Cluster Absorptive Capacity: a comparative study between Chile and Italy

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Introduction[1]

The aim of the project is to improve understanding of the processes of technological learning in clusters of firms. This is relevant because, despite a vast array of studies on clusters has been conducted in both advanced and developing countries, a dynamic theory of clusters is still far from being developed (Feser, 1998; Martin and Sunley, 2003). This work therefore intends to help fill a gap in the literature and to provide at least an analytical framework, based on the concept of cluster absorptive capacity, through which one could explain the backwardness of certain clusters, while others prosper and grow. In drawing my research design I therefore chose to analyse two clusters that are at different stages of their evolutionary path: a laggard one in Italy and a catching up in Chile. The study shows that the local knowledge systems and the learning patterns differ considerably between the two clusters analysed and discusses intuitively the main implications for policy.

The paper is structured as follows: Section 1 presents an overview of the literature, the theoretical framework and the research question for this work. Section 2 explains the methodology applied in this research and the operationalisation of key concepts. Section 3 presents the empirical evidence for the two clusters analysed. Section 4 discusses the results and provides suggestions for further analysis.

Section 1. Theoretical Framework

1.1. Clusters, firms and localised collective learning

The concept of 'cluster' has become fashionable in recent years. While academic studies on clusters proliferated (see e.g. Special Issues of *Regional Studies* (33/4; 1999) and *World Development* (27/9; 1999)); cluster policies have been adopted in both advanced and developing countries and, in some cases, these have been considered drivers of national economic growth (UNCTAD, 1998; Porter, 1998; OECD, 1999; 2001).
On the basis of successful stories of some Italian industrial districts and other productive local systems in different part of the industrialised world (e.g. Silicon Valley, Cambridge Region, etc.), scholars have also promoted the idea that clustering could be a viable way to overcome competitive backwardness of informal, isolated SMEs in the developing world (e.g. Schmitz, 1982; Schmitz, 1995). Hence, under different theoretical and analytical approaches, clusters in developing countries have been subject to extensive study during the '90s (van Dijk and Rabellotti, 1997; Nadvi, 1999; Rabellotti, 1999; Tewari, 1999; Visser, 1999; Schmitz, 1999; Yoguel, 2000¸ Cassiolato et al., 2003). Of course, in such contexts, clusters appear far from the idealised model of industrial districts (Rabellotti, 1997) and from the innovative and dynamic areas of the Silicon Valley type. Rather, they are heterogeneous sets of geographically agglomerated firms (Altenburg and Meyer-Stamer, 1999; Rabellotti and Schmitz, 1999), typically SMEs, specialised in the same or interrelated sectors (Humphrey and Schmitz, 1995) and with weak technological capabilities (Caniels and Romijn, 2001).
In these contexts, cluster studies originally emphasised the importance of co-operative behaviour and joint action between firms as a way to foster growth and face the challenges of international competitiveness. In the second half of the '90s, after a wave of studies focusing mainly on static advantages of clustering, scholars became aware of the need for a more dynamic analysis that took into consideration the processes of accumulation of knowledge and of technological capabilities (Rabellotti, 1995; Bell and Albu, 1999).
Indeed, this has been an issue of analysis in advanced countries where, among the most acknowledged features of clusters, is their potential to *promote innovation* at local level and to grow accordingly (Allen, 1983; Maillat at al., 1995; Asheim, 1996; Morgan, 1997; Maskell and Malmberg, 1999; Amin and Wilkinson, 1999).
At this respect, different interlinked arguments have been used to analyse and explain the potential for innovation of agglomerated firms. The first one centres on *geography:* firms operating within a geographically bounded area benefit from the free flow of intra-cluster knowledge (*spillovers*), which, in turn, is associated with innovation at firm level (Feldmann, 1999; Baptista, 2001). Geographic proximity, it is argued, particularly helps the diffusion of *tacit* knowledge, which is idiosyncratic and highly localised. More importantly, the literature emphasises the need for face-to-face interactions for un-codified knowledge

[1] This work presents the preliminary findings of a comparative study realised within my DPhil project at SPRU.

to be transferred. Secondly, the diffusion of knowledge is also tied to the presence of *productive linkages* within a cluster: vertical division of labour favours user-producer relations and interactive learning (Lundvall, 1988) and inter-firm co-operative behaviour is considered an important source of incremental technological change. A third aspect, which is also often taken transversally into consideration in cluster studies, is that of *social embeddedness* (Granovetter, 1985; Becattini, 1979). Social linkages, which are mainly tied to friendship, kinship and common socio-cultural background of both entrepreneurs and employees, shorten distances between actors and favour interaction. Social embeddedness breeds trustworthy relations and lowers transaction costs. Therefore, in a socially-bounded environment knowledge flows more fluidly and is said to foster processes of local learning.

On the basis of one or more of these arguments, clusters are often conceived as the locus of cumulative and interactive learning ('collective learning') (Lawson and Lorenz, 1999; Capello, 1999) that create a distinctive innovative environment to compete in the globalised world.
However, despite a vast array of empirical evidence (see among many others, Audretsch and Feldmann, 1996; Lawson 1997; Belussi and Gottardi, 2000), the link between clusters and innovation is, to great extent, still a black box and a 'theory of clusters' and their knowledge systems hasn't been developed yet (Martin and Sunley, 2003). In this paper, it is suggested that the existence of this link should to be taken cautiously and, more importantly, that the automatic relation between 'clusters' and 'dynamism' could be potentially misleading (Pavitt, 2001). This point is particularly relevant to prevent policies to be drawn from ideal-type high-tech clusters in the industrialised world and packed into 'best-practices' for developing countries.
More specifically, two main issues emerge:

- The first one, concerns the limited interest of cluster studies in the micro-characteristics of clusters, in particular in *firms*, their knowledge bases and innovative potential. The micro level is typically overshadowed by the 'meso' mechanisms of knowledge diffusion such as: inter-firm mobility of skilled labour force, geographical proximity for face-to-face interactions, degree of productive division of labour, and so on. The idea of technological externalities, in the Marshallian sense, predominates over firms' capacities to generate or benefit from such externalities. Hence, a risk exists that one misses a part of the story and ties meso-level mechanisms to economic or technological outcomes without bearing in mind that the meso level is (dynamically) tied to the knowledge base of firms (Dosi, 1988) that constitute the cluster.

- The second issue concerns the fact that the majority of the studies on clusters mostly concentrate on *intra-cluster* knowledge flows and on *local* processes of collective learning. More recently though, different authors have suggested that being too centred into their internal idiosyncratic competencies, industrial clusters face the risk of getting locked in old technological paradigms and separate progressively from the technological frontier (*negative lock-in*; Grabher, 1993). More importantly, there has been growing agreement on the fact that clusters need to be interconnected, from a productive and cognitive point of view, with external sources of knowledge (see among others Camagni, 1991, Freeman C., 1991, Rullani, 1994; Schiuma 2000).

According to the issues raised so far, this paper aims on one hand, at filling the vacuum left by cluster studies in developing countries, by improving the understanding of their learning and development processes and, on the other, at merging advanced and developing countries studies in order to develop an analytical framework to study patterns of localised learning in both contexts. At this regard, more specifically, this work is interested in improving the understanding of both the absorption of external knowledge at micro level and the creation of knowledge within clusters. In order to explore these issues, an analytical framework is elaborated in the next paragraph.

1.2. An analytical framework: the concept of 'Cluster Absorptive Capacity'

The framework proposed analyses the process of learning and knowledge change in clusters of firms, focusing on the concept of absorptive capacity developed by Cohen and Levinthal (1990). At the organisational level, they define 'absorptive capacity' as "the firms' ability to identify, assimilate and exploit knowledge from the environment" (Cohen and Levinthal, 1989: 569). Similarly, 'cluster absorptive capacity' is defined as the capacity of a cluster to absorb, diffuse and creatively exploit knowledge coming from outside the cluster (Giuliani, 2003a).

Certainly, micro- and meso- knowledge accumulation processes are dynamically related and it is believed that cluster absorptive capacity is a complex concept that does not coincide with the *sum* of single firms' absorptive capacities (cf. Cohen and Levinthal, 1990). Instead, to fully understand this concept, it is necessary to look at the structure of communication between the enterprises of the cluster and between these and extra-cluster sources of knowledge. The interconnection with external knowledge is a critical aspect of the learning process and it's dependent upon the existence of some 'technological gatekeepers' (Allen, 1977; Gambardella, 1993; Giuliani, 2003a), which are conceived here as firms that spontaneously bridge extra-cluster knowledge into the local knowledge system. What follows is a brief review of concepts and theories underpinning the analytical framework presented in this paper.

The first aspect regards the cognitive dimension of firms, which are considered *heterogeneous* agents characterised by different knowledge bases (Dosi, 1988; Nelson, 1991). Beside this, the present work relies on the assumption that different knowledge bases imply different levels of firms' absorptive capacity, which, in turn, influence the propensity to establish knowledge linkages (Cohen and Levinthal, 1990) with both intra- and extra-cluster sources of knowledge (Bell and Giuliani, 2003).

On the basis of this, the view here is that local knowledge systems in clusters ought not to be viewed as locus where spillovers diffuse evenly or randomly in the air. On the contrary, knowledge is *transferred*, *absorbed* and *created* by firms depending on their knowledge bases, on inter-firm cognitive proximity (Nooteboom, 1999; Cowan and Jonard, 1999) and relative absorptive capacity (Lane and Lubatkin, 1997). Moreover, horizontal knowledge exchange is often driven by the existence of a well structured *community* of knowledge workers (von Hippel, 1987; Drucker, 1993), whose communication is based on shared language, beliefs and technical background (Cowan *et al.,* 2000; Creplet *et al*., 2001). Recent contributions in fact emphasise the importance of *communities* of professionals at cluster level for knowledge diffusion and change (Lissoni, 2000; Breschi and Lissoni, 2001). The presence of these communities is conditional to certain enabling conditions, set of incentives, and opportunities which will not be subject to analysis in this present work. Nevertheless, it is believed that the *quality* of human resources at firm level constitutes a preliminary important condition for these communities to form and develop within clusters.

As concerns the absorption of extra-cluster knowledge, this work is based on the consideration that knowledge is acquired *unevenly* by localised firms according to their knowledge bases and cognitive proximity with frontier, external knowledge (Cohen and Levinthal, 1990). Therefore, the absorption process occurs either *directly*, when firms acquire knowledge directly from extra-cluster sources (i.e. suppliers, consultants, universities) or *indirectly*, when the process is a two- or multi-step one; in the latter case, firms acquire knowledge from local firms which have in turn acquired knowledge from external sources (two-step) or from other local firms that eventually have linkages with external knowledge (multi-step) (Rogers, 1983). Firms that acquire extra-cluster knowledge indirectly will have to rely on the presence of *technological gatekeepers*, that channel extra-cluster knowledge into the local knowledge system. This type of firm is important as it can be viewed both as an early adopter of novel technologies and methods of production and, in some cases, as a translator of complex, highly codified knowledge to more contextual and easily understandable knowledge for other local firms.

Finally, a critical distinction needs to be made between the absorption of knowledge in a pure *imitative* manner and the *creative* exploitation of knowledge. Clearly, it is important that firms in the cluster not only absorb external knowledge but also improve the acquired knowledge through internal experimentation and R&D. This is consistent with the idea of the two faces of R&D proposed by Cohen and Levinthal (1989) which suggest that R&D is not only the basis for developing innovations but also for building a knowledge base that allows firms to learn from external sources of knowledge.

On the basis of theoretical framework introduced, it follows that cluster absorptive capacity depends on the combination of different cognitive dimensions: firms' knowledge base, which depends on human capital and innovative effort; the degree of interconnectedness of firms in the local knowledge system and the degree of external openness, which might be tied to the presence of firms that behave as 'technological gatekeepers'.

The author is aware that these dimensions are dynamically related. The relation between firms' knowledge base and intra- and extra-cluster cognitive interconnection has been object of study of a previous work (Bell and Giuliani, 2003) and is therefore not analysed here. This present work has instead an inter-cluster comparative aim. It will try to measure the level of cluster absorptive capacity of different clusters on the basis of the combined observation of the above-mentioned cognitive dimensions. Table 1 presents an analytical framework, which will be taken as reference for this work.

Table 1: Analytical Framework

Levels of Cluster Absorptive Capacity	**Features of Cluster Absorptive Capacity**			
	Knowledge Base of Firms	*External Openness*	*Degree of Interconnectedness of the Local Knowledge System*	*Presence of Technological Gatekeepers*
Advanced (+ +)	High	High	Strong	Yes
⇓⇑	Intermediate levels of Cluster Absorptive Capacity			⇓⇑
Basic (- -)	Low	Low	Weak	No

***Source**:* Author's own

Certainly, reality might be more complex than the one described here, and vary considerably between a range of possible cluster absorptive capacity configurations. What this work is interested in doing, is to map the *relative* cluster absorptive capacity of two clusters and fit them into the continuous and infinite range in-between what, for simplicity, what we has named here '*basic'* and '*advanced'*. Accordingly, a cluster is considered '*advanced*' (see Table 1), if it has the features of an open knowledge system, which is well interconnected with external sources of knowledge (Bell and Albu, 1999). An advanced level of cluster absorptive capacity would also correspond to a highly innovative and interconnected local knowledge system, where potentially all firms would behave as technological gatekeepers. In this case, the process of local learning would therefore be dynamically reinforced by the interaction between localised and external knowledge.

This end of the story represents a stylised –potentially ideal – pattern of acquisition, diffusion and generation of knowledge. The opposite end, i.e. '*basic*', is associated with a closed knowledge system, where firms have weak knowledge bases and interconnect poorly both with extra- cluster sources of knowledge and with other local firms.

1.3. The research question

The idea of cluster absorptive capacity is useful to describe how well or how badly firms in a cluster *learn* collectively. More specifically, it allows to estimate the strength of stocks and flows of knowledge within a cluster and to describe, at one moment in time, the type of learning pattern that characterises it. This type of analysis tries to capture the dynamic side of clusters since knowledge takes time to be accumulated and patterns of learning, undertaken by firms or clusters, will influence what these will be capable of doing in the future. The concept of path dependency (Arthur, 1988; Dosi, 1988) suggests in fact that a certain level of cluster absorptive capacity is attained through an evolutionary process of accumulation of knowledge and formation of knowledge linkages, which might be positively or negatively associated with the cluster development path. Accordingly, cluster absorptive capacity might influence a cluster future achievements.

This work explores the relation between the long term development path of a cluster and its degree of cluster absorptive capacity. On the basis of an extensive literature review of clusters' studies in developing countries (see Giuliani, 2003a), it is expected this relation to be positive. The objective here is therefore to provide novel empirical evidence that supports this idea and that sheds light on the processes of learning of two different performing clusters.

Section 2. Methodology

2.1. Research Design and Collection of Data

The research design of this work is based on the selection of two clusters that, from secondary data, showed different long term performances. The two clusters selected for comparative analysis – Colline Pisane in Italy and Colchagua Valley in Chile – are significantly different in terms of stage of development and performance and at the same time they are comparable in terms of size and target markets.
The selection was based on secondary sources, i.e. specialised literature and interviews to key informants, which allowed identifying some suitable wine clusters in both countries. This phase, then, was followed by site-visits to different potential wine areas, and finally one cluster for each country was chosen for the analysis.

What follows is a brief overview of the criteria adopted to select these two case studies:

↔ Clusters at different stages of their evolutionary path and targeting the same market:

These are a basic requirement for exploring the research question. Despite the fact that both clusters target the international quality-wine markets, the Italian one - Colline Pisane - has the characteristics of a 'laggard' cluster, while the Chilean one –Colchagua Valley- that of a 'catching-up' cluster. To understand this, one needs to know that during the '80s and beginning of '90s the wine industry has undergone in many wine producing countries – certainly in Chile and in Italy- a process of transition from quantity- to quality-oriented production. This transition has been also defined 'wine revolution' (Crowley, 2000) for the strong impact on process and product innovation. The production of more high quality, sophisticated wines which are sold on the international markets is considered a good indicator for performances.

In view of that, Colchagua Valley is at a more advanced stage in terms of wine sophistication and performances. For the international appraisal of its products, it is considered as one of the most promising wine producing areas in Chile (Schachner, 2002). Colline Pisane, instead, has started the transition process later than Colchagua and hasn't achieved yet the performances of the latter cluster.

↔ Clusters with similar size:

Great part of the empirical analysis is based on graph theoretical methods (social network analysis), which constrains the analysis in two directions: first because social network analysis is feasible on a population of firms rather than a sample, which requires that, for the analysis to be feasible, a small cluster is selected (Wassermann and Faust, 1994). On the other, clusters need to be of similar or same size, in terms of number of firms, to allow graph theoretical measures to be comparable across them.

In view of these considerations, two fairly small clusters have been selected and a total of 64 wine producers has been interviewed (see Table 2).

Table 2: Research Design

Cluster	Development Stage	Number of Firms
Colchagua Valley	Catching up	32
Colline Pisane	Laggard	32

The data were collected during two separate fieldwork projects, both undertaken by the author between September and December 2003. Interviews were conducted directly with the technical personnel of the firms, typically the oenologist or agronomist. A structured questionnaire was adopted for that purpose, while relational data were collected through a roster recall method.

2.2. Operationalisation of key concepts: how to measure Cluster Absorptive Capacity

The attempt to *measure* the degree of cluster absorptive capacity might seem rather heroic. Actually, the idea here is not to provide an *absolute* value to which one can attribute an economic meaning *per se*. Rather, the interest is that of providing a *relative* measure whose meaning is conditional to the existence of a comparative value. Hence, attributing a value or a degree for cluster absorptive capacity may make a lot of sense in a comparative study like this one.
The theoretical framework identified the building blocks of cluster absorptive capacity which will be operationalised in the following order: (1) firms' knowledge base; (2) internal structure of the cluster knowledge system; (3) degree of external openness of the cluster and (4) existence of 'technological gatekeepers'. The operationalisation of these concepts has required the identification of suitable proxies or measures for each of them, which are briefly described in this paragraph and in Table 3.

(1) Firms' knowledge base

Firms' *knowledge base* has been proxied by a principal component analysis of four variables: *three* of them concern the background of technical human resources and *one* is a measure for the degree of experimentation led at firm level (see Table 3 and Appendix).
The emphasis on human resources is justified by a pilot fieldwork, that suggested that in this industry technical professionals (i.e. oenologists and agronomists) drive technical change within the firm. These can be conceived as 'knowledge workers' since they embody technical knowledge and *own* such an important 'mean of production' upon which the success of the final product is built (Drucker, 1993).
On the basis of this, the analysis looked at: (1) the level of education of professionals (degree, master, PhD); (2) the months of experience in the sector of professionals; (3) the number of firms in which each single professional has been employed previously. At the same time, the author is aware that a set of professionals do not translate immediately into *firms*, which have their own routines, organisational memory and knowledge development activities, that go beyond that of their single human resources. For this reason, the study included a measure of the experimentation carried out within each firm. According to a set of criteria (see Appendix) the experimentation effort was valued on a 0-4 scale.

(2) The internal structure of the cluster knowledge system

The local knowledge system has been analysed through graph theoretical methods (Wasserman and Faust, 1994), which allow the *structure* of the local system of knowledge to be traced and patterns of knowledge diffusion to be identified.
In order to collect relational data on knowledge transfer, a roster recall method was adopted. Accordingly, each firm is presented with a complete list (roster) of other local firms. The structural variables analysed are collected through the questions reported below:

> ***Q1*: Technical support received [inbound]**
> *Question Q1:* In the case you are in a critical situation and you need technical advice, to which of the local firms mentioned in the roster do you turn to?
>
> ***Q2: Transfer of technical knowledge (problem solving and technical advice) [outbound]***
> *Question Q2:* Which of the following firms do you think have benefited from the technical support from this firm?

Respondents were asked to provide *ratings* for each structural variable. The ratings range from a minimum value of 0 to a maximum of 3. The respondent was asked to attribute a value of 3, to those relations that contribute significantly to the process of technical change of the firm, whereas lower values were attributed to minor contributions. Both relations (Q1 and Q2) define *directed* linkages: Q1 defines the knowledge that each respondent firm has *received* from other local firms and institutions. While, Q2 defines the knowledge that each respondent firm has transferred to other local firms.

The relational dataset thus formed is used to calculate the following graph-theoretical measures (see Table 3 and Appendix): *network density*, which is a measure of the degree of interconnection of firms with the local knowledge system; *cohesive subgroups*, that is, small groups of firms that are strongly linked together, like *cliques, n-cliques* and *cores* (see Table 3); finally, in a case, a centrality indicator (*betweenness* centrality) was adopted to identify key local actors in the network. Specifically, *betweenness* measures the centrality of a firm on the basis of its likelihood to be on the cognitive path between any two other firms in the cluster.

(3) The external openness of the cluster knowledge system

External openness is measured on the basis of the existence of linkages with extra-cluster sources of knowledge with national and international actors. Also in this case, respondents were given a roster of possible actors, which they had to mark on a scale ranging from 0 to 3 according to the contribution to technical change of each knowledge source (see Appendix). 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 the firm?
> * Please include actors that are not mentioned in the roster if they are relevant
>
> ***Q4: Joint experimentation***
> *Question Q4*: Could you mark, among the actors included in the roster*, those with whom you have collaborated in research projects in the last two years?
> * Please include actors that are not mentioned in the roster if they are relevant

These questions were referred for both national and international actors. In the former case, the roster included private firms (such as suppliers or consultants), research institutions (i.e. Universities), technology transfer institutes and business associations. In the latter case, respondents were asked to mention themselves relevant sources of knowledge at international level.

(4) Technological Gatekeepers

Technological gatekeepers operate as bridges between external and internal knowledge systems. Hence, they are identified as those firms with high degree of *external openness* and, with respect to their intra-cluster knowledge linkages, with a high value of *out-degree centrality*. Out-degree centrality is a measure of the knowledge linkages that flow from a given firm to any other of the cluster (see Table 3).

Concepts for Cluster Absorptive Capacity	Elaboration of terms:	Measure adopted in the paper:
(1) Firms' knowledge base	This has two main components: (a) key human resources of the firm (b) propensity of firms to experiment and produce knowledge	Principal Component Analysis of four correlated variables: (a) Technical Professionals: Level of Education, Months of Experience, Number of Firms previously employed. (b) Degree of Experimentation: range from 0 to 4
(2) Intra-cluster knowledge system	Density of local knowledge linkages Formation of subgroups of highly interconnected firms within the cluster Position of firms within the local knowledge system	Network Density**:** The density of a graph is equal to the ratio of ties present in a graph to the maximum ties possible. Core-periphery analysis**:** analysis that allows to identify a cohesive subgroup of core firms and a set of peripheral firms that are loosely interconnected with the core. Cohesive subgroups: ↔ *Clique*: cohesive subgroup in which each firm is connected directly to *all* the other firms ↔ *2-cliques*: cohesive subgroup in which the firms are all connected through at most *one* intermediary ↔ *k –cores* (k=4): cohesive subgroup in which each firm is connected to at least k=4 other firms in the subgroup Betweenness Centrality: it measures the degree of cognitive interconnectedness of a firm on the basis of its likelihood to be on the geodesic (i.e. shortest) path of other firms' knowledge linkages. Normalised (*n*-) Betweenness Centrality: it is the betweenness divided by the maximum possible betweenness expressed as a percentage
(3) External Openness	Propensity to acquire extra-cluster knowledge	External Openness : Proxy for the number of linkages with extra-cluster sources of knowledge (see also Appendix)
(4) Technological Gatekeepers	Firms that have the following cognitive behaviour: (a) are highly connected with extra-cluster sources of knowledge (b) act as sources of knowledge for other local firms	(a) External Openness: see above (b) Outdegree Centrality Index: it measures the flows of technical knowledge that *originate from* the firm and are directed to other local firms - *dichotomous:* analyses the existence of linkages - *valued:* analyses the value given to each linkage on a 0-3 range

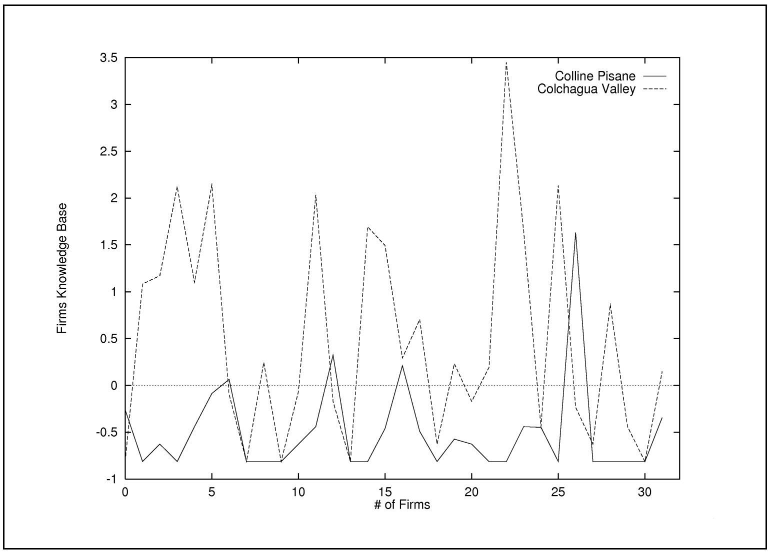
Table 3: Operationalisation of Key Concepts for Cluster Absorptive Capacity
Source: Authors' own

Section 3. Empirical Results

3.1. Firms' knowledge base

According to the empirical evidence collected, firm's knowledge bases vary considerably across the two clusters: in Colchagua Valley, firms appear to have stronger knowledge bases than in Colline Pisane, as shown in Picture 1. In fact, on average, firms in the former cluster reach a knowledge base's value of 0,49; while the value for Colline Pisane is – 0,49 (see Table 4).

Picture 1: A comparison of firms' knowledge bases in the two clusters



***Source*:** Author's own

Table 4 shows in more detail the differences across the two clusters. The first element to be stressed is that in Colchagua Valley, firms employ, on average, *better educated technical personnel*: each firm employs more than two employees [2,2] with degree or upper qualification [master, doctorate] in technical fields. The value for Colline Pisane is 0,37, which means that one out of three firms have on average only one technical graduate fully employed within the firm.
In addition to their educational background, professionals differ in terms of past working experience in the sector. In fact, in Colchagua Valley, professionals have longer previous experiences (164 months *per firm*) than those employed in Colline Pisane (28,6 months *per firm*). Furthermore, professionals in the Chilean case seem also more dynamic in terms of labour turn over and have, on average, been employed by different wine producers within the country and abroad considerably more than those of Colline Pisane (6,5 and 1,3 *per firm* respectively).
More importantly, the Chilean firms of Colchagua Valley perform more in-house experimental activities, than the Italian firms of Colline Pisane. The average value is in fact 1,59 and 0,69 respectively: in Chile, about half of the firms in the cluster leads experimentation in both the vineyard and cellar and eighty percent of them practice at least some form of experimentation. In contrast, in the Italian case, about sixty percent of firms do *not* practice any form of experimentation.

Table 4: Indicators for firms knowledge base

	Indexes of firm's knowledge base				
	Level of Education	**Months of experience in the sector**	**N. of firms previous experience**	**Degree of Experimentation**	***Knowledge Base*** [*min*; *max*]
Colline Pisane	0,37	28,6	1,3	0,69	- 0,49 [–0,8; 1,6]
Colchagua Valley	2,2	164	6,25	1,59	0,49 [–0,8; 3,4]

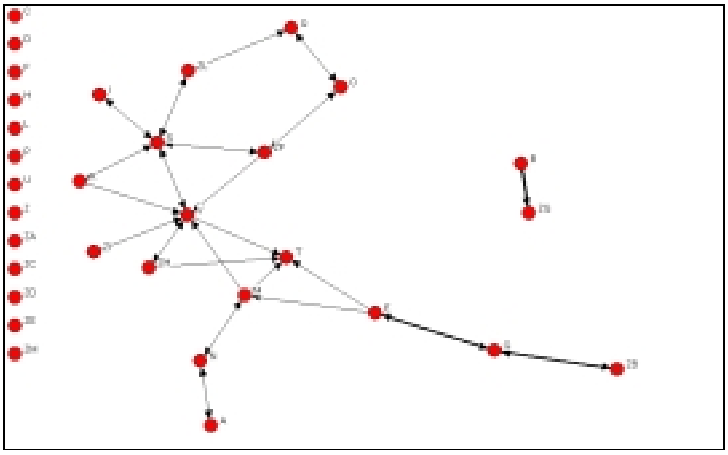
Source: Author's own
Note: The number reported in columns [2-5] refer to average firm values. The value reported in the last column refers to the standardised principal component [μ=0; σ=1]; .

3.2. Intra-cluster Knowledge Systems

3.2.1. Network Density

The density of a network is a measure of the degree of knowledge exchange between firms. Most of neo-Marshallian literature stresses the importance of technological externalities in clusters, since they allow the dissemination of knowledge among co-localised firms and favour innovative behaviours. At the same time, though, in a previous study the author has showed that knowledge does not diffuse evenly 'in the air' (Giuliani, 2003b) and that firms take advantage of localised knowledge, depending on their knowledge bases and on the cognitive distance with other local firms (Bell and Giuliani, 2003). This present study constitutes a step forward, since we show here two knowledge systems (Picture 2 and 3), where firms are differently interconnected.

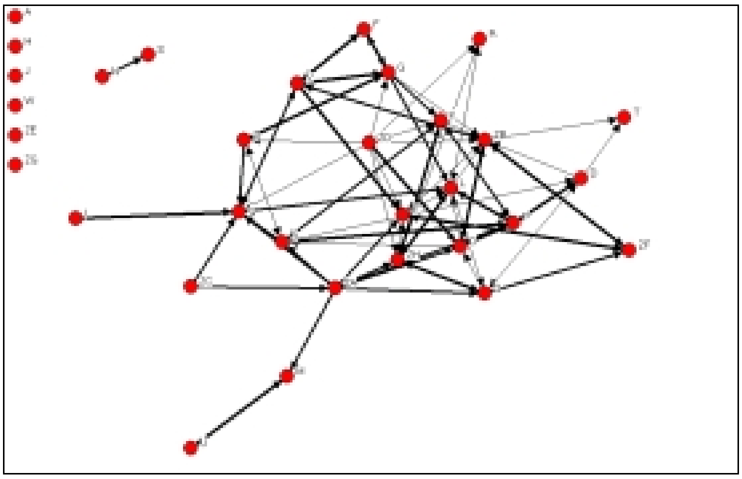
Picture 2: The Knowledge System in Colline Pisane



Source: Author's own
Note: Thicker lines correspond to links that are valued 2 or 3.

Picture 2 depicts the knowledge system of Colline Pisane. It is constituted by a main component of interconnected firms and by a set of isolated nodes. In the latter case, nodes represent firms that do not transfer nor receive technical knowledge from any other firms in the cluster and are therefore cognitive isolates.

Picture 3: The Knowledge System in Colchagua Valley



Source: Author's own
Note: Thicker lines correspond to links that are valued 2 or 3.

In contrast to Colline Pisane, Colchagua Valley is constituted by a denser local knowledge system. Beside the minor incidence of isolated firms, in this latter cluster, even firms that are not isolated tend to interconnect more than in Colline Pisane. This is shown analytically, by comparing the values of network densities of the two clusters considering both the whole datasets of firms and those without isolated firms (see Table 5). It is therefore interesting to note that, when observing results from the whole datasets, firms in Colchagua Valley establish only 10% of total possible knowledge linkages with other firms in the cluster, whereas in Colline Pisane, the value is much lower (3,6%). If isolated firms are not taken into consideration, firms in Colchagua Valley exploit 26% of possible linkages while the value for Colline Pisane is 10%.

Table 5: Network Density

	Network Density (with isolates)	**Network Density** (without isolates)
Colline Pisane	0,036	0,10
Colchagua Valley	0,098	0,26
Network Density Ratio (Colchagua V./Colline P.)	*2,8*	*2,6*

Source: Author's own
Note: Network Density represents the percentage of linkages on total possible linkages.

What emerges from this analysis is that firms in Colchagua Valley tend to interconnect on average three times as much as those in Colline Pisane. This is shown though network density ratio in Table 5; in both cases the value approximates three.

3.2.2. Strength of ties

Another aspect of intra-cluster knowledge exchange is the *strength* of knowledge ties, which is tied to the 'quality' of the knowledge transferred and the 'importance' of the linkages for inducing technical change. As regards this aspect, the analysis suggests that the two clusters differ considerably. In Colline Pisane, knowledge linkages tend to be rather weak since their average value is about one (Table 6). This means that

such linkages are not transferring highly relevant technical knowledge, and, as commented by a respondent during an interview in Colline Pisane, firms exchange knowledge mainly “every now and then, when they meet in special occasions, such as tasting fairs”.
In contrast, in Colchagua Valley ties are stronger and, as shown in Table 6 below, their average value approaches two.

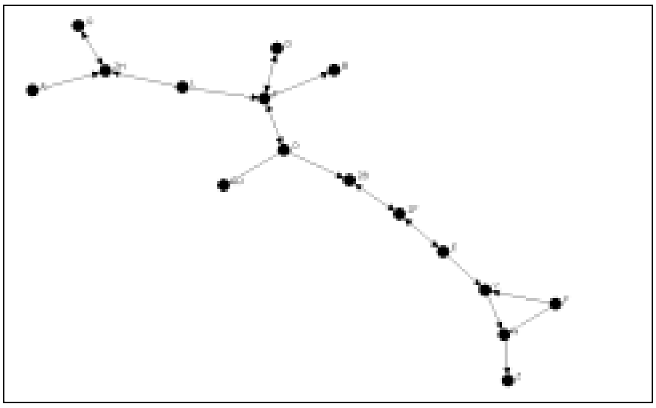
Table 6: Frequency of ties according to strength

	Frequency of ties according to strength			
	Low (1)	Medium (2)	High (3)	Weighted Average
Colline Pisane	31	4	1	1,16
Colchagua Valley	39	29	25	1,9

Source: Author’s own

In the Chilean cluster, therefore, data show that firms tend to establish stronger knowledge linkages. At this respect, we show in Picture 4 the network of knowledge linkages in the cluster, to whom the respondents attributed the maximum value.

Picture 4. Strong Linkages in Colchagua Valley



Source: Author’s own
Note: Value of linkages is three.

The empirical evidence seems consistent with the idea that these inter-firm knowledge linkages are mediated by the emergence of a *community* of technical professionals. Different contributions in the literature have emphasised that knowledge communities bind together different potentially competing firms (among others: von Hippel, 1987; Wenger and Snyder, 2000; Lissoni, 2001). It is suggested that these firms are strongly connected through their professionals, who need technical advice on specific matters and ask for it to other acknowledged and trustful peers. In the case of Colchagua, it is interesting to note that each professional is neither directly nor strongly connected to *all* the other professionals of the area. Instead, the strong connection is made only with two, maximum three peers, which are themselves connected strongly to other peers. Finding an theoretical explanation to this knowledge structure goes beyond the aim of this paper. Nevertheless, it is believed that this configuration might be an *efficient* one for transferring knowledge through the minimum possible linkages and interacting effort. In this case, the community constitutes a sort of *strong* cognitive backbone for the local knowledge system, to which the rest of the clustered firms interconnect in a much looser way.

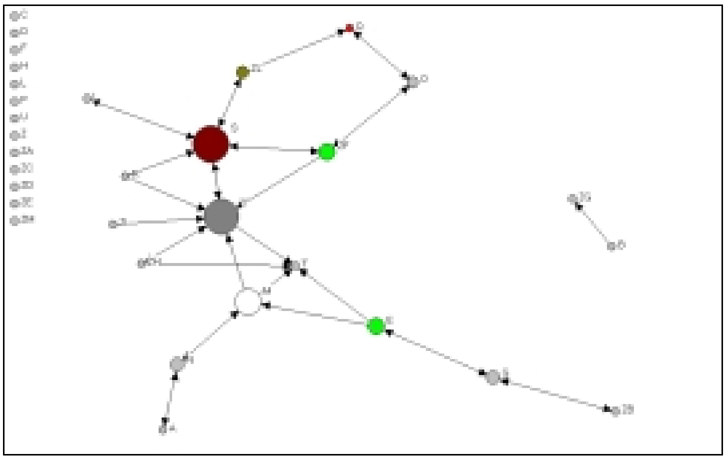
3.2.3. Structure of the intra-cluster knowledge system

The last aspect of the intra-cluster knowledge system concerns its *structure*. By structure we mean the way in which firms are interconnected, in terms of formation of cohesive subgroups and cores, as discussed in the methodological section.

The cluster of Colline Pisane, as shown in previous paragraphs, is characterised by a weak local knowledge system that involves only a limited number of firms; even so, it is possible to identify a *cliquish* pattern of knowledge exchange. By looking at Picture 4, one observes that technical knowledge circulates within *five* small *subgroups* – specifically, four *cliques* of three firms and one *2-clique* of 5 firms-, which are inter-connected by few *central* firms.

Central firms have been identified by *betweenness* centrality, which is a measure that views a firm as being in a favoured position to the extent that it falls on the shortest paths between other pairs of firms in the network. In Picture 5 below, it is possible to recognise central firms by observing the node's diameter.

Picture 5. Colline Pisane: structure of the Local Knowledge System



Source: Authors' own

Note: The size of each node is proportional to betweenness centrality

What emerges is that three main firms have higher betweenness (and n-*betweenness*) centrality: S with 82 (*26,8)*, V with 78 (*25,5)* and M with 53 (*17,3).* The values for S, V and M are far above the average betwenness centrality in the cluster, which is 9,9 (see Table 7 for details).

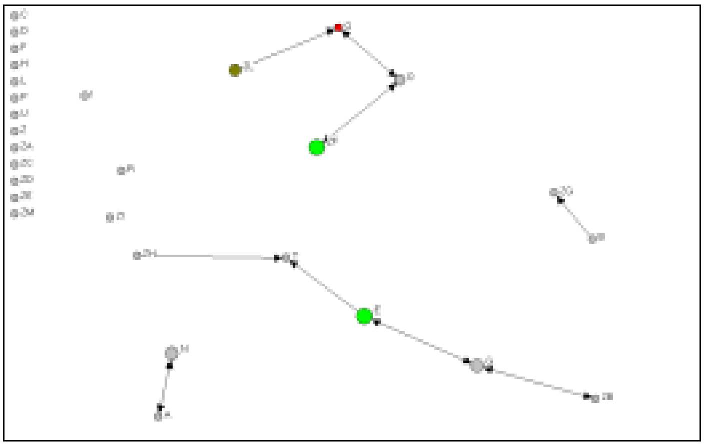
Table 7: Betweenness Centrality in Colline Pisane

Central firms	Betweenness	Nbetweenness
S	82	9
V	78	18
M	53	5
E	26	2,5
ZF	26	2
G	15	1
N	15	1
ZL	12	1
O	9	1
Q	1	1
Average	*9,9*	*1,06*

Source: Author's own

According to these results, the elimination of these firms or their un-cooperative behaviour would disconnect the network (see Picture 6). It is therefore suggested here that the local knowledge system in Colline Pisane is *weakly anchored to three key firms* and therefore it is potentially vulnerable to their learning behaviour.

Picture 6. Disconnection of the Local Knowledge System in Colline Pisane



Source: Author's own
Note: The size of each node is proportional to betweenness centrality

The case of Colchagua Valley is considerably different from the previous one. The local knowledge system is more complex and rather than being cliquish, it shows a typical *core-periphery* pattern of knowledge exchange (Borgatti and Everett, 1999). This means that there is a subgroup of firms in the network that is highly interconnected and constitutes the cognitive *core* of the local system, while the firms that gravitate around the core form part of a *periphery*. Firms in the core tend to be highly interconnected among them; instead, peripheral firms tend to establish loose linkages with the core firm and not to interconnect with other peripheral firms.
More specifically, as shown in Table 8, the density of these 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) vary in each case[2]. It is higher for core-to-core relations (0,571), which means that core firms tend to transfer knowledge more often within the core. Core firms are also sources of knowledge for peripheral firms (core-to-periphery density is 0,155) but this relation is much looser than the previous one. At the same time, core firms tend not to receive knowledge from peripheral firms (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).

Table 8. Density of linkages within and between core and peripheral groups

	The Density of Linkages (Knowledge transfer from row to column)		**Average Knowledge Base**
	Core	**Periphery**	
Core (*n_C=14*)	0, 571	0,155	**0,58**
Periphery (*n_P=18*)	0,083	0,026	**-0,45**

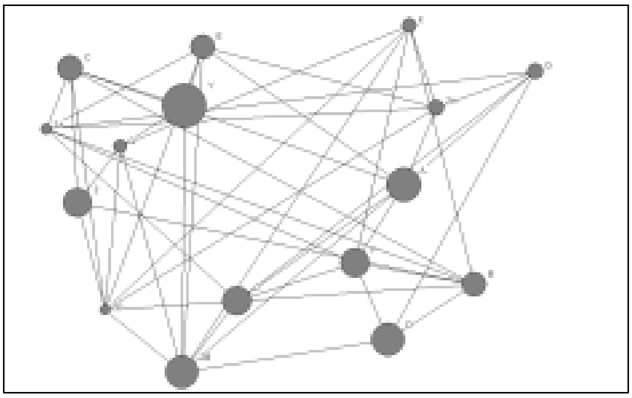
Source: UCINET 6 applied to author's own data.

The core-peripheral network observable in Colchagua Valley might be considered a good structure for the diffusion of knowledge at local level, for two sets of reasons: on one hand because there is an intense

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

exchange of knowledge within the core. Core firms, in fact, are all linked together by the local community of professionals (see also Par. 3.2.2.), who exchange and incrementally improve knowledge, creating a self-reinforcing environment of collective learning; on the other hand, core firms are important drivers of more advanced technical knowledge for laggard firms in the periphery. At this respect, in fact, it is interesting to observe that core firms have an average 'knowledge base' of *0,58,* while the same data for peripheral firms is *–0,45*. This seems consistent with the idea that key core firms, having higher knowledge bases, boost local processes of incremental learning and stimulate some peripheral firms to ask for technical advice, although these relations are not as strong as those within the core group.
Core firms, instead, form part of a fairly dense and cohesive subgroup of highly interconnected firms. To improve the understanding of this subgroup, we included the analysis of *4*-cores within the network. Basically, this operation identifies those firms that have established at least 4 knowledge linkages with other firms of the subgroup. Hence, if we take into consideration any inter-firm knowledge linkages, independently of the strength, then we find a complete network of interrelated firms, as shown in Picture 7 below.

Picture 7: The core group in Colchagua Valley: an analysis of *4*-cores



Picture 2: The core group: an analysis of *4*-cores, considering any knowledge linkage
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.
(Source: UCINET 6 on author's own data).

3.2.4. A Synthesis

To conclude, these two clusters show different patterns of localized learning (Table 9). On one hand, Colline Pisane is weakly anchored to few firms and knowledge linkages are poor, mainly limited to small cliques of firms. There isn't, in other words, an environment of 'collective learning' or an 'industrial atmosphere' that fosters processes of incremental innovation at local level. On the contrary, most firms seem to rely on their internal competencies or on the acquisition of knowledge through the market (see next paragraph).
In Colchagua Valley instead, firms are more interconnected cognitively and linkages seem to be more stable and stronger. Knowledge flows primarily within a subgroup of firms (i.e. the core), which are connected through a local knowledge community. Within the core, in fact, knowledge is exchanged through joint problem solving of technical professionals ('knowledge workers'), who collectively contribute to the incremental improvement of localized knowledge. Albeit mainly restricted within the boundary of such community, technical knowledge also flows to some peripheral firms, partially strengthening the process of local learning.

Table 9: Intra-cluster knowledge systems in Colline Pisane and Colchagua Valley. A synthesis

	Intra-cluster Knowledge System		
	Network Density	**Strength of Ties**	**Structure of the Local Knowledge System**
Colline Pisane	0,036	Weak	Cliquish
Colchagua Valley	0,098	Strong	Core-periphery

Source: Author's own

3.3. <u>External openness of the cluster</u>

The extra-cluster sources of knowledge in both clusters are primarily constituted by research institutes and universities, suppliers, consultants and business associations. As shown in Table 10, firms in Colchagua Valley have a higher propensity to co-operate with research institutes than firms in Colline Pisane. In the latter case, in fact, only 28% of respondents declare of benefiting of the transfer of technical knowledge from such institutions. This percentage is considerably higher (69%) in the Chilean case, where industry-university linkages appear to be more frequent. Suppliers of inputs are equally important in the two clusters since around 60% of the firms name them as sources of knowledge. An additional source of knowledge is constituted by technical consultants: in both clusters the vast majority of firms hire consultants to promote technical change. At this respect, firms in Colline Pisane typically hire domestic consultants, while firms in the Chilean case have stronger linkages with international consultants, typically French, Australian, South African or Californian. Finally, business associations seem to play a relevant role in technology transfer only in the Chilean case.

Table 10: Sources of extra-cluster knowledge and external openness

	% of firms with at least one knowledge linkage with:				**External Openness**
	Research Institutes	**Suppliers**	**Consultancies** [domestic; foreign]	**Business Associations**	
Colline Pisane	28%	56%	97% [97%; 0%]	3%	3,4
Colchagua Valley	69%	60%	97% [69%; 53%]	56%	7,4

Source: Author's own

From the results commented above, it emerges that firms in Colchagua Valley are more interconnected to extra-cluster sources of knowledge than firms in the Italian cluster. The values for 'external openness' are in fact 7,4 and 3,4 respectively. It clearly contradicts the general view that advanced countries have stronger national innovation systems; in this case at least, the Chilean cluster appears to be far more dynamic in terms of acquisition of extra-cluster, typically frontier knowledge, than the Italian one. In the next paragraph, we will show how extra-cluster knowledge percolates into the cluster's knowledge system through technological gatekeepers.

3.4. *Interfacing extra- and intra-cluster knowledge flows: the presence of technological gatekeepers*

In this last part of the work, we are interested in identifying the presence of firms that have a high degree of external openness and that at the same time contribute to the diffusion of acquired knowledge to other local firms (i.e. 'technological gatekeepers'). Also in this case, empirical results mark a great difference between the two clusters. In Colline Pisane, in fact, there is no clear evidence of technological gatekeepers, whereas in Colchagua Valley, one observes the emergence of several firms that perform such a role.
Table 11 reports the main findings of the analysis. In columns, we listed the labels of firms of both clusters, that have a considerably high level of out-degree centrality[3]. According to this listing rule, Table 11 includes one firm belonging to the Colline Pisane case and ten firms from Colchagua Valley.

Table 11: Technological Gatekeepers

	Measures for technological gatekeeping			**Number of technological gatekeepers**
	Out-degree C. (dich.)	**Out-degree C.** (valued)	**External Openness**	
Colline Pisane				**0**
S	5	5	4	
Ave. cluster	*1*	*1,2*	*3,4*	
Colchagua Valley				**9**
B	*6*	*10*	*9*	
C	*8*	*15*	*8*	
E	*6*	*11*	*12*	
K	5	9	10	
L	*7*	*13*	*12*	
O	5	12	12	
P	*6*	*15*	*8*	
Q	5	9	3	
ZB	*10*	*13*	*11*	
ZH	*7*	*12*	*7*	
Ave. cluster	*2,9*	*5,3*	*7,4*	

Source: Author's own

If we consider the degree of external openness, we observe that in the Italian cluster the only firm with relatively high out-degree centrality (firm 'S') has a low degree of external openness (4), especially if compared to average of Colchagua Valley's (7,4). Accordingly, such firm has the features of a local 'source' of knowledge, rather than that of a 'technological gatekeeper'.
In contrast, Colchagua Valley tells us a very different story. Among the firms listed in Table 9, nine have a high degree of external openness and are therefore considered here as 'technological gatekeepers'[4].

Section 4. Discussion of Empirical Results

4.1. Assessing Cluster Absorptive Capacity

[3] A cut-off value of *five* on dichotomous data was chosen arbitrarily by the author. This includes firms that transfer knowledge to at least 15% of firms in the cluster.
[4] For a comprehensive analysis of firms' cognitive positions and technological gatekeeping in the Colchagua Valley cluster, see also Bell and Giuliani (2003).

From the empirical evidence showed in previous sections, it is possible to draw a final picture of the level of cluster absorptive capacity of the two selected clusters. As said, the attempt to *quantify* cluster absorptive capacity is beyond the aim of this paper. This final part, instead, is an effort to provide a *qualitative* overview on the basis of the quantitative data provided so far.
The conclusion that can be drawn is that the cluster of Colline Pisane has a *lower degree* of cluster absorptive capacity if compared to Colchagua Valley. This consideration is based on an analytical reconstruction of the elements that build the concept. More specifically, firms' knowledge base is weaker in Colline Pisane and also the innovative effort led at firm level is rather limited; in the latter cluster, moreover, the knowledge system is based on weak ties and a high number of firms appear to be cognitively isolated. While intra-cluster knowledge diffuses poorly across localized firms, extra-cluster knowledge in this cluster is only slowly boosting a process of technological change. Few linkages are in fact established with external sources of knowledge and none of the firms play the interfacing role of technological gatekeeper. In Colchagua Valley, instead, firms have stronger knowledge bases and tend, on average, to experiment more. Moreover, compared with the previous cluster, the local knowledge system appears more structured and strong linkages appear more frequent. Furthermore, the presence of firms that behave as technological gatekeepers, allows extra-cluster technical knowledge to be more easily diffused within the cluster (see Table 12).

Table 12: Comparing Cluster Absorptive Capacity in Colline Pisane and Colchagua Valley

	Determinants of Cluster Absorptive Capacity:				Degree of CAC
	Firms' Knowledge Base	**Intra-Cluster Knowledge System**	**External Openness**	**Technological Gatekeepers**	
Colline Pisane	- Weak HR - Poor innovators	Weak ties Cliquish	Low	None	-
Colchagua Valley	- Strong HR - Moderate innovators	Strong ties Core-periphery	Medium	Nine	+

Source: Author's own

The evidence shows therefore, that these two clusters, which have different performances and are at different stages of their evolutionary path, have also different levels of cluster absorptive capacity. According to results, therefore, better long term performances are here associated with higher cluster absorptive capacity.

4.2. Discussion and final conclusions

The aim of this work was that of shedding light on the process of knowledge absorption, diffusion and creative exploitation in clusters of firms. Accordingly, it provided detailed and analytical evidence of two clusters' learning processes and emphasises the main differences between them.
Albeit rich in empirical data, the paper hasn't so far discussed extensively the theoretical explanations and implications of the evidence collected. This concluding part is therefore proposed to summarise the key issues emerging from the empirical analysis and to address some outstanding concerns which need to be further investigated.

A key issue that emerges from the paper, regards the link between cluster absorptive capacity and long term performance of a cluster. Albeit limited in scope, these results suggest that a positive relation might exist between the two dimensions. Certainly, in the short period, the success of a cluster might be related to a set of other variables. In the case of the wine industry, success might depend, e.g., on excellent natural endowments, on booming international markets, on the exploitation of regional positive reputation, built up by other neighbouring wine areas etc. But in the long term, these factors might not be sufficient. In presence of a more competitive market and of a slow down of consumptions' trends, it might be suggested that clusters with higher absorptive capacities might do better than others. At least, these will be able to compete on the basis of their knowledge endowments and accumulated competencies. Given the cumulative nature of knowledge, and the subsequent long term evolution of cluster absorptive capacity, it might be the case that we can predict what a cluster is capable of achieving in the future on the basis of present levels of cluster absorptive capacity. For this reason, it is important to spell out the main components of this process and to improve the understanding the link between micro- and meso- learning behaviours.

At this respect, another key issue that emerges in this story, is that the <u>quality</u> of clustered <u>firms</u> might be central to promote knowledge generating networks within the cluster. More importantly, it has showed that, in the cases analysed, the "knowledge in the air" marshallian (and neo-marshallian) story of *cluster*'s learning and innovation is somewhat fake. Hence, it seems at least inaccurate to conceive clusters as potential "cognitive laboratories", as it has done for industrial districts (Bellandi, 1989). In the case of Colline Pisane, for example, the intra-cluster knowledge system is remarkably weak and no collective learning process is detectable; even in the more advanced cluster of Colchagua Valley the circles within which knowledge is <u>diffused</u> and <u>generated</u> are restricted to a relative small proportion of firms (see on this also Bell and Giuliani, 2003). For this reason, it is suggested here that the geography-spillover-innovation story (Feldmann, 1999) is a good story when firms have advanced knowledge bases and creatively take advantage of geographical proximity. In contrast, in the presence of firms with weak knowledge bases, the process of diffusion of knowledge 'slows down' and so does its innovative potential. Besides, in this case, firms tend to have limited linkages with extra-cluster knowledge and, at the same time, not to produce knowledge in-house. Consequently, it can be argued that very limited absorption and generation of <u>new</u> knowledge by cluster firms has an impact on the quality of knowledge that is ultimately diffused and its potential to induce technical change in the cluster. This generates ideal conditions for negative lock-ins.

Cluster policies normally tend to foster co-operative networks (Schmitz, 1995) and collective mechanisms of co-ordination also by appointing brokers to manage the relations (Martin and Sunley, 2003). This work, which focused purely on cognitive/knowledge networks, is not in principle suggesting that the more networked the firms are, the better it is: if in poorly connected clusters firms face cognitive isolation, too much networking might not necessarily be a viable strategy for development. Instead, this work would like to stress that before network policies are promoted, the role of firms and their knowledge endowments in the formation and enhancement of such networks ought to be better understood.
It is believed that further investigation should be directed to the analysis of cognitive positions of firms within the cluster; particularly to the mechanisms and incentives (or lack of) that lead to the emergence of technological gatekeepers on one hand, and cognitively isolated firms on the other.

APPENDIX

A: Knowledge Base

Knowledge base includes measures of *human resources* and *experimentation* (R&D). In our case, a factor has been extracted through principal component analysis, which is a combination of the following four variables.

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:

Human Resource = 0.8* Degree + 0, 05* Master + 0,15* 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.

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* n° months (national)+ 0,6* n° 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.

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*n° firms (national)+ 0,6* n° firms (international)

This variable is regarded important in this specific sector on the basis of its 'biological' variability and poor standardisation. The opportunity of turning over different firms and experiencing different harvests in different regions is in fact highly formative as it provides elements and benchmarks for problem solving.

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 that explains 75% of the variance. This has been considered sufficiently satisfactory to adopt is as a cumulative indicator of 'knowledge base'. The factor extracted has been standardised.

B: Centrality

The identification of central actors in a network is among the primary uses of graph theory. Indeed, attempts to quantify the position of actors in a network date back to Moreno's work (1934) on the notions of sociometric 'stars' and 'isolates'.
In this work we adopted two main measures of centrality: actor degree centrality (out-degree centrality) and betweenness centrality.

The **actor degree centrality** depends on the links that one actor has with the other actors of the network. It is a simple measure because it counts the direct ties with other actors. It can be calculated both for undirected and directed graphs. In the latter case, as in Q1 and Q2, we will have both indegree and outdegree centrality indexes. The indegree counts the number of ties incident *to* the node and the out degree 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.

This formulae provides values that are not comparable across networks of different sizes. For this reason it is possible to standardise the measure by:

$C'_D(n_i) = d(n_i)/(g-1)$

In our study, outdegree centrality provides a measure of the firms that transfer knowledge in the network, among which we will find technological gatekeepers. It is also useful to study the cognitive positions of firms in the network.

Actor betweenness centrality is a measure of centrality that consider the position of actors in-between the shortest paths that link any other actors of the network. In other words, an actor is central if it lies between other actors on their *geodesics*, that is, on the shortest path between them. Hence of we have a large betweenness centrality, the actor must be *between* many of the actors via their geodesics.
How it is calculated: Let g_{jk} be the number of geodesics linking actors j and k. Then, if all the geodesics are equally likely to be chosen for the path, the probability of the communication using any one of them is $1/ g_{jk}$. The probability that a distinct actor i lies on the geodesics between j and k is $g_{jk}(n_i)$. Hence, the actor betweenness index for n_i is simply the sum of these estimated probabilities over all pairs of actors not including the i^{th} actor.

$Cb\ (n_i) = \sum_{j<k} g_{jk}\ (n_i)/ g_{jk}$

This index has a minimum of zero when ni falls on no geodesics and a maximum which is (g-1) (g-2)/2 which is the number of pair of actors not including ni. (g=total nodes in the network)
Since the index value depends on g, it's standardised version will therefore be:

$Cb'\ (stand)\ (n_i) = cb\ (n_i) / [(g-1)\ (g-2)\ /2]$

C: Cohesive Subgroups and Core/Periphery Models

Cohesive subgroups are subsets of actors within a network among whom there are relatively strong, direct, intense ties. One normally expects greater homogeneity among the members of a cohesive subgroups than between different subgroups. The literature has provided many methods for identifying cohesive subgroups (see e.g Alba, 1973; Freeman, 1992); here we make reference to cliques and n-clans.

A **Clique** in a graph is a maximal complete subgraph of three or mode nodes. It consists of a sub-set of nodes all of which are adjacent to all of the members of the clique. In a graph we can have more overlapping cliques. They are considered as a very strict definition of cohesive subgroup because it includes only directly connected nodes.
By definition, an ***n*-clique** is a maximal sub-graph in which the largest geodesic distance (i.e. the shortest distance between any two nodes), *d*(i, j) between all nodes in the subgraph is no greater than *n* (Wassermann, Faust, 1994). In this paper we used a value of n=2. 2-cliques are in fact subgraphs in which all members need not to be adjacent but all members are reachable through at most one intermediary.

A ***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.

Core/Periphery models are based on the notion of a two-class partition of nodes, namely, a cohesive subgraph (the core) in which actors are connected to each other in some maximal sense and a class of actors which are more loosely connected to the cohesive subgroup but lack any maximal cohesion with the core (Borgatti and Everett, 1999). 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.

D: External Openness

External Openness has been analysed considering the knowledge linkages of firms with extra-cluster sources of knowledge. The questionnaire included a list of institutions and research centres that form part of the National Innovation System. Suppliers and consultants were also taken into consideration, as well as any other linkage at national and international level.

In the analysis, we have grouped the linkages into ten 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'. If a firm has the maximum level for each source, it means that is it well interconnected with all the sources and reaches or approaches a value of 30 for external openness.

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