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This Working Paper has been written in the context of the 2004-2005 European Forum programme on 'The Role of Universities in the Innovation Systems', the overall direction and coordination of which was carried out by Professor Rikard Stankiewicz, EUI, and Dr Aldo Geuna, EUI and SPRU, University of Sussex.

The growing role of universities in the 'knowledge economy' is well known. A dynamic and well-balanced academic system is a key engine of innovation and economic development. Doubts persist however as to whether Europe's universities are fully capable of fulfilling that role. The members of the Forum approached these issues by focusing on the following research themes: (1) Universities and the changing dynamics of knowledge production; (2) Patterns of the division of labour in research and innovation system; (3) The internal organisation of academic systems: tensions and adaptations; and (4) Diversity, innovativeness, and the governance of academic systems.

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Abstract

Public research organizations (PROs) are increasingly considered central actors in the process of economic development of national and sub-national contexts. In recent times their direct involvement with the industry has increased, and policies have been designed to promote PRO-Industry (PRO-I) networking. However, a voice of concern has come from those worried by the increased popularity of the 'entrepreneurial university,' a term used to describe universities which open their research to commercial ends. These have stressed the importance for PROs to pursue fundamental quests, as long-term economic development is grounded on basic and serendipitous research. This paper starts from considering the tension existing between these two views. Drawing on Burt's 'structural holes' idea, the paper develops a concept of 'efficient' PRO-I knowledge network, which minimises the cost of direct PRO-I linkages, while maximising the diffusion of PRO-I generated knowledge in the economic system. Based on micro-level data in the wine industry and in two national contexts (Chile and Italy), the paper uses a combination of methods (social network analysis, econometrics) to explore the factors that affect the structural characteristics of PRO-I networks in terms of their efficiency.

Keywords: Public research organizations, knowledge networks, structural holes, wine industry

1. Introduction*

Public research organizations[1] (PROs) are increasingly considered central actors in the process of economic development of national and sub-national contexts. In recent times their direct involvement with the industry has increased and policies have been designed to promote PRO-Industry (hereinafter, PRO-I) networking. However, a voice of concern has come from those worried by the increased popularity of the 'entrepreneurial university,' a term used to describe universities which open their research to commercial ends. These have stressed the importance for PROs to pursue fundamental quests, as long-term economic development is grounded on basic and serendipitous research (Nelson, 2004). In view of this, it has been observed that PROs' increasing orientation towards industry may end up shaping their research agenda towards more applied research with visible short term outcomes, which will eventually downplay the role of basic research. This paper starts from considering the tension existing between these two views: on the one hand, the consideration that PROs are central actors in the economic development process, and on the other, that PROs' enhanced networking with the industry may come at a *cost* in the long term for the development process itself (Section 2.1). On the basis of this, a research question is raised in Section 2.2 which speculates on the conceptualisation of 'efficient' PRO-I knowledge networks, which may resolve the tension discussed above, and therefore minimise the *cost* of direct PRO-I linkages, while maximising the diffusion of PRO-I generated knowledge in the economic system.[2] Using methods of social network analysis (Wasserman and Faust, 1994), this paper operationalises the concept of PRO-I network efficiency. Inspired by Burt's (1992) work on 'structural holes,' it analyses firms' brokering and PRO-I network redundancy. As will be discussed in Section 2.2, the presence of broker firms is highly desirable as they allow PROs' generated knowledge to be transferred into the economic system, behaving as technological gatekeepers of the PRO-I network (Giuliani and Bell, 2005). In contrast, excessively redundant PRO-I networks, by that meaning networks where firms, which are highly connected in their economic system, also have linkages with the same set of PROs, are considered to be 'inefficient.' Section 2.3 elaborates a series of research hypotheses, to explore the factors that affect the formation of direct PRO-I linkages and of brokering firms, considering both firm-level and PRO-level characteristics. This is done to provide a micro-level interpretation of what may affect the formation of 'efficient' PRO-I networks. The analysis is carried out on empirical data. As illustrated in Section 3, the empirical analysis is applied to two wine producing areas, in Chile (Colchagua) and Italy (Bolgheri/ValdiCornia), and considers the population of fine wine producers in each area, as described in Section 4. In both cases, PROs are not situated within each of the wine areas but they are scattered in the national territory. Section 4 also presents the operationalisation of concepts used to assess and compare the levels of the two PRO-I network efficiency and to test the hypotheses of the research. Section 5 presents the empirical results. It shows that the Chilean PRO-I network is more efficient than the Italian one in that it has more broker firms and a limited redundancy (Section 5.1). The test of

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1 With the term public research organizations I refer here generically to both public universities and non-university research institutes.

2 The concept of efficiency here strictly refers to the cost that arises for the society as a whole when researchers in PROs shift from long term serendipitous research to more applied short term research. As such, it is not related with firm-level costs of networking.

hypotheses (Section 5.2) reveals that the two cases differ considerably in the way micro-level variables, both at the firm and PRO-levels, affect the formation of direct linkages and brokerage. Section 6 discusses the results, elaborates briefly on possible policy implications and provides suggestions for further research.

2. Theoretical Framework & Research Hypotheses

2.1 PRO-Industry networking and development: the inherent tension

From a developmental point of view, universities and PROs in general are increasingly considered central players in the economic system.[3] The whole National System of Innovation literature (Lundvall, 1992; Nelson, 1993) and its sub-national versions (e.g. Cooke, 2001a; Charles, 2003; Kitagawa, 2004) suggest that the generation of public knowledge from PROs is, together with industrial R&D, an engine of growth. This literature also emphasizes the need of PROs and industry to interact and be part of a system of relationships that enhance the regional and national innovative capacity. This central role of PROs in national and sub-national contexts has received rising consideration by the literature, and several studies have highlighted the changing role of Universities in the economic system, characterised by the reduction of their historical 'ivorytowerism' (Gibbons et al., 1994; Etzkowitz, 2002) and by the start up of a 'third mission' (Etzkowitz and Leydesdorff, 2000), based on PROs' more direct contribution to industry. Terms like the 'entrepreneurial university' or the 'commercialisation of academic research' (e.g. Etzkowitz, 1998; 2003) were coined to describe a new type of involvement of Universities in business: 'There are two dynamics at work (…): one is an extension of university research into development, the other is an insertion into the university of industrial research goals, work practices and development models. These activities may initially take place as isolated and separate initiatives. At a later time, they may fold back upon each other in spiral fashion and become integrated into each other (…).' (Etzkowitz, 1998)

If it is true that university-industry linkages are not *per se* a recent phenomenon (Etzkowitz, 1998), it is equally true that these linkages have considerably augmented in the recent past. This may be due to an increasing trans-disciplinarity of the knowledge production process, which requires tight interaction among science and technology (Faulkner, 1994), as well as to the policies that both in the US and in Europe—and now increasingly more in developing countries—have promoted the interaction of public research institutions and the industry (Geuna, 2001; Velho and Saenz, 2002; van Looy et al., 2003; see also, Mowery et al., 2001). This higher involvement of PROs with industry has been accomplished by a set of different mechanisms and channels of interaction (Bonaccorsi and Piccaluga, 1994). These range from informal meetings, to consultancy work commissioned by the industry and not involving original research, collaborative research and joint research programmes to, finally, the licensing of university patents or the purchase of prototypes developed by the industry (Schartinger et al. 2002; D'Este and Patell, 2005). Supported by a series of successful case studies (e.g. Saxenian, 1994; Longhi, 1999; Cooke, 2001b), a view has been widely accepted that PRO-I networking, through one or more of these channels, is a desirable thing, since it allows PROs to play a more active and visible role in the economic development of national or sub-national systems.

The 'big push' towards PRO-I networking has also generated a series of issues of concern. The process of diverting science to the needs of technological change and the increasing problem-solving orientation of academic research is believed by many to come at a cost, and several critics have been moved to the 'entrepreneurial' model of PROs (Slaughter and Leslie, 1997). Changes in the incentive structure of academicians may well favour short term effects to industry but they are likely to

3 In this paper I consider PROs as a broadly defined set of public research institutions of both university and non-university nature. It should be noted, however, that there is an enormous heterogeneity in the structure, size, and behaviour of PROs, both within the same nation and across countries, which affect the role that they play within the economic system they are part of (Mowery and Sampat, 2004).

undermine economic growth over the long term (Dasgupta and David, 1994). In the same vein, Pavitt (2001) and Nelson (2004) warned that the basic research system is responsive to society's needs and that serendipity 'is the reason why scientific research often has practical pay-off, and the chances of serendipity are greatest when bright and dedicated scientists are free to attack what they see as the most challenging scientific problems in the way they think most promising' (Nelson, 2004, p. 456). Moreover, 'the notion that academic scientists have no idea and do not care about the practical problems that their research might illuminate has never been fully true' (Nelson, 2004, p. 456). These views conceive the 'entrepeneurial university' as a model that may inhibit researchers' intellectual freedom and consequently take them further away from their natural role in PROs (Tapper and Salter, 1995). What follows is therefore that PRO-I networking *may come at a cost* as high dedication to industry networking on highly applied and problem-solving oriented research may risk to undermine PROs commitment to basic, long-term research.

These views highlight an inherent tension between the developmental goals of those who try to increase PRO-I networking and those who are sceptical about the 'entrepreneurial university model' and the hybridisation of PROs' historical role as generators of public knowledge. This tension is taken as an inspiring motive for this empirical study. Specifically, this study looks at whether it is possible to identify PRO-industry knowledge networks, whose structural characteristics are more efficient in minimising the tension discussed above. This is further elaborated in the section that follows.

2.2 Conceptualizing an 'efficient' PRO-Industry network structure

PRO-I networks are often mentioned in the literature but seldom, with few exceptions (Owen-Smith and Powell, 2004; Owen-Smith et al., 2002), are they studied in their structural characteristics. As Smith-Doerr and Powell (2003) noted, the literature on networks has taken two quite distinct directions: one focused on methods and another one on governance. While most studies tend to take the latter direction, this paper takes the former and studies PRO-I networks using graph-theoretical tools to explore the structural characteristics of networks and the positions of different social actors, namely PROs and firms, in the network. Within this tradition of studies, considerable effort has been made to associate certain network structures to performance (Powell and Smith-Doerr, 2003). The underlying idea is that the best connected people in a network enjoy higher returns – a condition that also allows the maximisation of returns at a more aggregate level. An influential contribution in this respect is represented by Burt's (1992) work on structural holes. In contrast to Coleman (1990), who emphasised the advantages of network closure, where agents are all connected to each other, Burt (1992; 2001) elaborated a theory of brokerage between otherwise disconnected subgroups of a network, which is vital to the overall network performance. As he put it: 'where closure creates advantage by lowering the risk of cooperation (….), brokerage, creates advantage by increasing the value of cooperation' (p. 208). In other words, the presence of many brokering agents promote diverse and non-redundant interactions, thus stimulating creativity and learning. Interactions of this type are associated with the formation of 'structural holes' in that agents with brokering roles are not densely connected to the other network agents – i.e. they bridge otherwise disconnected agents – thus they are surrounded by 'holes'. These concepts are not new to sociological and, lately, physicist thinking. Indeed, on the stream of Milgram's famous six degree of separation study (1967), Granovetter (1973), first, and Watts and Strogatz (1998) later, have stressed that sparse distant networking and local 'cliquishness'[4] may be a desirable network structure, which favours more diverse networking (i.e. between distant nodes) and therefore enhances creativity and innovation, also avoiding the costs of too dense networking – i.e. the network redundancy (Borgatti, 1997). The whole idea underlying these studies is thus that *too* densely connected actors generate overlapping linkages which are redundant, meaning that they are likely to carry information with very similar content. It should be observed that redundant networks are not necessarily detrimental to innovation, in fact, they may also be desirable.

4 The term 'cliquishness' refers here to the high density of interconnection among neighbouring nodes in a social structure.

However, since the formation of direct PRO-I linkages has a cost, as previously discussed, the argument here is that the diffusion of available knowledge can occur in a more parsimonious, efficient way, where not all actors are connected to the others but where the network structural characteristic still permits knowledge to be spread to the actors of the economic system. Shifting from the sociological to the economic perspective, Cowan and Jonard (2003) advanced in this direction, developing a theoretical model that links the structure of a network of economic agents to their performance, in terms of their collective capacity to innovate. They mentioned that high 'cliquishness' may produce a *negative effect* related to repeated interactions with the same informational content and show that when a *small fraction* of linkages is at 'long distance,' connecting actors forming part of different local cliques (i.e. the 'small world' structure) performance is higher, under particular firm-level conditions. Moreover, Cowan (2004) has speculated on how network structures may connect to economic efficiency. In that context, since networking has a cost (Jackson and Wolinksy, 1996) in terms of time and effort paid to the formation of linkages, redundant networks may not only be less likely to promote innovation and creativity but they may also be more inefficient. However, with few exceptions (e.g. Wilhite, 2001), the economic literature has yet not fully addressed this issue, as Cowan (2004) himself mentioned: 'there has been considerable work now describing economic networks, and it is clear that the small world structure is pervasive, yet there has bee little empirical work addressing the efficiency of different structures.' (p. 17).

In contrast to these studies, this paper does not address the relationship between structure and performance. Instead, it takes a step behind, and attempts to operationalise the concept of PRO-I network efficiency and to explore the micro-level determinants of efficient structures. As stated previously, the *cost* is related with the *direct* PRO-I networking as discussed in the conceptual Section 2.1. In this respect, too high PRO-I networking may undermine the intellectual freedom of researchers, who may also become more focused on short-term, problem-solving activities than on more fundamental quests. Hence the formation of PRO-I linkages entail a relevant opportunity cost for the researcher, since the time and resources spent networking with the industry may be subtracted to serendipitous research, as Nelson (2004) pointed out. Given this, and retaining that PRO-I networking is desirable to achieve certain developmental goals, the question is formulated as follows: *Is there a PRO-I knowledge network structure which minimises direct PRO-I linkages, while maximising the diffusion of PRO-I generated knowledge to the economic system?*

A way to explore this question is by going back to Rogers' (1983) work on diffusion of innovations. He argued that innovation is diffused through a two-step or multi-step process, which implies that firms adopt technologies at different times, and is made conditional on the previous adoption by other firms in the economic system – a view at odds with the concept of 'knowledge spillovers.' Consistent with Rogers (1983), the view here is that PRO-I knowledge is not diffused pervasively in the economic system, by way of intra- or inter-industry knowledge spillovers (Jaffe, 1989; Anselin et al., 1997), but it is diffused through a rather structured multi-step process. This means that once a direct PRO-I linkage is formed, the outcome of such direct linkage – in the form of. a distinctive piece of knowledge or of an innovation – is spread through an *indirect*, multi-step process of knowledge diffusion within a national, sub-national context, depending on the level of analysis.

Accordingly, *brokering roles* are played here by firms which directly establish knowledge linkages with PROs and contribute to the diffusion of acquired knowledge to the other firms of the economic system. Brokers operate as some sort of 'technological gatekeepers' (Giuliani and Bell, 2005) showing *active cognitive positions,* acting therefore as either sources or mutual exchangers of knowledge and contributing to the indirect diffusion of PRO-I generated knowledge in the economic system.[5] The

5 In Giuliani and Bell (2005), a 'cognitive position' refers to the position of a firm in the network of knowledge. As explained in Section 4, firms are 'sources' of knowledge when they respectively transfer more knowledge than they receive; 'mutual exchangers' when there is a balanced knowledge transfer process. They are 'absorbers' of knowledge when they respectively receive more knowledge than they transfer and 'isolates' when they barely receive or transfer any valuable knowledge.

gatekeeping or brokering concept, which was originally developed within intra-organisational studies (e.g. Allen, 1977; MacDonald and Williams, 1994), refers here to firms which transfer PRO-acquired knowledge to other firms in their economic system. Why would they do so? One way to understand this behaviour is through reciprocity of knowledge exchange (Gross and McMullen, 1982): the economic reason why a firm transfers knowledge to another, sometimes rival, is because it expects to have useful knowledge back. In his famous study on 'know-how' trade, von Hippel (1987) observed that know-how traders seem to follow the rule of reciprocity, and as one of his respondents commented: 'how much is exchanged depends on what the other guy knows – must be reciprocal.' (von Hippel, 1987: 295) This view thus considers reciprocity as expected, as it represents the pay-off for the knowledge transferred (see also Carter, 1989; Schrader, 1991). However, knowledge sharer needs not resort to explicit reciprocity calculations and, as found by Giuliani and Bell (2005), unreciprocated knowledge transfer may as well take place. This means that firms may behave as local sources of knowledge, transferring more knowledge than they receive from other firms. The explanation of this behaviour has a rather sociological flavour. To start with, it should be noted that the link across firms is normally formed by technicians, engineers, and, broadly speaking, knowledge workers, who go and search for valuable knowledge outside the boundaries of their firm, with the objective of solving complex technical problems. Recall von Hippel (1987): 'when required know-how is not available in-house, engineers typically cannot find it in publications either: Much is very specialized and not published anywhere' (p. 76). In another work, Giuliani (2005) found that this search is guided by two selection criteria: the first is by looking for a source of knowledge that is homophilous (i.e. share a common language, interest and technical background), quite consistent with the sociological view of human interactions (e.g. McPherson et al., 2001). Secondly, among the homophilous sources of knowledge, the search is oriented towards the ones that are more likely to *be able to suggest a good solution to a problem*. Hence, those knowledge workers that are known for being *highly experienced* or for working in a *technologically advanced* firm are more likely *targeted* for advice on specific technical problems.

The presence of strong linkages to PROs may flag strong in-house capabilities, an aspect that may induce other firms to ask for advice. Accordingly, firms with more linkages to PROs are more likely to be targeted by other firms. Whether these targeted firms are willing to disclose their acquired knowledge is another matter. Indeed, Giuliani (2005) finds that when asked, these targeted knowledge workers seem to be willing to disclose at least part of their acquired knowledge *even* when they know that this will not be reciprocated. Unlike the view of economists, who conceive reciprocation as the pay-off for the act of releasing knowledge (e.g. von Hippel, 1987; Schrader, 1991), the lack of reciprocation seems to sociologists not to hinder the transfer of knowledge. This view is found in a recent work by Bouty (2000), who argued that if professionals form part of a community of trustful peers, reciprocity may not be a precondition for knowledge exchange. Moreover, knowledge workers operate under a set of incentives which is not the typical one associated to entrepreneurs. They release knowledge because it is part of their informal professional code of conduct. Of course, the provision of free advice does not imply that all knowledge is released unconditionally. This is done with the caveat that knowledge workers *do* select the type and quality of knowledge that they release and adjust the quality and persistence of linkages to the characteristics of the recipient knowledge worker and firm (Uzzi, 1997).

These considerations suggest that firms that have linkages with PROs may be more targeted by other firms in their economic system, and find themselves in the condition of transferring knowledge either mutually, expecting a reciprocal knowledge transfer, or in an imbalanced way, thus being sources of local knowledge. In both cases, firms would be acting as PRO-I brokers. As such, brokering is important as it allows PRO generated knowledge to reach firms which have no direct contact with PROs and therefore enhances the PRO's developmental function. Conversely, one should consider the lack of brokers the case in which firms *do* have direct linkages with PROs, but show *passive cognitive positions* in the economic system, where they act as local absorbers or isolates (i.e. non-brokers, see

Section 4 for operationalisation).[6] In this case, the cost of direct PRO-I networking is not offset by the indirect diffusion of PROs' generated knowledge to the rest of the firm in the system. This is illustrated by Figure 1(a), where PROs, indicated by red squares, establish direct linkages with some of the firms in the system (black circles), which in turn do not indirectly diffuse the acquired knowledge to the rest of the firms.

The existence of many brokering firms is nevertheless not the panacea. Recall that I am conceptualising here 'efficient' PRO-I networks, where redundancy needs to be minimised. Hence, the question here is: How many firms, which are linked to each other in their economic system, through inter-firm transfer of knowledge, are also linked to the same set of PROs? In this conceptual model, I make an assumption that, at a given point in time, firms and PROs are endowed with a limited stock of knowledge, which can be shared or diffused. Following from this, redundancy occurs when the actors of the network share their available stock of knowledge with *all* the other members through intense and repeated interactions. In a PRO-I network therefore, high redundancy implies that many pairs of firms in the industry have established knowledge linkages with each other *and* they are also linked to the same or same set of PROs. This is displayed by Figure 1(b) where most of the firms are brokers *and* highly interconnected at the local level.

Figures 1(a) and 1(b) both depict two inefficient PRO-I knowledge networks since, for a given set of *direct* PRO-I linkages, the effects on the economic system in terms of the formation of *indirect* linkages would be either negligible, as in Figure 1(a), or redundant, as in Figure 1(b). On the basis of this, an efficient structure would be one where non-redundant brokers are detected, as in Figure 1(c). Figure 1(c) illustrates a stylised PRO-I network structure, where the costs of PRO-I direct networking are limited and the developmental impact of PROs enhanced, since all firms in the economic system are directly or indirectly tied to brokers. For this reason, Figure 1(c) is a representation of an 'efficient' network. Reasonably enough, this concept of efficiency should allow some redundant networking to take place, as this breeds interactive learning and innovation processes. Therefore, the idea is that there exists a conceptual redundancy threshold, above which the network is no longer efficient. Finally, a PRO-I network structure would be more efficient when brokering firms are not merely passive recipients of PROs' generated knowledge, but contribute to this knowledge improvement in their own right. In this respect, internal capabilities of broker firms are important as they permit, firstly, intense and bi-lateral direct interactions with PROs, and secondly, they avoid quality downgrading of knowledge in the brokering process.

Figure 1: PRO-Industry network structure: brokers, redundancy and efficiency

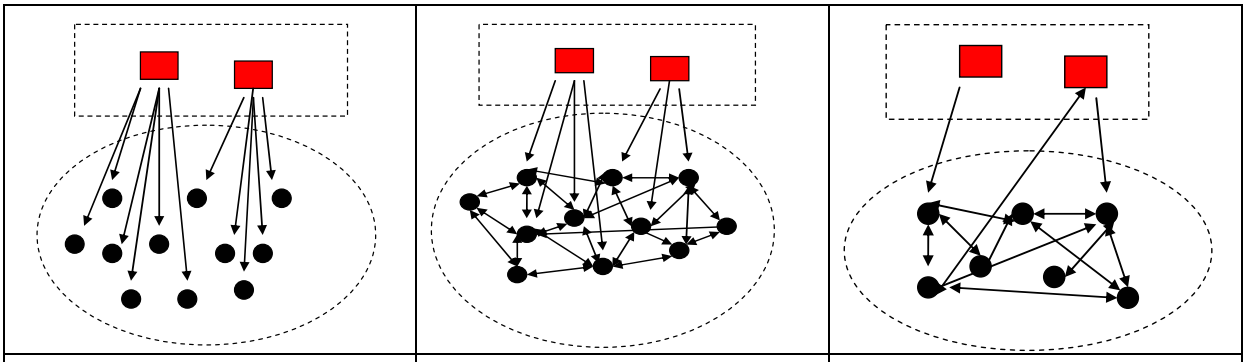

Figure 1(a)	*Figure 1(b)*	*Figure 1(c)*

Note: Red squares flag PROs, black circles flag firms in the economic system.

6 Giuliani and Bell (2005) show that these behaviours are more likely to be observed when firms have weak knowledge bases and therefore have either little to transfer – as in the case of absorbers – or have limited capacity to absorb, as in the case of isolates.

The following section develops original research questions to explore some of the factors that may drive the formation of an efficient PRO-I network structure.

2.3 What drives the formation of 'efficient' PRO-I network structures? Research hypotheses

This section develops original research hypotheses to examine how key firm- and PRO-level characteristics influence the formation of PRO-I direct linkages and the presence of brokering roles. The first set of research hypotheses speculates on whether a key firm-level characteristic, the intensity of experimentation (EI), is associated to a higher propensity of firms to form knowledge linkages with PROs. Several studies in the literature have in fact explored how firm characteristics affect the formation of different types of linkages to PROs. As an example, some have shown empirically that a size effect exists in PRO-I networking, such that *larger* firms are more likely to interconnect with PROs (Fontana et al. 2003; Laursen and Salter 2004; Arundel and Geuna, 2004; Mohen and Hoareau, 2003; Cohen et al. 2002). Others have more specifically argued that firms with *higher R&D intensity* have more university collaborations by way of their enhanced absorptive capacity (Arundel and Geuna, 2004; Fontana et al., 2004; Cohen and Levinthal, 1990; Schartinger et al. 2001).

This paper considers the formation of PRO-I linkages on two grounds. The first one is the transfer of technical advice from PROs to firms, occurring both in the form of informal conversations by academics and technicians in the industry as well as by other forms of consultancy-based formal agreements. Given the specificity of the industry considered here (the wine industry, see Section 3), technical advice linkages (TAL) carry information aimed at the solution of technical problems which may have occurred in the production process of the firm – e.g. on how to fight a given pest. The second type of linkage refers more specifically to the formation of collaborative research projects among the firm and the PROs (CRL). In the wine industry, CRLs are formed on projects that are of interest for both parties, the public research organizations and the industry, such as for example the understanding of the factors that allow new clones of a given vine variety to be matched with the soil of a given geographical area. Typically, whereas TALs envisage short term interactions among the two parties, CRLs imply medium- to long-term collaborations as often research projects in this field may last from two to several years.

On the basis of the existing literature about the formation of direct PRO-I linkages, it is argued here that in-house experimentation intensity of firms is likely to affect their propensity to link up with PROs for both TA and CR purposes. This argument operates in two directions: first, firms with more intense in-house experimentation will be both more capable of searching for relevant knowledge and of absorbing the received knowledge, thus creating an incentive for their search (Cohen and Levinthal, 1990). Besides, their higher internal experimentation intensity will stimulate them to search for complementary, advanced, research skills by the PROs. Secondly, PROs will be more interested in interacting with more 'capable' firms, since the chances of reverse knowledge transfer may also be high. Thus, the first hypothesis is developed as follows:

> *Hypothesis 1: Firms' experimentation intensity is positively associated with the formation of linkages with PROs.*

Once direct PRO-I are established, the acquired knowledge may or may not be diffused to firms in the economic system. The diffusion occurs when firms with direct linkages with PROs, of either (both) TA or (and) CR types, behave as brokers and therefore act as local sources or mutual exchangers. Elaborating on the results of a previous research (Giuliani and Bell, 2005), I argue here that brokers will be firms with higher in-house experimentation. As mentioned in Section 2.2, firms characterised by higher experimentation intensity will be more frequently targeted by other firms operating in their economic system, and thus they will be more likely to transfer a yet *selected* amount of knowledge to the other firms, acting as a broker in the PRO-I network. On the basis of this, the following hypothesis is formulated:

Hypothesis 2: Firms' experimentation intensity is positively associated with the probability of acting as PRO-I brokers.

The propensity to form PRO-I linkages does also depend upon PROs' characteristics. As mentioned by Mowery and Sampat (2004), public research organizations vary in their structure, size and strategies and therefore should not be considered as homogeneous entities. In this paper I look at two dimensions of such diversity, which are expressed in PROs' scientific productivity and in their geographical distance to industry. I draw on Mansfield and Lee (1996) study, which looks at whether the prestige of universities affects the likelihood of them being linked and supported by the industry. Mansfield and Lee found that top universities had a major short term impact on industrial innovation, also consistent with Tornquist and Kallsen (1994). However, they more interestingly observed that 'second tier', less prestigious universities had an absolute advantage on more applied research, where firms need to interact frequently with university researchers. This result is also in line with D'Este and Patell (2005), who found that whereas highly-rated university departments in the UK have no impact on the probability of university researchers to engage in a variety of collaborations, departments rated low in terms of research quality have a positive impact on the probability of a researcher involvement with industry. This indicates that in less prestigious universities, academic personnel are more willing to interact with the industry and operate for the solution of their technological problems.

The role played by the 'quality' or prestige of a department or university is nevertheless to be considered in combination with the relative geographical distance with the industry. In this respect, a number of studies have looked at the geographic proximity among PROs and the industry. Jaffe's (1989) seminal work opened a quite influential stream of studies on the importance of geography for the diffusion of university knowledge to the industry (Adams, 2002; Arundel and Geuna, 2004; Acs et al., 1992; Anselin et al. 2000; Fischer and Varga, 2003). The importance of geographic proximity resides in the fact that knowledge has a tacit component that needs direct contact between academicians and industry people to be transferred. In this domain, Mansfield and Lee (1996) found that geographic proximity matters for the transmission of knowledge but it matters more for low-rated faculties. This is ascribed to the fact that, as remarked, it is in such faculties where the academic personnel is more willing to co-operate with the industry for the solution of specific, highly applied technical problems that frequently need face-to-face interactions. Arundel and Geuna (2004) moreover found that a proximity effect exists but it tends to decline with an increase of firms' R&D expenditures.

These studies therefore suggest that the importance of geographic proximity to the formation of PRO-I linkages is conditional to, firstly, the quality or prestige of the faculty/university and, secondly, the level of firm experimentation intensity. Hence, the relation between firm experimentation intensity and linkages to PROs interacts with both the quality of PROs' research and their geographical relative distance from the industry. More specifically, the interaction is such that firms with higher experimentation intensity are more likely to interact *also with* long distance and more prestigious PROs. In contrast, firms with lower experimentation intensity will have poor interactions with PROs – consistent with Hypothesis 1 – but when these interactions will take place, they will be mostly with geographically proximate and less prestigious universities. Following this argument, the following hypotheses are formulated:

Hypothesis 3(a): Firms with higher experimentation intensity will be linked also to long distance and lower quality PROs.

Hypothesis 3(b): Firms with lower experimentation intensity will be linked to short distance and lower quality PROs.

3. The Context

3.1 The wine industry: globalisation of markets and the role of scientific research

As mentioned in Section 1, this empirical study is contextualised in the wine industry. This section provides an overview of the industry, showing how production and exports have changed over the past decades and how this has been accompanied by a scientific and technological shift. In effect, the wine industry has undergone major structural industrial and market changes in the past few decades. Known for being a traditional, craft-based activity, wine production has recently emerged as a knowledge-intensive manufacturing process, fed quite substantially by applied scientific research. Wine consumption has also changed, shifting market preferences from quantity, non-premium wines to quality, premium wines. On the side of production, technology and techniques of grape-growing and wine making have undergone processes of increased codification of knowledge and this has allowed countries, which were not traditional 'old world' wine producers, to 'catch-up' and emerge as exporters of fine wines. Hence, during the past two decades, particularly so in the 1990s, countries like Australia, New Zealand, South Africa, Chile and Argentina have become competitive on the international market of premium wines, challenging old producers. The shares of world wine total exports for traditional producing countries like France, Italy, Spain and Portugal have been eroded over time in favour of new world exporters, such as Chile and Argentina (Anderson and Norman, 2001).

The evolution of the wine industry in the international scenario is related to changes in the methods of production. Historically, public research organizations have played a central role in this industry. The first generation of intense scientific research was spurred on by the devastation caused by the phylloxera outbreak in the 1800s. To save the industry, countries whose economies relied on this production, such as France (Paul, 1996), had to make an intense scientific effort: 'science played a large role in the constitution of the devastated vineyards, and especially in the preservation of quality wines from *vinifera* vines' (Paul, 1996: 10-11). Loubere (1990) argued that French universities have been the protagonist of this process: 'The men who discovered that grafting European vines onto American root stock in order to combat phylloxera were highly trained scientists connected with the University of Montpellier. And in Bordeaux, during the 1880s, an enological research institute was created by Ulysse Gayon, a student of the great Louis Pasteur.' (p. 8) Following this, critical advances in oenology also found their natural terrain in the France of the nineteenth century. Louis Pasteur is considered by many as the father of modern oenology (Paul, 1996). Being the first to apply microbiology and to understand the process of wine fermentation, he initiated oenology as a scientific field. Throughout the following century, scientific discoveries and technological changes progressed at the same pace and pushed through a renovation of practices and methods.

Because of the pioneering research effort undertaken by its research institutions (e.g. the University of Bordeaux for oenology and the University of Montpellier for agronomy and viticulture), historians consider France as the driving force for the revolutionary scientific and technological changes in the industry. However, more recently research has become increasingly international and different leading research centres in both viticulture and oenology have emerged around the world. Different authors (Aylward, 2003; Unwin, 1991) remark that a recent process of technological renovation was spurred on by the consistent investment of new producer counties, such as California, Australia, New Zealand and South Africa, in creating or strengthening research institutions specialised in wine research and training. And it was particularly in the 1970s and 1980s that some of those countries started investing in what could be named a 'wine system of innovation' (Aylward, 2003). Institutions like the University of California Davis or Roseworthy College in Australia can be considered pioneers in this process, allowing for the training of highly skilled oenologists and agronomists that eventually contributed to implementing technical changes at firm level. Thus the research efforts undertaken throughout the world during the second half of the twentieth century have considerably changed the industry. Major changes are encountered in the techniques of production. What once used to be driven by the manual dexterity of farmers is now highly codified and managed by much more highly skilled

professionals. This has enhanced the interaction of the industry with public research organizations, which still represent a critical source of knowledge for wine producers.

3.2 Chile and Italy, national and sub-national overviews

There are deep differences between Chile and Italy. The former is an industrializing country, whose economy is currently tied to the export natural-resource based industries (Katz, 2001; CEPAL, 2002), whereas the latter is known to be a successful case of post-war economic growth, characterised by a shift from agriculture to traditional industries. In spite of Italy being an industrialised economy, if compared to a Latin American country as Chile, both countries are characterised by a rather weak National System of Innovation and by historically poor industry-university linkages (Malerba, 1993; Arocena and Suzt, 2001; Benavente, 2004). Within this frame, however, industries tied to agriculture, such as wine, have historically benefited from the support of public research organizations, as mentioned in the previous section. Italy and Chile are no exception in this respect. As it will be discussed later, a few public research organization, such as the *Agenzia Regionale per lo Sviluppo e l'Innovazione nel settore Agro-forestale* (ARSIA) in the Italian case and the *Instituto Nacional de Investigacion Agropecuaria* (INIA) in Chile, have even a mandatory role to operate as sources of technological and scientific knowledge to agriculture.

As mentioned in the previous section, the wine industry has undergone a period of sustained growth in the 1990s. This has occurred in both new and old wine producing countries. This study takes into consideration two wine areas which have grown substantially during the 1990s and are similar under several respects. Both areas have demonstrated a high potential in the production and export of fine wines, recognised at the international level. The Chilean wine area, situated about 200 kilometres south from Santiago, is denominated Valle de Colchagua. The area is a rural territory, with a history of wine production dating back to the end of the 1800s. However, it was starting from the 1980s that wine producers in Colchagua – spurred on by the favourable conditions of the wine industry on the international market (Schachner, 2002) – undertook a trajectory of growth which coincided also with major organisational and technological changes. During the 1990s, the area was characterised by the proliferation of firms that produced wine for domestic and foreign markets with an orientation towards quality. Together with long established firms, domestic and foreign investors were attracted by the favourable *terroir* and therefore established new production plants in the area. During the same period encouraging market conditions boosted the planting of new vineyards, doubling in size in the second half of the 1990s (S.A.G., 2000).

Among the several wine producing areas in Italy, this study considers another highly dynamic case, situated along the Tyrrhenian coast in Tuscany in the area of Bolgheri and Val di Cornia. There is a long tradition of wine producing in the area, within the numerous monasteries that have populated the territory since the seventeenth century. The presence of several aristocrat families in the area initiated the tradition in wine production. Until the first half of the 1900s, however, wine-making there was mainly based on the old, quantity-oriented pattern of production and on the use of autochthon vine varieties, while it was in the 1960s, when a local aristocrat, being a great fan of the fine red wines of Bordeaux, decided to make a red wine using French grapes and techniques (Mansson, 1996). In particular, the introduction of new methods of production spurred a renovation, somewhat close to a technological breakthrough, characterised by the introduction of French vines – typically Merlot and Cabernet – by the adoption of controlled fermentation and the use of 60-gallon barrels (barriques) for aging. In the late 1970s, few small producers began aiming at producing high quality wines and in the 1980s new firms were established in the area of Bolgheri-Val di Cornia, with an orientation to quality. The 1990s was a period of pronounced growth for the firms in the area, characterised by booming wine prices and economic prosperity.

This overview suggests that these two wine areas are characterized by a rather similar historical trajectory, both being areas with a long tradition in wine production and having grown, especially in

terms of the quality of wines during the 1980s and the 1990s, in correspondence with the worldwide boom in fine wines' consumption. Both areas have thus gained international appraisal, also acknowledged by sectoral publications (e.g. www.winespectator.com).The two areas are also not too dissimilar in terms of their institutional setting. Both are characterized by the presence of a business association (Viñas de Colchagua in Chile; Consorzio D.O.C. and its attached Stada del Vino Costa degli Etruschi in Italy), whose functions are mainly that of promoting the area and marketing their wines. In Italy, the local consortium has also functions of representing and managing wine production according to D.O.C. production regulations.[7] The affiliation to the local association or consortia varies widely across the two areas. Only about 40 per cent of firms are part of the local association Viñas de Colchagua in Chile, whereas a higher percentage (85 %) of firms in Bolgheri and Val di Cornia are part of the local consortium. It should be remarked however that such local associations do not play any relevant role either in sustaining firms' individual or joint innovative efforts, or in connecting firms to public research organizations.

4. Methodology

4.1 Collection of data

The collection of data used for this study has involved both firms and selected public research organizations. Firm level data includes the whole population of fine wine producers in each wine area.[8] As a result of this, the study includes 32 fine wine producers in the Colchagua area and 41 in Bolgheri/Val di Cornia. Table 1 reports descriptive statistics of some firm-level characteristics such as their size, measured by the number of employees; their ownership, (i.e. whether they are foreign-owned or domestic firms), and their organisation structure. In this respect, by independent, vertically integrated firms, I refer here to those that are not part of a larger corporation and that perform all the phases of the production chain within the cluster. This type, which characterizes the vast majority of firms in the sample, differs from the cases in which local firms or plants are part of a group or a larger corporation and are either vertically integrated locally, thus performing all the phases of the productive chain within the cluster, or they are vertically disintegrated, in which case only a part of the production process is undertaken locally (e.g. grape-growing).

The collection of data at the firm level was implemented through field interviews based on a structured questionnaire. Interviews were carried out with technical professionals or, when these were not available, with those more directly involved with the production process, in some cases the entrepreneur himself. Interviews were normally held within the premises of the winery and had an average length of one hour.

7 D.O.C. stands for *Denominazione di Origine Controllata* and refers to a geographical indication shown on the label of fine wines that meets the requirements set out by specific production regulations and national and community legislation. It should be noted however that Bolgheri/Val di Cornia is particularly famous for high quality wines, which are produced outside D.O.C. regulated areas.

8 The inclusion of the total population of fine wine producers is also necessary to process relational data through social network analysis (Borgatti and Molina, 2003). In the case of Bolgheri/Val di Cornia, one very recently established firm is missing. However, due to its incipient operating activity in the area, it is highly likely this not to affect the results of this research.

Table 1: Data: characteristics of firms

Characteristics of firms by:	Cluster	
	Chile (Colchagua) (N= 32)	**Italy** (Bolgheri/Val di Cornia) (N= 41)
(a) Size (employees)		
Small (1-19)	28%	90%
Medium (20-99)	66%	4%
Large (≥100)	6%	6%
(b) Ownership		
Domestic	81%	95%
Foreign	19%	5%
(c) Organisation Structure		
1. Independent, vertically integrated	66%	93%
2. Part of a group, vertically integrated firms	22%	7%
3. Part of a group, vertically disintegrated firms	13%	-

Apart from general background and contextual information, the interviews were designed to obtain three sets of information which are relevant for this present study: (1) firms' technical advice and collaborative research linkages with a list of national PROs;[9] (2) the inter-firm transfer of knowledge within the economic system in which firms operate, Colchagua in the Chilean case and Bolgheri/Val di Cornia in the Italian one and finally (3) the intensity of experimentation carried out at firm level. Table 2 reports the questions addressed in the questionnaire to collect this information.

The collection of data at the firm level has permitted to list the public research organisations that have established at least one TAL or CRL with the firms interviewed. In the Chilean case, these turned out to be the University of Chile, the Catholic University in Santiago, the University of Talca and the Instituto Nacional de Investigacion Agropecuaria (INIA). In the Italian case the relevant PROs were the Universities of Pisa, Florence, Siena and Milan, as well as the Istituto Vitivinicolo di Conegliano Veneto and the Agenzia Regionale per lo Sviluppo e l'Innovazione nel settore Agro-forestale (ARSIA).

Table 2: The collection of key variables in the questionnaire

(1) Firms' technical advice and collaborative research linkages with a list of national PROs
The interview asked about the firms' acquisition of knowledge from domestic PROs. Specifically, respondents were asked to name, on a roster of possible PROs, those which had contributed to the technical enhancement of firms (TAL). They were also asked to indicate whether the firm had co-operated with any of those sources for joint research and experimentation (CRL). The questions addressed are reported below:
TAL 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 each of the actors mentioned in the list, according to the quality of information obtained. Add up additional actors in the list if necessary: 0= none; 1= low; 2= medium; 3= high].
CRL Could you mark, among the actors included in the roster, those with whom this firm has collaborated in research projects during the last two years? [Please indicate the benefits of the research project in each case by marking the identified firms on the following scale: 0= none; 1= low; 2= medium; 3= high].

9 Respondents were provided with a roster that included a set of specific institutions, e.g. particular universities, and other public research organizations and they were also left free to add relevant PROs that were not included ex-ante in the list.

Table 2: The collection of key variables in the questionnaire (*cont.*)

(2) The inter-firm transfer of knowledge
An important part of the data collection concerned network data. In the questionnaire-based interview, 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 was asked the questions reported below: 1 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 rate the importance you attach to the knowledge linkage established with each of the firms according to its persistence and quality, on the basis of the following scale: 0= none; 1= low; 2= medium; 3= high]. 2 Which of the following firms do you think have benefited from technical support from this firm? [Please indicate the importance you attach to the knowledge linkage established with each of the firms according to its persistence and quality, on the basis of the following scale: 0= none; 1= low; 2= medium; 3= high]. *Note:* Respondents were asked to rate each of the mentioned relationships on a scale of 0 to 3. A value of 0 is given when no linkage is formed. A value of 1 corresponds to an occasional knowledge linkage with limited content in terms of quality of the knowledge flow, whereas a value of 3 corresponds to a persistent knowledge linkage that carries fine-grained knowledge. It is worth remembering here that this study was designed to collect cross-sectional data only. Therefore, the relational data gathered through the above-mentioned roster studies refer to the very recent past in which the interviews have been carried out (maximum of two years).
(3) Experimentation intensity
A key variable for this research is the degree of experimentation of firms. An appropriate proxy for knowledge creation efforts has been developed since information about expenditure on formal R&D would have been both too narrowly defined and too difficult to obtain systematically. Experimentation intensity was measured on a scale ranging from 0 to 4 on the basis of: 1 Whether firms had performed any form of experimentation on an individual and collaborative basis in the past 2 years. 2 The areas in which such experimentation has been carried out – ranging from tests on vine clones or varieties, to the management of the irrigation, pruning and training systems, and to the fermentation and ageing techniques. 3 Whether such experimentation had increased in the past five years *Note*: An assessment of the intensity of experimentation was also carried out on the basis of qualitative evidence collected about the most relevant experimentation carried out in the past five years by each of the firms.

As indicated by Table 3, to permit the exploration of the research hypotheses, two types of information about the mentioned public research organizations were gathered: the first one is the geographical distance to the industry. The second one refers to the quality of scientific research of each public research organization. For this I relied on the on the collection of data on scientific publications based on the ISI Web of Knowledge (ISI WoK) database. The search criteria has been the name of single departments within each PRO, whose discipline was connected to the agronomics or oenological fields, thus, for example, the search for the University of Florence included the Interfaculty Dept. of Vegetal Biology, the Dept. of Agronomic Engineering, the Dept. of Soil and Plant Nutrition, the Dept. of Agrarian Biotechnologies, and so on (a full list of the departments searched for each PRO is provided in the Appendix B).[10] The selection criteria was designed in a way to dispose of all the publications whose content was about human beings or animals or it was explicitly about non-industry relevant vegetal species (e.g. potato, tomato, beans and the like). A summary of the collection of PRO-related variables is provided in Table 3. A small sample of public research organizations have also been interviewed using an unstructured questionnaire, namely: the Catholic University, the INIA and the University of Talca in Chile and the University of Pisa and Florence in Italy.

10 In the search process, double checks have been performed also by searching the name of researchers listed in each selected department's web page.

Table 3: The collection of PRO-related key variables

(1) Geographical distance to firms

The distance is measured in kilometres between the city of localisation of each PRO and the main town/village within each of the two wine areas. The measures are based on Virgilio Mappe (Italy) and www.sitios.cl (Chile.)

(2) Scientific output

Data about the scientific output of PROs' specific departments have been downloaded by the ISI Web of Science – Science Citation Index Expanded – 1954 to present. The search criteria has been the Agronomic-related departments of the listed PROs (see Appendix B for a full list). This search allowed the collection of the following PRO-related key variables:

1	Author's name, year, title and journals' title of each publication
1	Number of publications issued per department since 1954
2	Number of researchers having at least a publication appearing in the ISI-WoK, per PRO
3	Number of times each publication has been cited by other ISI-WoS publications (i.e. 'times cited')

4.2 Key variables and operationalisation of concepts

Table 4 summarises the basis of the measures and indicators used for this empirical analysis. In particular Table 4 (A) reports the measures used for the analysis and comparison of PRO-I networks in terms of their 'efficiency,' namely: (1) the presence of brokering firms and (2) the redundancy of the network. Table 4 (B) reports briefly the variables used for the test of hypotheses.

Table 4: Operationalisation of key concepts

(A) Efficiency of the PRO-I network

(1) Brokering	
Brokers	Firms with at least one TAL and/or CRL, whose cognitive position is that of Sources (S) or Mutual Exchangers (ME)
Non-brokers	Firms with at least one TAL and/or CRL, whose cognitive position is that of Absorbers (A) or Isolates (I)
Source (S)	Firm, whose Indegree/Outdegree Centrality Index < 1
Mutual Exchanger (ME)	Firm, whose Indegree/Outdegree Centrality Index = 1
Absorber (A)	Firm, whose Indegree/Outdegree Centrality Index > 1
Isolate (I)	Firm, whose Indegree/Outdegree Centrality Index = 0
Outdegree Centrality Index	Measure of 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)
Indegree Centrality Index	Measure of 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.*
(2) Redundancy	
Redundant PRO-I network	Network where firms which are linked in the economic system where they operate, are also connected to the same set of PROs
Network of common PROs	Network in which a linkage exists if two firms have a linkage to the same PRO, based on Questions 1 Table 2
Network of inter-firm transfer of knowledge	Network of inter-firm knowledge transfer, based on Questions 2 Table 2
Structural equivalence matrix of common PROs	Correlation matrix from the original 'Network of common PROs.' It uses a convergence of iterated correlation (CONCOR) method to measure each actor's structural equivalence (Borgatti et al., 2002). Two actors are structurally equivalent if they have identical ties to the other actors in the network. Thus, if firm **a** is linked to PROs *f* and *y* and firm **b** is linked to PROs *f* and *y,* it means that **a** and **b** are structurally equivalent. In this case the correlation will be equal to 1 and this will be the value corresponding to cell (**a, b**) in the correlation matrix. This value ranges from – 1 to 1 according to the degree to which actors **a** and **b** are structurally equivalent.
Structural equivalent matrix of inter-firm transfer of knowledge	Correlation matrix from the original 'Inter-firm transfer of knowledge.' As above, with the exception that in this case **a** and **b** are structural equivalent, if firm **a** is linked to firms *k* and *j* and **b** is also linked to firms *k* and *j*.

Table 4: Operationalisation of key concepts (*cont.*)

(B) Test of Hypotheses	
(1) Hypothesis 1	
Firm experimentation intensity	Measure ranging from 0 to 4, where 0 means that no experimentation is carried out by the firm and 4 means that the firm has a very high intensity of experimentation
TAL	Number of technical advice linkages established by each firm with PROs
CRL	Number of collaborative research linkages established by each firm with PROs
PROL	Number of linkages established by each firm with PROs for both TA and CR purposes
(3) Hypothesis 2	
Firm experimentation intensity	See above B (1)
Brokering	See above A (1)
(4) Hypothesis 3	
Geographic distance	Number of kilometres between the city of localisation of each PRO and the main town/village within each of the two wine areas.
Quality of PROs	Impact of PRO' departments (ID)= The sum of 'times cited' of the publications produced by departments in each PRO considered in this study, divided by the sum of publication vintage (i.e. the number of years since first published) for the same departments. Impact of publications (IP)= The sum of the ratios between the number of 'times cited' of each publication, normalised by their vintage, and the number of publications present in the ISI WoK for that PRO. Impact of researchers (IR)= The sum of the ratios between the number of 'times cited' of each publication normalised by their vintage, and the number of researchers present in the ISI WoK for that PRO.
Firm experimentation intensity	See above B (1)

5. Empirical results

5.1 Comparing efficiency of PRO-I networks

The first part of this empirical analysis consists in the exploration of the structural characteristics of the PRO-I network in the Chilean and Italian contexts. Consistent with Section 2, this is done firstly by analysing the presence of broker firms in the network, and secondly by measuring and comparing redundancy. As concerns brokering, it should first be noted that there are not significant differences between the two cases in terms of the formation of direct linkages with PROs, as illustrated by Table 5. The Mann-Whitney test is not significant, particularly so for TA linkages, where in both the Chilean and the Italian cases, 66 per cent of firms in the cluster have established at least one TAL with PROs. Chilean firms seem instead slightly more open to the formation of CR linkages with national PROs (47%) than Italian ones (29%) but also in this case the difference is not statistically significant.

Table 5: Direct PRO-I linkages

	Chile	**Italy**	**Statistics** *Mann-Whitney test* (Asymp. Sig. 2-tail)
(a) Technical assistance:			
Percentage of firms with at least one TAL[(1)]	66%	66%	*Not significant (0.873)*
Among them:			
Number of TALs per firm	2.09	1.70	
(b) Research collaboration			
Percentage of firms with at least one CRL[(2)]	47%	29%	*Not significant (0.125)*
Among them:			
Number of CRLs per firm	1.40	1.33	

Note: (1)TAL stands for technical assistance linkage with PROs. (2) CRL stands for collaborative research linkage with PROs.

Given this striking similarity in the formation of direct linkages with PROs, I look here at the presence of broker firms. Table 6 reports a series of statistics on PRO-I network brokers. First, it shows the number of brokers and their percentage on the total number of firms with active cognitive positions in the area (i.e. sources (S) and mutual exchangers (ME)). It illustrates that all firms with active cognitive positions in Chile are also PRO-I brokers, whereas this percentage is comparatively lower in the Italian case (63 %). In this case, the difference is statistically significant as shown by the result of the Mann-Whitney test. More interestingly, Table 6 shows that 67 per cent per cent of firms with passive cognitive positions (i.e. absorbers (A) and isolates (I)) have at least one linkage with a national PRO in Italy, whereas this percentage is smaller in the Chilean case (50%). Such a difference is statistically significant only at 10 per cent. Not surprisingly therefore, in the Chilean case the number of brokers is about fifty per cent higher than the number of non-brokers (the ratio is 1.56), while in the Italian case brokers are about one third of non-brokers (the ratio is 0.35). This means that in the Italian wine area, only about one third of the overall direct linkages are formed by brokers. In the Chilean case instead, brokers are much more common to find among the firms with linkages with PROs. This result is also consistent with the values of the average out-degree centrality of firms with at least one linkage with PROs (Table 6, point 6), where Chilean firms with a direct link to PROs tend to transfer more knowledge to the rest of the cluster firms, both in dichotomous and valued terms: the normalized out-degree centrality indexes are 17.85 and 34.56 versus 12.85 and 21.78 of the Italian case (the difference is statistically significant).[11] These features therefore show that the Chilean case does much better in diffusing PRO-acquired knowledge to the other cluster firms, whereas in the Italian wine area, a vast majority PRO-acquired knowledge is not diffused within the area but is kept within the boundaries of each recipient firm. Finally, as discussed in Section 2, the quality of brokering, measured here by the average experimentation intensity of brokers, matters. In this respect Table 6 (point 7) shows that Chilean brokers have higher in-house experimentation (2.5) than in the Italian ones (1.71), although the difference is not statistically significant.

Table 6: Brokers

	Chile	**Italy**	**Statistics**(2) *Mann-Whitney test* (Asymp. Sig. 2-tail)
1. N. of brokers (1)	*14*	*7*	*Significant**
2. Percentage of brokers on total S and ME in the area	100%	63%	*(0.013)*
3. N. of non-brokers	*9*	*20*	*Significant**
4. Percentage of non-brokers on total A and I in the area	50%	67%	*(0.076)*
5. Brokers/ non-brokers	1.56	0.35	
6. Average normalized out-degree centrality of brokers			
- dichotomous	17.85	12.85	*Significant** *(0.079)*
- valued	34.56	21.78	*Significant*** *(0.012)*
7. Average experimentation intensity of brokers	2.50	1.71	*Not significant (0.255)*

Note: (1) Brokers are measured considering both the existence of TA and CR linkages. (2) ** Significant at 5%: *Significant at 10%.

These data seem to suggest that the Chilean case has overall a higher number of brokers when compared to the Italian one. This is also illustrated by Figure 2, where brokers (blue squares) are much more visible in the Chilean case (Figure 2(a)) than in the Italian one (Figure 2(b)).

11 The use of a normalized index is needed to compare out-degree centrality values of networks of two different sizes.

Figure 2: PRO-Industry networks

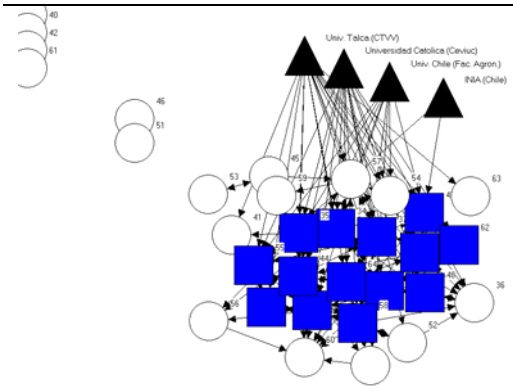

Figure 2(a): The Chilean case

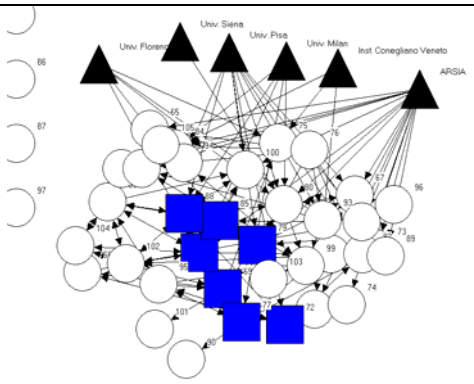

Figure 2(b): The Italian case

Note: Blue square nodes flag PRO-I brokers, round white nodes flag the rest of the firms; black triangles flag PROs.

The second dimension of PRO-I network efficiency concerns its redundancy. Using the Quadratic Assignment Procedure (QAP) correlation (Borgatti et al, 2002), I look at the co-occurrence of two pairs of networks. The first one, which I call here Model 1, is between the 'Network of common PROs' and the 'Network of inter-firm knowledge transfer,' described by Table 4 (A) (2). In Model 1, if the two networks are highly correlated it means that the firms, which are connected in the economic system where they operate, share also linkages with the same set of PROs – thus implying high redundancy. The second correlation is between the 'Structural equivalence matrix of common PROs' and the 'Structural equivalent matrix of inter-firm transfer of knowledge' (Table 4 (A) (2)) (Model 2). Each of these two matrixes measure the extent to which the actors in the network are similar in terms of whom they are connected to. Thus, in the 'Structural equivalence matrix of common PROs', the values of each cell are a measure of the degree of similarity of firms in terms of the linkages to the same set of PROs, whereas the 'Structural equivalence matrix of inter-firm knowledge transfer' represents the degree of similarity of firms in their pattern of interconnection with the rest of the firms in the economic system where they operate. Therefore a high correlation between these two matrixes would imply high redundancy.

The results of the two QAP correlations are illustrated in Table 7. The QAP correlation for Model 1 is weak in the Chilean case and not significant in the Italian case. This means that, in the former, there is a small yet significant redundancy of linkages (p=0.000). This is shown by the low values of the Pearson and Jaccard coefficients: 0.24 and 0.17 respectively. The Jaccard indicates that only 17 per cent of firms that have linkages at the local level are also linked to the same public research organization. This is not observed in the latter case, the Italian one, where, instead, the two networks do not overlap. The results of the second QAP correlation (Model 2) are consistent with those of Model 1. This second correlation is a more direct measure of redundancy. Very weak correlation is found in the Chilean case – Pearson 0.193 and Simple Matching 0.204, and no correlation at all is found in the Italian one.

Table 7: The analysis of redundancy in PRO-I linkages

	Chile		**Italy**	
QAP correlation Model 1	coefficient	*p*-value	coefficient	*p*-value
Pearson	0.240	0.000	-0.011	0.313
Jaccard	0.171	0.000	0.037	0.615
QAP correlation Model 2				
Pearson	0.193	0.000	-0.017	0.343
Simple matching	0.204	0.038	0.194	0.499

These results prompt two types of considerations. First, that no redundancy is observed in the Italian case. This means that firms that are connected within their economic system do not interconnect to the same set of PROs, allowing for a potentially high degree of variety in the PRO-I knowledge network. However, as a result of the very limited incidence of brokers in this network, the knowledge acquired through the direct interaction of firms with PROs tends to be retained within the boundaries of the firms that interface PROs. Thus, in spite of not being redundant, this network is not efficient in compensating the costs of direct PRO networking with the spreading of the acquired knowledge into the economic system. Going back to the conceptual model developed in Section 2.2, this network is less efficient in comparative terms. In the Chilean case, the cost of direct networking is offset by higher diffusion of knowledge operated by broker firms. This generates a positive effect on the whole economic system, and on its development potential. In this latter case, moreover, the observed redundancy is rather low, a condition that breeds processes of interactive learning and innovation, as suggested in Section 2.2.

Following these considerations, the Chilean PRO-I network is, in relative terms, more efficient than the Italian one. Yet, this story is still in need of an interpretation. Which factors may explain this striking difference? In Section 2.3 I have advanced some research hypotheses about firm- and PRO-specific variables that may explain the formation of PRO-I linkages. The hypotheses are explored empirically in the section that follows.

5.2 Understanding differences: the role of actors' characteristics

5.2.1 Firm-level characteristics: the experimentation intensity

As an introduction to the test of Hypothesis 1, I provide here some descriptive statistics on PRO-I direct linkages and firm experimentation intensity. As shown by Table 8, in the Chilean case, as the total number of direct PRO-I linkages (PROL) increases, so does the average value of firm experimentation intensity (EI). This is not the case in the Italian wine area, where the pattern is much more mixed.

Table 8: Statistics on PRO-I linkages and firms' experimentation

	Chile		**Italy**	
Number of linkages with PROs (PROL)	Frequency	Average EI	Frequency	Average EI
0	9	0.44	14	1.28
1	3	0.33	11	0.45
2	6	1.67	7	0.57
3	6	1.67	5	2.20
4	5	3.40	1	2.00
5	1	4.00	1	2.00
6	1	4.00	1	3.00
7	1	4.00	1	0.00
Total	32		41	

In order to test Hypothesis 1 I apply here an Ordered Probit estimation using the pooled sample of the two wine areas and the areas' fixed effects. The regression estimates whether firm-level experimentation intensity (EI) affects positively the likelihood of firms to establish knowledge linkages with public research organizations (PROL). The results are presented in Table 9. Consistent with Table 8, they show that firm level experimentation intensity affects positively the formation of linkages with PROs (PROL) only in the Chilean case, whereas no significant effect is found in the Bolgheri/Val di Cornia area. In the former case, a coefficient of +0.779 exceeds all the thresholds

shifts. Therefore, an increase in the level of experimentation is associated with a large shift in the number of linkages with PROs. These results are found controlling for several firm level characteristics, such as size, ownership and organization structure and for the area dummy (Area Italy) (see Appendix A for correlation matrix). Accordingly, Hypothesis 1 is supported only by the evidence of the Chilean area.

Table 9: PRO-I linkages and firm experimentation intensity

	Coefficient (s.e.)[(2)]
EI Chile	**0.779 (0.173)*** **
EI Italy	0.099 (0.140)
Size (Log employees)	-0.147 (0.145)
Ownership	0.112 (0.487)
Org. Structure 1 [(1)]	1.177 (0.707)
Org. Structure 3 [(1)]	0.280 (0.640)
Area Italy	-0.515 (0.471)
Thresholds	
μ_1	-0.242
μ_2	0.364
μ_3	0.974
μ_4	1.740
μ_5	2.429
μ_6	2.739
μ_7	3.142
Number of obs.	73
Log likelihood	-111.75
Pseudo R2	0.1371

Note: (1) Org. Structure 1 and 3 refer to the classification of Table 1(c).
(2) *** Significant at 1%.

Applying a Probit estimation method, I then test Hypothesis 2, i.e. whether firms with higher experimentation intensity are more likely to act as brokers in the PRO-I network. The results are shown in Table 10, which reports the marginal effect calculated from Probit coefficients. I consider here the pooled sample using data of both the Chilean and the Italian wine area and control for firm and areas' dummies.

Table 10: PRO-I brokers and firm experimentation intensity

	Marginal effects (s.e.)
EI Chile	**0.190 (0 .084)** **
EI Italy	0.073 (0.059)
Size (Log employees)	0.036 (0.059)
Ownership	0.128 (0.198)
Org. Structure 1 [(1)]	-0.230 (0.139)
Org. Structure 3 [(1)]	-0.142 (0.273)
Area Italy	-0.053 (0.197)
N. obs.	73
Wald Chi2(7)	17.37
Log pseudo-likelihood	-33.428
Pseudo R2	0.2369

Note: (1) Org. Structure 1 and 3 refer to the classification of Table 1(c).
** Significant at 5%.

The table shows that the level of experimentation is positive and significant only in the Chilean wine area (EI Chile). More specifically, in the Chilean case, the increase in experimentation intensity by one unit increases the probability of a firm behaving as a broker by 19 per cent, on average and ceteris paribus. In contrast, in the Italian case the intensity of firm experimentation does not affect the probability of firms behaving as brokers. These results are found even after controlling for several firm level characteristics, such as size, ownership and organization structure and for the area dummy (Area Italy) (see correlation matrix in the Appendix A).

This result is not entirely surprising. Given the outcome of Hypothesis 1, firms in the Italian PRO-I network link up to PROs even with relatively low experimentation intensity. However, as discussed in Section 2.2, these firms are less likely to be sought or asked for advice by the rest of the firms in the economic system (Giuliani and Bell, 2005). In fact they will be able to absorb only a small portion of the knowledge that is potentially available by the PRO (Carter, 1989; Cohen and Levinthal, 1990), thus having very little to transfer. Likewise, due to their limited capacity to elaborate on the absorbed knowledge, they may even downgrade the knowledge that they have absorbed by passing it by to other firms (Giuliani, 2005), hindering other firms to ask for advice. Not surprisingly, then, these firms tend not to behave as brokers in the Italian PRO-I network. Conversely, in the Chilean case, brokers have higher in-house experimentation intensity and, consistent with Section 2.2, they are more likely to be targeted by other firms and to be able to transfer knowledge with valuable content. A question is therefore left open for investigation. Why do Italian firms with low in-house experimentation link up to PROs so intensively? This question is explored in the section that follows.

5.2.2 PRO-level factors: geographic proximity and quality of PROs

Hypotheses 3 (a) and 3 (b) test the relationship between firm experimentation intensity, PRO-I geographic proximity and the quality of PROs. To test these hypotheses, I first explore whether there is a positive relationship between PROs' geographic proximity and the average experimentation intensity of firms – as found by Arundel and Geuna (2004). In this respect, it should be noted that within the short distance, which I arbitrarily set within range of 100 kilometres, there are no relevant PROs with which firms in the Chilean area of Colchagua could link up to. Instead, all Chilean PROs are situated within a medium range distance, approximately between 100 and 200 kilometres. These are the University of Talca in the neighbouring VII region and the University Catolica, University of Chile and the National Institute for Agricultural Research (INIA) located in Santiago de Chile. In the Italian case, firms have established linkages with short, medium and long distance PROs. There is one University in the neighbouring town of Pisa (short distance), one in Florence (University of Florence) and a PRO (ARSIA), also in Florence, situated at a the medium distance from the Bolgheri/Val di Cornia area.[12] Finally, at the long distance, firms in the Italian area of Bolgheri/Val di Cornia link up with the University of Milan and the Research Institute of Conegliano Veneto, in the northern part of Italy.

Table 11 compares the Chilean and Italian case with respect to: (i) the distance of PROs to firms (in the rows), and (ii) the cumulative number of TALs and CRLs; (iii) the average experimentation intensity of firms (in the columns). While no variation is observed for the Chilean case, as all PROs are located within a medium distance, the Italian case reveals that the longer the distance of the PROs, the higher the average experimentation intensity of firms. This is true for TALs, which shift from 0.20 to 0.71 to 1.85 and for CR linkages, which range from a minimum of 1.33 to a maximum of 2.00 for long distant PROs. This result is illuminating on the behaviour of the Italian firms. It shows that geographic proximity facilitates PRO-I interactions even when firms have poor experimentation intensity – a result that explains the high number of direct linkages and the lower incidence of brokers.

12 The University of Siena, having only one linkage to a firm in the Bolgheri/Val di Cornia area, has been dropped.

This result can also be considered in line with the findings of Arundel and Geuna (2004) on the behaviour of European firms.

Table 11: PRO-I geographical distance and firms' experimentation intensity

	Chile				Italy			
PRO-I distance	Cumulative N. of TALs (N. firms)	Average EI	Cumulative N. of CRLs (N. firms)	Average EI	Cumulative N. of TALs (N. firms)	Average EI	Cumulative N. of CRLs (N. firms)	Average EI
Short distance	-	-	-	-	11 (5) [(a)]	0.20	3 (3) [(a)]	1.33
Medium distance	44 (21)	2.19	27 (15)	2.4	21 (19) [(b)]	0.89	8 (7) [(b)]	1.57
Long Distance	-	-	-	-	8 (7) [(c)]	1.85	5 (4) [(c)]	2.00

Note: Short distance is within 100 kilometres; medium distance is between 100 and 200 kilometres and long distance is above 200 kilometres. *(a)* It includes firms with linkages only to the short distance PRO. *(b)* It includes firms, which have linkages with medium distance PROs, may include firms in *(a)*. *(c)* It includes firms, which have linkages with long distance PROs, may include firms in *(a)* and *(b)*.

This result is further explored by adding a third dimension to the analysis: the quality of PROs, measured by a set of impact indicators, at the level of the PRO department (ID), publication (IP) and researcher (IR) (for operationalisation, see Table 3(2) in Section 4). Tables 12 and 13 report a summary of the empirical results. In absolute terms, and not entirely surprising, the results suggest that Chilean PROs have comparative less scientific publications in the ISI WoK database, than Italian PROs: in the former case the number of researchers with publications is on average much lower than in the latter, and, also, scientific publications of the Italian PROs started appearing in the ISI WoK database about a decade before the Chilean, approximately in the 1970s. These differences, however, have more to do with the scale and vintage of Italian PROs than with their actual prestige or quality. In fact, if one looks at the three impact indicators (ID, IP, IR), the difference is not so wide. Thus, the University of Talca and the Catholic University in Santiago de Chile have similar high impact indicators to those of the University of Florence, the University of Milan and the Research Institute of Conegliano Veneto in Italy. In contrast, similar low impact indicators are found for the University of Pisa in Italy and both the University of Chile, and to a lesser extent, the INIA.

More specifically, as illustrated in the previous section, in the Chilean case firms with higher experimentation intensity are more likely to establish a higher number of linkages to PROs. At the same time, higher quality PROs tend to form more intense linkages with firms which, in this case, are among those with stronger internal experimentation intensity. As shown in Table 12, in fact, the University of Talca and the Catholic University in Santiago that rank first in terms of their IP and IR indicators are also those with a higher number of TA and CR linkages to firms.

Table 12: PRO' scientific publications and impact indicators in Chile

PROs	**N. Pub.**	**N. Res.**	**Year first Pub.**	**Quality of PRO**			**N. TALs**	**N. CRLs**	**Ave EI (TA)**	**Ave EI (CR)**
				ID	IP	IR				
Medium Distance										
University of Talca	**63**	**42**	**1988**	**0.70**	**0.74**	**1.11**	**17**	**9**	**1.64**	**2.00**
Catholic University, Santiago	**25**	**18**	**1986**	**0.45**	**0.65**	**0.91**	**16**	**10**	**1.68**	**2.00**
University of Chile, Santiago	32	24	1982	0.34	0.28	0.38	9	5	1.66	2.40
INIA, Santiago	27	24	1992	0.66	0.21	0.23	2	1	2.00	4.00

The Italian case is also illuminating, but in fairly different direction. As shown in Table 13, the neighbouring University of Pisa is relatively less prestigious, having the lowest scores in the impact indicators (ID=0.32, IP=0.58 and IR=0.86). However, it remains striking that it has created numerous linkages to the industry, particularly with firms having low experimentation intensity. This is an interesting result, which is consistent with Mansfield and Lee (1996) and D'Este and Patell (2005). Indeed, this result is due to both the fact the University of Pisa being geographically proximate to the industry and also to some of the university departments' 'mission' to operate as a hub of knowledge for the wine makers scattered in the neighbouring territory. Interviews carried out with university researchers there also corroborates this interpretation. In contrast, Table 13 reports that, by and large, firms with higher EI are linked to PROs, which are both at medium-long term geographical distance and have higher impact indicators. This is found for the University of Florence, the University of Milan and the Research Institute of Conegliano Veneto. Finally, a specific consideration needs to be made for the case of ARSIA. As already mentioned, this is a public research organisation with a mandatory role to perform also as a technology transfer centre. This clarifies why, in spite of the very poor publication records, it does have a remarkable number of linkages with wine producers.

Table 13: PRO' scientific publications and impact indicators in Italy

PROs	N. Pub.	N. Res.	Year first Pub.	Quality of PRO			N. TALs	N. CRLs	Ave EI (TA)	Ave EI (CR)
				ID	IP	IR				
Short distance										
University of Pisa	**61**	**41**	**1973**	**0.32**	**0.58**	**0.86**	**11**	**3**	**0.20**	**1.33**
Medium Distance										
University of Florence	**228**	**141**	1974	**0.75**	**0.92**	**1.49**	5	3	**1.80**	**2.33**
ARSIA	2	2	1997	0.88	0.44	0.44	16	5	0.68	1.4
Long Distance										
University of Milan	**267**	**194**	1973	**0.76**	**0.92**	**1.49**	5	5	**2.2**	**2.2**
Institute of Conegliano Veneto	**23**	**13**	**1980**	**0.67**	**0.95**	**1.68**	**3**	**-**	**1.33**	**-**

These results seem therefore supportive to both Hypotheses 3 (a) and 3(b). In the Chilean and Italian cases, firms with higher experimentation intensity tend to establish linkages with geographically distant PROs and they do so more intensively with higher quality PROs (Hypothesis 3(a)). However, in the Italian case the geographic proximity of the neighbouring University of Pisa and its highly territorial-oriented mission, also fosters networking of firms with very weak in-house experimentation intensity (Hypothesis 3 (b)). This latter hypothesis is not tested in the Chilean case, where no PRO is situated at short distance to the industry.

6. Conclusions

The central role of PROs in fostering economic development has received increasing consideration in the literature, and several studies have highlighted the changing role of universities in the economic system, characterised by the reduction of their historical 'ivorytowerism' and by the start of a 'third mission', based on PROs' more direct contribution to industry. This trend has however raised a series of issues of concern. The increasing problem-solving orientation of academic research is believed by many to come at a cost, and several critics have been moved to the 'entrepreneurial' model of PROs. Changes in the incentive structure of academicians may well favour short term effects to industry but they are likely to undermine economic growth over the long term. Thus, a tension is envisaged

between the developmental goals of those who try to increase PRO-I networking and those who are sceptical about the hybridisation of PROs' historical role as generators of public knowledge. This tension was taken as an inspiring motive for this empirical study, which was spurred by the need to understand the formation of PRO-I networks, whose structural characteristics were to minimise this tension.

In order to explore this issue, a conceptual model of PRO-I network efficiency has been developed here, drawing on Burt's (1992) idea of structural holes. Accordingly, an efficient PRO-I network is one where the costs of direct PRO-I networking, are offset by the high diffusion of PRO-generated knowledge to the overall economic system. In this sense, an efficient network has a high incidence of broker firms and a low level of redundancy of linkages. In comparative terms, this empirical work has shown that the Chilean PRO-I network is more efficient than the Italian one. This is due to the fact that the two cases have a similar cost of direct PRO-I networking (see Section 5.1), but the developmental impact of such direct linkages is stronger in the Chilean case, where, as stated previously, the incidence of brokers is much higher. This rather striking result has been explored by a series of hypotheses testing, involving both firm and PRO-specific variables. The test of hypotheses reveals that PRO-I networking is more *selective* in Chile, where it is especially firms with an advanced experimentation profile that link up to PROs. Not surprisingly then, firms that establish linkages with PROs operate as brokers in the network, as illustrated by Hypothesis 2. These firms in fact carry out in-house experimentation more intensively, as a result being sought out more often than others for technical advice. Finally, in this case, the evidence is consistent with the fact that the selection operates bilaterally: it is not only firms with stronger experimentation intensity that search PROs' collaboration, but also higher quality PROs seek and choose to collaborate with firms from which they can draw valuable knowledge (Hypothesis 3 (a)). This selectivity is at odds with the more *pervasive* PRO-I networking observable in the Italian case. There, the University of Pisa, located at short distance to the industry and ranking relatively poorly in terms of impact of its publications, promotes intensive networking with firms, independent on their internal capabilities, as shown by the test of Hypothesis 1 (a). Once directly connected, however, these firms tend not to diffuse the acquired knowledge to the rest of the firms in the economic system, be it for their weak absorptive capacity or for the fact that they are less likely to be sought out for technical advice. Not surprisingly then, brokers are less common to find in this network. Finally, the presence of a neighbouring university whose mission is oriented to improve the territory, plays here a key role in shaping the PRO-I network, and presumably also in curbing its efficiency.

Accordingly, if the patterns reported here are widespread, interesting questions about policy arise. The policy debate is currently focusing on whether PROs should enhance networking with industry or not, and this paper highlights that what matters is the mode through which PRO-I networking is formed, rather than its promotion *per se*. Thus, policies designed to foster pervasive networking processes between public research organisations and industry may eventually breed redundant PRO-I networks, which are undesirable from a public spending perspective. In view of this, the promotion of PRO-I linkages among selected partners may be a more parsimonious option for policy makers.

To conclude, this paper entails a set of limitations, which should be considered for further research. Firstly, it takes into account only two types of linkages between PROs and the industry—technical advice and collaborative research—when several contributions have shown that the relations between public research organisations and firms are based on a much higher variety of linkages (Bonaccorsi and Piccaluga, 1994; D'Este and Patell, 2005). Further research should therefore consider other forms of linkages, including the mobility of skilled human resources. Secondly, this study has explored the relationship between a selected number of micro-level variables and a meso-level structural characteristics of PRO-I networks, associated with the concept of efficiency. However, this study did not associate PRO-I network efficiency with measures of firm-level performance. This is an important direction of future research because, if on the one hand an efficient network structure minimises the cost for society of direct PRO-I networking, on the other it may eventually imply a higher degree of concentration in the distribution of firms' performance. In effect, it is reasonable to associate an

efficient PRO-I network to an economic space where most of the PRO-originated knowledge is concentrated in a few well connected brokers. Accordingly, brokers could be in the position of exerting control on the diffusion process of the acquired knowledge. In such a way this could lead to a hierarchical access to PRO-I generated knowledge, a fact that may eventually imply a more uneven distribution of the benefits associated to it. Put to the extreme, the distribution of firms' performance in a given economic space may be an endogenous variable shaping a PRO-I network structure itself. This leads to, but leaves open, questions about the relation between efficient PRO-I networks, industry structure and firms' performance. In particular, does a more pervasive PRO-I networking spread the gains of PRO-generated knowledge, and favour an even development process? Or, placed in different terms, how does a more efficient PRO-I network impact on the distribution of the gains associated with the linkages formed between public research organizations and firms?

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Appendix

A. Correlation matrix

	PRO-I Linkages	PRO-I broker	EI Chile	EI Italy	Size	Ownership	Org. Str. 1	Org. Str. 2	Org. Str. 3
PRO-I Linkages	1.00								
PRO-I broker	0.48	1.00							
EI Chile	0.55	0.50	1.00						
EI Italy	0.00	-0.02	-0.30	1.00					
Size	0.24	0.35	0.61	-0.12	1.00				
Ownership	0.21	0.10	0.23	-0.17	0.14	1.00			
Org. Str. 1	0.43	0.09	0.35	0.09	0.28	0.41	1.00		
Org. Str. 2	0.12	0.24	-0.51	-0.13	0.21	-0.08	-0.09	1.00	
Org. Str. 3	-0.45	-0.22	0.40	-0,01	-0.37	0.31	-0.81	-0.4943	100

B. List of PROs' departments

With reference to Section 4.1, the faculties and/or departments searched in the ISI-WoK database are summarised below. Where the PRO has no internal faculties or departments, the search has been performed with the single name, matched with the place and the name of their researchers as in the web page.

1. PROs in Chile

a. University of Talca: Facultad Ciencias Agrarias (Dep. Horticultura, Dep. Produccion Agricola y Centros Tecnologicos), Instituto de Biología Vegetal y Biotecnología.
b. University of Chile (Santiago): Facultad Ciencias agronòmicas (Dep. industria y enologia, Dep. de ingenieria y suelos, Dep. de recursos, Dep. de sanidad vegetal, Dep. de producción agricola).
c. Catholic University (Santiago): Facultad Ciencias agronòmicas y Facultad Ciencias Biologicas (Dep. de sanidad vegetal, Dep. de producción agricola; Dep. de ciencias vegetales, Dep. de fruticultura & enologia, dep. Dep. chem & bioproc engn; Dep. Ecologia, Dep. de omol & enol, Dep. de ciencias forestales).
d. INIA (Santiago): -

2. PROs in Italy

a. University of Pisa: Facoltà di Agraria (Dip. di Coltivazione e Difesa delle Specie Legnose, Dip. di Agronomia e Gestione dell'Agroecosistema, Dip. di Biologia delle Piante Agrarie, Dip. di Chimica e Biotecnologie Agrarie).
b. University of Florence: Facoltà di Agraria (Dip. interfacoltà di biologia vegetale, Laboratori di botanica agraria e forestale, Dip. di ingegneria agraria e forestale, Dip. di ortoflorofrutticoltura, Dip. di scienze del suolo e nutrizione della pianta, Dip. di scienze agronomiche e gestione del territorio agroforestale, Dip. di biotecnologie agrarie, Dip. di scienze e tecnologie ambientali forestali.)
c. University of Milan: Facoltà di Agraria (Consorzio A&Q, Istituto di idraulica agraria, Istituto di ingegneria agraria, Istituto di patologia vegetale, Dip. di produzione vegetale, Dip. di scienze biomolecolari e biotecnologie, Dip. di scienze e tecnologie alimentari e microbiologiche, Dip. di scienze molecolari agroalimentari)
d. ARSIA: -
e. Research Institute of Conegliano Veneto: -