms would act as net contributors into the knowledge system (in particular, with External Stars and Active Mutual Exchangers behaving more like Technological Gatekeepers), and the internally isolated firms would either connect into the system as knowledge acquirers or exit the industry. The other direction would be towards a system in which extra-cluster sources of knowledge became the dominant drivers of learning and innovation in an increasingly competitive market, with firms among the Technological Gatekeepers and Active Mutual Exchangers reducing their willingness to act as net 'sources' of knowledge (i.e. behaving more like the External Stars). The cluster knowledge system would then turn 'inside-out', exhibiting a different kind of polarised structure. The most technologically advanced and dynamic firms would concentrate their knowledge links with actors outside the spatial cluster, contributing little or nothing to the intra-cluster system. Increasingly isolated other cluster firms, without their links to sources of new knowledge, would fail to compete in growing markets.

Both these directions of change would be likely to enhance the overall growth and competitive performance of wine production in the Colchagua Valley. But they would result in two very different meanings of 'cluster'. One would conform to the conventional expectations of cluster analysts: a coherent cluster-centred knowledge system would act as a positive influence on the innovative activities of the spatially associated firms. The other would virtually eliminate the role of spatial clustering as an influence on the learning and innovative activities of firms that would remain geographically, but not cognitively, associated.

In that context, if the patterns reported here are widespread, interesting questions arise about policy. It seems fairly clear that, since learning and innovation are driven primarily by the knowledge bases (absorptive capacities) of individual firms, measures designed merely to foster spatial agglomeration may have limited influence—a view consistent with that of Breschi and Malerba (2001). Similarly, measures designed to foster intra-cluster communication and collaboration might not do much to change firms' cognitive roles if those also are shaped primarily by their knowledge bases as well as strong underlying motivations. In contrast, measures focused on strengthening firms' knowledge bases might be expected to lead to stronger extra-cluster links, greater new knowledge creation and more intensive intra-cluster diffusion.

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Appendix A. Absorptive capacity

Absorptive capacity has been measured by applying a Principal Component Analysis to the following four correlated variables:

A.1. Variable 1: Human resources

This variable represents the cognitive background of each firms' knowledge skilled workers on the of their degree of education. According to previous studies regarding returns to education, we assume that the higher the degree of education the higher is their contribution to the economic returns of the firm. On this assumption we weight each knowledge skilled worker differently according to the degree attained so that:

$$\text{Human resource} = 0.8 \times \text{degree} + 0.05 \times \text{master} + 0.15 \times \text{doctorate}$$

A weight of 0.8 has been applied to the number of graduate employees in the firm which include also those that received higher levels of specialisation. In such cases the value adds up a further 0.05 times the number of employees with masters and 0.15 for those that have a Ph.D.

Only degrees and higher levels of specialisation in technical and scientific fields related to the activity of wine production (i.e. agronomics, chemistry, etc.) are taken into account.

A.2. Variable 2: Months of experience in the wine sector

This variable has been included as it represents the cognitive background of each of the abovementioned resources in temporal terms. Time is in fact at least indicative of the fact that accumulation of knowledge has occurred via 'learning by doing' (Arrow, 1962). More in detail, the variable is the result of a weighted mean of the months of work of each knowledge skilled worker in the country and abroad:

Months of experience in the sector = 0.4 × no. of months (national) + 0.6 × no. of months (international).

To the time spent professionally abroad we attributed a higher weight because the diversity of the professional environment might stimulate an active learning behaviour and a steeper learning curve. The learning experiences considered are those realised in the wine industry only.

A.3. Variable 3: Number of firms in which each knowledge skilled worker has been employed

This variable includes the professional experience in other firms operating in the wine industry. Also in this case we weighted differently national and international experiences, giving to the latter a higher weight.

Number of Firms = 0.4 × no. of firms (national) + 0.6 × no. of firms (international)

A.4. Variable 4: Experimentation

In this case, the level of experimentation at firm level has been calculated according to the following scale:

(0) for no experimentation;
(1) when some form of experimentation is normally carried out but only in one of the activities of the productive chain (either in viticulture or vinification);
(2) when is led in at least two activities of the productive chain (normally in both viticulture and vinification);
(3) when at least two activities of the productive chain are marked and the firm has been engaged in one joint research project with a university or a research lab in the last 2 years;
(4) when at least two activities of the productive chain are marked and the firm has been engaged in more than one joint research project with a university or a research lab in the last 2 years.

Principal Component Analysis extracted one component, which we adopted as a measure of absorptive capacity.

Appendix B. Sociometric measures

B.I. Degree centrality depends on the links that one node has with the other nodes of the network. It is a simple measure because it counts the direct ties with other nodes. It can be calculated both for undirected and directed graphs. In this study, we computed both In-degree and Out-degree centrality. In-degree counts the number of ties incident to the node; Out-degree centrality the number of ties incident from the node.

$$C_D(n_i) = d(n_i)$$

where $d(n_i)$ is the sum of the nodes adjacent to that node.

B.II. Actor betweenness centrality is a measure of centrality that considers the position of nodes in-between the geodesic (i.e. shortest path) that link any other node of the network.

Let g_{jk} be the proportion of all geodesics linking node j and node k which pass through node i, the betweenness of node i is the sum of all g_{jk} where i, j and k are distinct.

$$C_B(n_i) = \sum_{j<k} g_{jk}\frac{(n_i)}{g_{jk}}$$

This index has a minimum of zero when n_i falls on no geodesics and a maximum which is $(g-1)(g-2)/2$ (g = total nodes in the network) which is the number of pair of nodes not including n_i.

B.III. Core/periphery models are based on the notion of a two-class partition of nodes, namely, a cohesive subgraph (the core) in which nodes are connected to each other in some maximal sense and a class of nodes which are more loosely connected to the cohesive subgroup but lack any maximal cohesion with the core. The analysis sets the density of the core to periphery ties in an ideal structure matrix. The density represents the number of ties within the group on total ties possible (Borgatti and Everett, 1999).

B.IV. k-core is a subgraph in which each node is adjacent to at least a minimum number k of the other nodes in the subgraph.

Appendix C. External openness

External openness has been measured considering the knowledge linkages of firms with extra-cluster sources of knowledge. In the analysis, we have grouped the linkages into 10 sources and channels of extra-cluster knowledge. The importance of each source for the transfer of technical knowledge into the firm is measured on a 0–3 scale, where 0 stands for 'no importance' and 3 for 'maximum importance'.

References

Alba, R.D., 1973. A graph theoretic definition of a sociometric clique. Journal of Mathematical Sociology 3, 113–126.

Allen, T.J., 1977. Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization. MIT Press, Cambridge, MA.

Altenburg, T., Meyer-Stamer, J., 1999. How to promote clusters: policy experiences from Latin America. World Development 27 (9), 1693–1713.

Amin, A., Cohendet, P., 2004. Architectures of Knowledge. Firms, Capabilities and Communities. Oxford University Press, Oxford.

Anderson, K., Norman, D., 2001a. Global wine production, consumption and trade: 1961–1999. A statistical compendium. CIES Wine Statistical Compendium, Centre for International Economic Studies, University of Adelaide, Australia.

Anderson, K., Norman, D., 2001b. Globalisation and the worlds' wine markets. CIES Discussion Paper 0143, Centre for International Economic Studies, University of Adelaide, Australia.

Arrow, K.J., 1962. The economic implications of learning by doing. Review of Economic Studies 29, 155–173.

Asheim, B.T., 1994. Industrial districts, inter-firm cooperation and endogenous technological development: the experience of developed countries. In: UNCTAD, Technological Dynamism in Industrial Districts: An Alternative Approach to Industrialization in Developing Countries?, United Nations, New Yorkand Geneva, pp. 91–142.

Audretsch, D., Feldman, M.P., 1996. R&D spillovers and the geography of innovation and production. American Economic Review 86 (3), 630–640.

Baptista, R., 2000. Do innovation diffuse faster within geographical clusters? International Journal of Industrial Organization 18, 515–535.

Becattini, G., 1989. Sectors and/or districts: some remarks on the conceptual foundations of industrial economics. In: Goodman, E., Bamford, J. (Eds.), Small Firms and Industrial Districts in Italy. Routledge, pp. 123–135.

Becattini, G., Rullani, E., 1993. Sistema locale e mercato globale. Economia e Politica Industriale 80, 25–49.

Bell, M., Albu, M., 1999. Knowledge systems and technological dynamism in industrial clusters in developing countries. World Development 27 (9), 1715–1734.

Belussi, F., Gottardi, G., 2000. Models of localised technological change. In: Belussi, F., Gottardi, G. (Eds.), Evolutionary Patterns of Local Industrial Systems. Towards a Cognitive Approach to the Industrial District. Ashgate Publishing Ltd., Aldershot.

Borgatti, S.P., Everett, M.G., 1999. Models of core/periphery structures. Social Networks 21, 375–395.

Borgatti, S.P., Everett, M.G., Freeman, L.C., 2002. Ucinet 6 for Windows. Analytic Technologies, Harvard.

Breschi, S., Lissoni, F., 2001. Knowledge spillovers and local innovation systems: a critical survey. Industrial and Corporate Change 10 (4), 975–1005.

Breschi, S., Malerba, F., 2001. The geography of innovation and economic clustering: some introductory notes. Industrial and Corporate Change 10 (4), 817–833.

Brown, J.S., Duguid, P., 1991. Organizational learning and communities-of-practice: Toward a unified view of working, learning and innovation. Organization Science 2 (1), 40–57.

Camagni, R., 1991. Local milieu, uncertainty and innovation networks: towards a new dynamic theory of economic space. In: Camagni, R. (Ed.), Innovation Networks: Spatial Perspectives. Belhaven Press, London, pp. 121–142.

Capello, R., 1999. Spatial transfer of knowledge in high technology milieux: learning versus collective learning processes. Regional Studies 33 (4), 353–365.

Cantwell, J., Iammarino, S., 2003. Multinational Corporations and European Regional Systems of Innovation. Routledge, London, New York.

Carter, A.P., 1989. Know how trading as economic exchange. Research Policy 18, 155–163.

Cassiolato, J., Lastres, H., Maciel, M., 2003. Systems of Innovation and Development: Evidence from Brazil. Edward Elgar, Cheltenham.

Cohen, W.M., Levinthal, D.A., 1989. Innovation and learning: the two faces of R&D. The Economic Journal 99, 569–596.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35, 128–153.

Coleman, J., 1990. Foundations of Social Theory. Harvard University Press, Cambridge, MA.

Creplet, F., Dupouet, O., Kern, F., Mehmanpazir, B., Munier, F., 2001. Consultants and experts in management consulting firms. Research Policy 30 (9), 1517–1535.

Crowley, W.K., 2000. Chile's wine industry: historical character and changing geography. In: Yearbook, Conference of Latin Americanist Geographers, pp. 87–101.

Del Pozo, J., 1998. Historia del Vino Cileno. Desde 1850 hasta hoy. Editorial Universitaria, Santiago de Chile.

Dicken, P., Malmberg, A., 2001. Firms in territories: a relational perspective. Economic Geography 77 (4), 345–363.

Dosi, G., 1997. Opportunities, incentives and the collective patterns of technical change. The Economic Journal 107, 1530–1547.

Drucker, P., 1993. Post Capitalist Society. Butterworth, Oxford.

Gambardella, A., 1993. Innovazioni tecnologiche e accumulazione delle conoscenze: quale modello per le piccole e medie imprese negli anni '90? Piccola Impresa/Small Business 2, 73–89.

Giuliani, E., 2002. Cluster absorptive capability: an evolutionary approach for industrial clusters in developing countries. Paper Presented at the DRUID Summer Conference, Copenhagen/Elsinore 6–8 June.

Grabher, G., 1993. The weakness of strong ties: the lock-in of regional development in the Ruhr area. In: Grabher, G. (Ed.), The Embedded Firm. Routledge, London, pp. 1–32.

Guerrieri, P., Iammarino, S., Pietrobelli, C., 2001. The Global Challenge to Industrial Districts. Edward Elgar, Cheltenham.
Haas, P.M., 1992. Introduction: epistemic communities and international policy coordination. International Organization 46 (1), 1–35.
Humphrey, J., Schmitz, H., 1996. The triple C approach to local industrial policy. World Development 24 (12), 1859–1877.
Lane, P.J., Lubatkin, M., 1998. Relative absorptive capacity and interorganizational learning. Strategic Management Journal 19, 461–477.
Lissoni, F., 2001. Knowledge codification and the geography of innovation: the case of Brescia mechanical cluster. Research Policy 30, 1479–1500.
Malmberg, A., 2003. Beyond the cluster—local milieus and global economic connections. In: Peck, J., Yeung, H.W.C. (Eds.), Remaking the Global Economy. Sage, London, pp. 145–159.
Malmberg, A., Maskell, P., 2002. The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering. Environment and Planning A 34 (3), 429–449.
Markusen, A., 1996. Sticky places in slippery space: a typology of industrial districts. Economic Geography 72 (2), 294–314.
Marshall, A., 1919. Industry and Trade. Macmillan, London.
Marshall, A., 1920. Principles of Economics. Macmillan, London.
Maskell, P., Malmberg, A., 1999. Localised learning and industrial competitiveness. Cambridge Journal of Economics 23 (2), 167–186.
McPherson, M., Smith-Lovin, L., Cook, J.M., 2001. Birds of a Feather: Homophily in Social Networks. Annual Review of Sociology 27, 415–444.
Nadvi, K., Schmitz, H., 1999. Clustering and industrialization: introduction. World Development 27 (9), 1503–1514.
Owen-Smith, J., Powell, W.W., 2004. Knowledge networks as channels and conduits: The effects of spillovers in the Boston Biotechnology Community. Organization Science 15 (1), 5–21.
Paul, H.W., 2002. Science, Vine and Wine in Modern France. Cambridge University Press, Cambridge, MA.
Porter, M., 1998. On Competition. Harvard Business School Press, Boston, MA.
Rabellotti, R., 1999. Recovery of a Mexican cluster: devaluation bonanza or collective efficiency? World Development 27 (9), 1571–1585.
Rogers, E.M., 1983. Diffusion of Innovations, third ed. The Free Press, New York.
S.A.G., 2000. Catastro Viticola Nacional. Servicio Agricola y Ganadero. Departamento de Proteccion Agricola, Santiago de Chile.
Saxenian, A.L., 1994. Regional Advantage. Culture and Competition in Silicon Valley and Route, vol. 128. Harvard University Press, Cambridge, MA.
Schachner, M., 2002. The Next Napa? Chile's Colchagua Valley is Aiming for Big Time. Wine Enthusiast, March, Elmsford, New York.
Schrader, S., 1991. Informal technology transfer between firms: cooperation through informal trading. Research Policy 10, 153–171.
Tapia, P., 2001. Los Vinos de Colchagua. PMC Pinnacle Worldwide y Ed. Planetavino, Santiago de Chile.
Von Hippel, E., 1987. Cooperation between rivals: informal know-how trading. Research Policy 16, 291–302.
Wasserman, S., Faust, K., 1994. Social Network Analysis. Methods and Applications. Cambridge University Press, Cambridge, MA.
Wenger, E.C., Snyder, W.M., 2000. Communities of practice: the organizational frontier. Harvard Business Review, January–February, 139–145.