The Role of Research in Wine:
the Emergence of a Regional Research Area in an Italian Wine Production System

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1.   Introduction[1]

In recent years, the wine industry has been involved in a deep process of technological modernisation within which science and investigation have tremendously increased their relevance. These changes are a global phenomenon involving both traditional wine producing countries – such as France, Italy and Spain – as well as new emerging producers –as the US, Australia, and most recently South Africa and Chile. At this respect, there is a general agreement in the literature that the process of technological renovation in the industry has been spurred by large investments made by new producing countries aimed at creating or strengthening research institutions, while the traditional wine areas in Europe have lagged behind, somehow locked in old technologies and methods of production, due to path dependency (Aylward, 2003; Unwin, 1991).

It is well known that technological backwardness and decline of industry competitiveness are not sole a worry in the wine industry but rather a general major concern in many European countries, and particularly in Italy. In response to the European gap in research and innovation, EU and national institutions have introduced a wide range of programmes and initiatives (e.g. research consortia, technological infrastructures, innovation centres, science parks). At the level of the European Union, the promotion of consortia between firms, universities, research centres and public agencies has been the main instrument adopted, funded through six Framework Programmes in a row.

In 2000, the European Commission is then published a milestone document "Towards a European Research Area" (ERA), aiming at the creation of an European market for research, at the restructuring of the European research architecture and at the development of an European research policy, overall aspiring to enhance competitiveness in economic and innovation systems within the European Union.

Within ERA, *"regions are believed to play an important role (…). Despite advances in information and communication technologies, geographical proximity remains one of the most decisive factors in innovation processes, for example through the development of research infrastructure such as Science and Technology Parks and specialised equipment and facilities, regional networks of small and medium sized companies, clustered around universities and corporate R&D centres of (multinational) companies."*(deBruijn and Lagendijk, 2005: 1). Thus at the regional level, the role of science and technology, of the university-industry linkages and of the related policies are hot research topics for both scholars, practitioners and policy makers.

The Regional Government of Piedmont, a northern Italian region where one of the country most important and old established wine producing area is located, has recently issued a law[2] to promote the emergence of a regional system of research and innovation, identifying the main guidelines and objectives in terms of supporting scientific research. One of the major novelty of this law is to explicitly adopt a systemic approach within the general framework set up by the European Research Area, as stated in its Article 1 *"to organise, support and coordinate the regional research system within the European Research Area"*. In this view, regional public policies should strengthen the networking among different actors operating at regional level, e.g. universities, public research centres, firms, extension agencies, business associations. Besides, a new body, the Regional Committee for Scientific Research and Innovation, will be created to take charge of the planning and coordination of the initiatives developed within the Region.

Given the direction towards which the regional research system is moving to, it seems highly meaningful to investigate which are the key pillars of the system today. The actual picture may in fact be helpful to size the efforts required by public actors and research organisations in order to achieve the main goal of the legislator (i.e. to create a regional research area).

In this paper, focusing on the wine regional research system, we intend to provide a detailed account of the structural features of the institutions acting in the region during the last decade as well as of their existing interactions. This latter point is relevant to assess whether a basis of a regional research area already exists.

The interest of undertaking this study on the wine regional research system is twofold: top quality wines are indeed a flag product of Piedmont[3] and besides, as stressed before, research and science have recently become key factors of competitiveness in the wine global industry. The empirical analysis is based on detailed interviews to key informers at research centres, universities, extension agencies, business associations and other associations acting as *opinion/lobbying* groups, undertaken between November 2005 and May 2006. Besides, it draws on a database of all the research projects on relevant topics for the wine industry, funded by the Regional Government of Piedmont in the period 1990-2003, listing all the participating bodies as universities, research labs, business associations and firms. Social network analysis is employed to describe the structural properties of the network stemming from these projects. With all these information we elaborate a detailed picture of actors, linkages and processes underpinning the regional wine research system.

The paper is structured as follows. After, a second section briefly discussing the rationale for science and technology policy, in the third section we introduce the methodology of analysis and in

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[2] Regional Law n° 4, 30th January 2006.
[3] Piedmont, after Veneto, is the second main exporting region in Italy with a share of almost 18% of total Italian wine exports in 2005 (Istat and ICE).

the forth section we discuss the main empirical findings. The final section concludes drawing some policy implications.

2. Science and Technology: the rationale for policies

Drawing on the evolutionary thinking (Dosi *et al.*, 1988; Nelson and Winter, 1982) the literature on the Systems of Innovation (Edquist, 2005; Lundvall, 1992; Malerba, 2004; Nelson, 1993) has extended the rationale for public intervention in research and technology with respect to the conventional wisdom based on under-investments in research and more broadly in innovative activities, due to inappropriability of the full benefits arising from these investments (Arrow, 1962; Nelson, 1959). [4] Within this approach, market failure is also occurring in the access and transfer of knowledge. Accordingly, there is space not only for policies aimed at subsidizing the production of an optimal amount of knowledge, but also at encouraging the transfer of knowledge and information and strengthening the linkages among research institutions and firms. In other words, the failure of the market also stems from the cost of accessing, transferring and exploiting successfully the knowledge already available in the system (Mowery, 1994). This literature refers to the above as a systemic failure, related to the inability of the market mechanism to account for and cope with problems arising from path dependency, technological lock-in, changes in technological paradigms, investments in scientific infrastructure (research labs, technical institutes), institutional matters (regulations, social behaviours), network problems (strong vs. weak linkages), and so on and so forth.

In this theoretical framework, innovation policy is not meant to be a substitute for private action, but rather it is intended as additional, that is to foster actions (e.g. R&D investments, R&D cooperation networks) that would not be otherwise undertaken (Buisseret *et al.*, 1995). In particular, the literature has introduced the concept of behavioural *additionality* to identify public interventions aimed at modifying the behaviour of an organisation[5] (Georghiou and Roessner, 2000).

Following this reasoning, in term of policy, the systemic approach has recently had a deep influence on the framing of innovation policies at EU, country and regional level as well as across sectors, inspiring a number of different innovation measures (Chaminade and Edquist, 2006a). Several initiatives have been set up in order to enhance the diffusion of technology and knowledge to firms, fostering the collaboration between firms and research organisations (CEC 2001; De Bruijn and Lagendijk, 2005). These instruments include the promotion of business centres, the support to the establishment of local research infrastructures, the creation of science parks and the construction of

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[4] A sub-optimal equilibrium is reached since the individual marginal return, the benefits accruing to firms or organisations, arising from the investment in research activities differs from the social marginal return, the benefits to society.

regional networks between firms and research organisations. At European level, the promotion of consortia between firms, universities and research centres has gained the central stage of Science and Technology Policy becoming the most important source of European Union funding and support to innovation under the six consecutives Framework Programmes.

Following this way of thinking, the evaluation of innovation policies has shifted the attention from the measurement of the inputs and outputs, and therefore from questions related with the additionality of public subsidies with respect to firms R&D expenditures and with the compatibility of results comparing with expectations, moving from how and where public money are spent, to the monitoring of the relationships arising from public intervention. This change incorporates the main issues of the systemic approach and allows to explore a number of related topics, overlooked by the conventional view based on market failure. In this new context, there is much more scope for investigating the extent to which public interventions foster collaboration between different actors, exploring the amount and nature of linkages and the content and nature of exchanges arising from these relationships. This framework helps to provide a detailed picture of the actors operating in the system, their characteristics, their role and position in the network of relationships and overall it allows to examine the extent to which the system is vulnerable as well as its efficiency in spreading knowledge and information.

There is a growing bulk of evidence in the economics of innovation that gives account of these new wave of policy experiences. It is beyond our scope to provide an overall review, here we only want to draw the attention to two, very different, strands of literature because of their relevance for our analysis: a first group of studies is focused on regional innovations systems and a second group on innovation and science policies.

The studies focused on the role of local polices in supporting R&D and on regional innovation systems are mainly based on case studies, providing a picture of the actors involved, of the linkages and learning channels existing among them and of the policies implemented at local level (Cooke *et al.*, 1997; Morgan, 1997). Their focus is on local development issues as the impact on employment, the nurturing of local high tech firms, the characteristics of the socio-institutional environment (e.g. trust, common cultural values) the competitiveness of territories; besides, they are mostly concerned with problems of cohesion and convergence between different regions (Sanz-Menédez and Borrás, 2000).

The second group of studies are focused on the role of innovation policies at supranational level (e.g. European R&D consortia) to support research and innovation activities carried out by firms and public organisations. More recently, the attention is shifted towards the analysis of the

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[5] For example in the context of EU research consortia, this means that public policy is additional, and then effective, if it enhances collaboration between firms and public organisations (e.g. universities, research labs; technological centres), which would not interact without public intervention (Luukkonen, 2000: 713).

structural features of innovation systems and particularly of network policies (Breschi and Cusmano, 2004; Malerba *et al.*, 2006). The use of social network analysis, common in these studies, contributes to provide some analytical tools that consent to rigorously describe relationships, exchanges, typologies of contacts, position and evolution of organisations involved in programmes, and more broadly offer insights on how to overcome systemic failure.

In this paper borrowing from both approaches, we aim at contributing to the literature focusing on research and innovation policies, also using social network analysis, to study a regional research system.

3.   Methodology and data

3.1   The database

The empirical analysis is based on a database listing all the research projects in the agricultural field funded by *Regione Piemonte* since 1991 (Table 1). From this database we have selected all the projects related with viticulture and oenology, obtaining a dataset of 48 projects involving 193 actors (e.g. university departments, research centres, extension agencies, firms). The projects cover a very wide range of research areas; among them there are bio-agriculture, product quality, plant and soil defense, quality system, varietal improvement and biodiversity.

The database contains a large set of information concerning the actors involved in the research projects, an in-depth description of the topic investigated, the starting date, the present status of the project and eventually the main findings.

With the available information, a relational database has been created in order to depict the network of relationships among all the actors involved in the research projects. The database covers a long time period, from 1991 to 2003, allowing to trace the network of collaborations over more than a decade.

In addition through in-depth interviews to directors and senior researchers of the main organisations involved in the regional research programmes and from primary sources, we have also collected information about actors' core competences, their main fields of activity and their geographical location.

Table 1   R&D Piedmont Regional Programme in Viticulture and Oenology

Actors involved	• 193 actors of different types: firms, public research centres, business local associations, extension agencies, private labs, training schools and universities
Field of research	• 48 different project financed during the period 1991-2003 in different fields as bio-agriculture, product quality, plant and soil defense, varietal improvement, quality system, biodiversity

Source: Research Unit of the Agricultural Department, Regione Piemonte
 (www.regione.piemonte.it/agri/ita/agriservice/ricerca/index.htm)

3.2   Methodology of analysis

Social network analysis and graph theory are employed to describe the structural characteristics and to provide a visual representation of the web of linkages among all the actors participating to the regional research projects. In addition, the information collected with interviews to key informants complement and support the results of network analysis, allowing to investigate in depth the nature, role and key features of the institutions involved in the R&D projects.

As far as the network analysis is concerned, the unit of analysis is the individual organisation. Organisations are classified according to their main role in the R&D project:

- The first category (EXT) includes organisations mainly devoted to provide services as laboratory tests and to the diffusion of knowledge either formally (e.g. training courses) or informally (e.g. field demonstrations of new wine-making techniques). Private laboratories, local business associations, extension agencies and technical schools are included;
- The second category (R&D) consists of organisations undertaking R&D activities, as university departments and public research centres;
- The third category (PROD) includes firms which are both grape growers and wine producers, which participate to the field studies of the projects.

In the rest of this section, we briefly present the main concepts and tools of network analysis adopted in this study and their use. A network can be defined as a set of actors linked by some relational ties. Actors are depicted as vertices (or nodes) of a graph and the relationship between them is represented by lines. In our context, the nodes are the organisations and the connecting lines indicate that actors collaborate in at least one research project. The strength of the relationships is measured through the number of projects in which each actor participates, thus actors collaborating in more than one project maintain stronger ties. Moreover, we consider only non-directional ties (edges), that is all actors are considered equally involved in the relation. This choice is made to reduce the complexity of the analysis.

The aim of our analysis is to depict the network of linkages generated by the participation in the regional research programme, identifying some structural characteristics of this network and calculating some conventional measures such as density, number of components, average distance, clustering.

Moreover, network analysis is used to assess the role played by the different categories of organisations in the network, using two useful measures: the degree centrality and the betweenness centrality (Wasserman and Faust, 1994). The degree centrality measures the number of nodes incident to a given node. This means that actors with an higher degree centrality have many

alternative links at disposal; therefore, they are less dependent on others and at the same time more powerful, since they have access to many different sources. In our context, this means that central organisations do have many contacts and through them they access a vast array of information and knowledge. In the same vein, we may argue that these organisations may themselves be key sources of information for their network, depending on their specific nature and activity.

The betweenness centrality is defined as a node that lies on the shortest path between two other nodes. This node is a sort of intermediary between the two other nodes, and because of this strategic position it can influence the communication and the exchange of information between them. This implies that organisations that show higher betweenness centrality are more influential, since they can facilitate or rather interrupt the flow of knowledge in the network. A specific and relevant case is that of *hubs*, that is nodes which represent a gate for a group of other organisations connected through it to the rest of the network. An excessive number of hubs may represent a weakness in the network structure because it becomes very vulnerable, given that the removal of these strategic nodes strongly reduces the overall connectivity of the network.

In the network analysed in this paper, organisations characterised by high degrees of centrality and betweenness are defined as *hubs*, which are able to connect distant actors in the network. Therefore, the degrees of centrality and betweenness centrality are computed for all the organisations involved in the network, which are then accordingly ranked. The most influential organisations, defined as the hubs of the network, are those being ranked in the first places for both indicators.

The results of the network analysis are presented in section 4.3 to complement the qualitative analysis of the Wine Regional Research System (RRS) of Piedmont, its main actors and policies presented in the sections 4.1 and 4.2.

4 The Wine Regional Research System (WRRS) of Piedmont

4.1 Policies in the WRRS: an overview

The "Regional Programme for Research, Experimentation and Demonstration" is the framework through which the Department of Agriculture of the Regional Government of Piedmont funds science and research projects in agriculture. Organisations funded by the Regional Programme are public and private research institutions, such as universities, regional or national research centres and technical organisations, such as local extension agencies, laboratories, technical high schools, technological centres. The programme is not meant to finance basic research, nor industrial research, but rather it aims at funding projects whose findings have to be general –not representing few actors' interests- and public –not appropriated by the projects partners- and they should be relevant in the agricultural production system. In this context, collaboration between research institutions and technical organisations is intended to favour the dissemination of the findings to end-users (e.g. firms), being the latter key actors in the process of knowledge transfer. The

participation at each project of at least one scientific institution and a technical organisation is in fact an explicit requirement to access funds. Typically, the team is composed by a prime contractor, who mostly matches with the scientific leader of the project, and several partners, which can be either extension organisations, associations of producers or firms.

The mechanism to access funds is quite straightforward. The Department of Agriculture, after consulting with all the main stakeholders in the field, defines a list of research priorities for the next three years, then publishes a call for tenders and finally evaluates and selects among the submitted proposals the projects to be funded.

Moreover in order to address specific issues or to cope with occurring emergencies, the Department of Agriculture, through its research and extension units (e.g. Tenuta Cannona and Regional Advisory Phytopathological Service), often in collaboration with some partners, can directly lead some research projects, which therefore are additional to the projects selected with the calls for tenders.

Taking into account the total funding of the Programme in the period under analysis, it is important to note that there is a continuous and significant increase from 800 thousand € in 1990 to 2,6 € millions in 2005. Within the Programme, the research projects on wine related issues represent an important and stable share, corresponding to roughly the 20 percent of the total budget.

In this paper, we do focus on these sub-group of wine projects for which we provide below some further information. Figure 1 shows the steady growth in terms of number of funded projects from 1991 to 2003. The total number of projects funded and here examined is 48 to which overall 193 actors participate. Among those actors, firms are the largest category and this is explained by the fact that firms' participation in projects mainly consists in providing a field site where conducting the experimentations (Table 2). On average several firms participate to the same projects, with an extreme case of a project in which there are 32 firms. Moreover, the average number of projects per firm indicates that their participation is often occasional, quite the opposite of the research and extension organizations which do participate repeatedly to projects, as it will also be confirmed beyond by the network analysis. It may be worth to notice that there are projects in which firms do not participate at all and this depends on their content as shown in Figure 2. Firms do participate a lot in projects on plant defence and quality of product, which are by large the two areas receiving the largest part of funding[6], while in the remaining fields of research their participation is less frequent.

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[6] According to our key informers, more than 70% of the total amount of resources available in the regional programme goes in these two areas of research.

Figure 1 – Number of on-going projects in wine-related issues funded by the Regional Research Programme in Piedmont
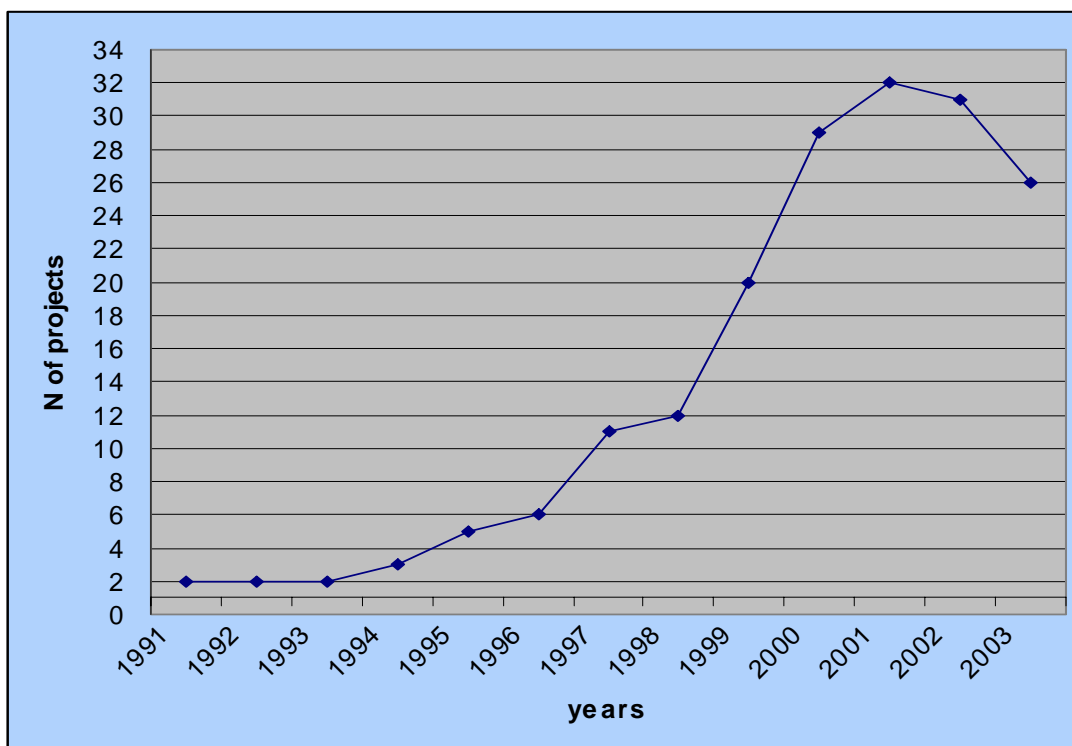

Table 2 - Summary statistics of the wine projects (1991-2003)

	EXT	R&D	PROD
Total number of actors	23	15	155
Distribution of actors (%)	11,9	7,8	80,4
Average number of actors per projects	1,81	1,27	3,5
Average number of project per actor	3,91	4,07	1,05
Maximum number of actors per projects	4	6	32
Minimum number of actors per projects	1	1	0
Maximum number of projects per actors	19	15	3

*Actors can participate to more than one project

Figure 2 - Organisations participating in projects by focus of the project (1991-2003)
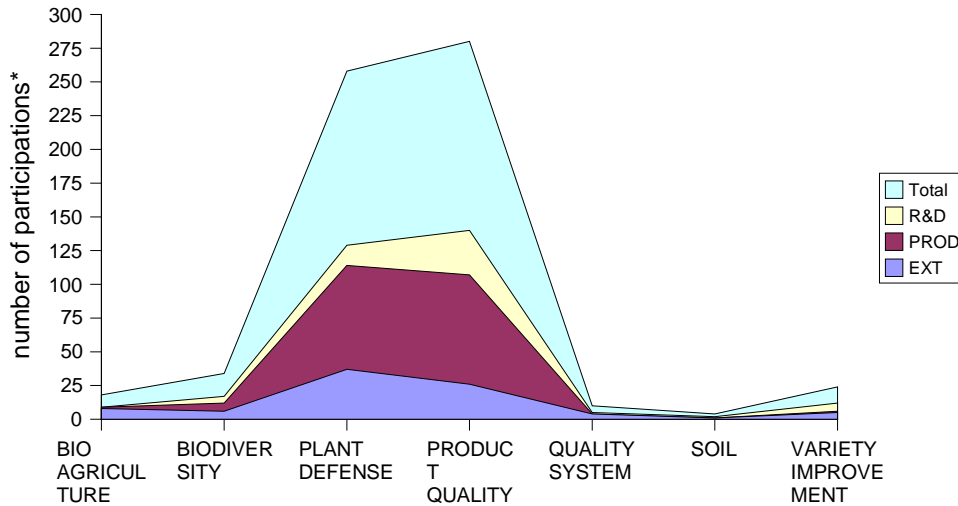
*Actors can participate to more than one project

4.2 The main actors in the WRRS

In this section we present some information about the main research and extension organizations which participate in the wine-related projects funded by Regione Piemonte.

Research Organizations

At the regional level, there are a number of research institutions participating to the R&D projects funded by the Region in the field of oenology and viticulture (Table 3). Among them, there is the Institute of Plant Virology (IVV), a centre specialised on wine-related research belonging to the National Research Council (CNR) network.[6] In Piedmont, the IVV has its headquarter and a branch which is located at the Faculty of Agronomy.[7] IVV carries out basic and applied research, besides offering consultancy services to the Ministry of Agriculture and Forestry and to local regional extension agencies as the Regional Advisory Phytopathological Service and Tenuta Cannona. Its main areas of research specialisation are studies on problems related to viruses and the diseases they cause and the improvement of the sanitary status of vines. There is also substantial research work done in the field of evaluation and testing of sustainable means to control viruses, in the elaboration

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[6] The National Research Council is the largest Italian research public body whose aims are to promote, coordinate and carry out research in every scientific and technological sectors. Within the CNR, there is a network of 107 research institutes which are distributed all over the country and divided in specialised centres and territorial sections. The CNR employs more than 4 thousand permanent researchers (Rolfo and Calabrese, 2005).

[7] There are two other branches outside Piemonte: one at the University of Milano and the other at the University of Bari.

of infection forecasting models to analyse and prevent the diffusion of specific diseases and in the production of customised diagnostic kits for special needs and users.

Table 3 – The main research organizations participating in the projects funded by Regione Piemonte

Name	Activity	Main field of research	N° of researchers	N° of publications (Isi)	N° of recent national or EU project	Region
Research Organisations						
Institute of Plant Virology (IVV) – CNR	Research	Microbiology/ virology	10	32	26	Piedmont
Experimental Institute of Oenology – CRA	Research	Oenology	5	4	17	Piedmont
Experimental Institute of Viticulture – CRA	Research	Viticulture	26	10	18	Veneto
DEIAFA – Mechanics area, Faculty of Agronomy - University of Torino	Education & Research	Field and crop engineering	2	9	5	Piedmont
Department of Arboriculture and Pomology, Faculty of Agronomy - University of Torino	Education & Research	Viticulture	5	31	16	Piedmont
Institute of Viticulture, Faculty of Agronomy, Catholic University of Piacenza	Education & Research	Microbiology/ virology	5	52	9	Emilia Romagna
Institute di Enthomology and Vegetal Pathology, Faculty of Agronomy, Catholic University of Piacenza	Education & Research	Enthomology	6	9	5	Emilia Romagna
Department of Arboriculture, Faculty of Agronomy - University of Bologna	Education & Research	Viticulture	7	18	--	Emilia Romagna
Department of Agronomy and Forest Management , Faculty of Agronomy - University of Firenze	Education & Research	Viticulture	19	7	9	Tuscany
Department of Horticulture , Faculty of Agronomy - University of Firenze	Education & Research	Microbiology/ Viticulture	9	0	--	Tuscany
Department of Vegetal Production - area of Arboriculture, Faculty of Agronomy, University of Milano	Education & Research	Viticulture	9	33	18	Lombardy
Institute of Enthomology, Faculty of Agronomy, University of Milano	Education & Research	Enthomology	2	0	--	Lombardy

Institute of Vegetal Pathology, Faculty of Agronomy, University of Milan	Education & Research	Microbiology/ Virology	5	14	20	Lombardy

The Research Council in Agriculture (CRA) is a network of almost 30 organizations undertaking research in the field of agriculture, under the supervision of the Ministry of Agriculture and Forestry (MIPAF). There are two institutes specialised on wine related issues which both participate in the projects funded by the Regione: the Experimental Institute of Oenology (ISE) located in Piemonte, and the Experimental Institute of Viticulture, in Veneto (Conegliano). The Experimental Institute of Oenology was founded in 1872 and it has its head office in Asti where four research units are located: Oenological Chemistry, Oenological Microbiology, Oenological Technology and Mechanics and Sensory Analysis. Its institutional task is conducting physical, chemical and biological studies on the composition and processing of grapes and the preparation, conservation and technological improvement of wines. The Institute also carries out applied research on topics as pesticides, genetic improvement of vines, innovative techniques to improve the quality of wines, clone and yeast selection, post-harvest activities related to wine making technology and environmental management of vineyards. ISE also manages three experimental vineyards, one near the headquarter in Piemonte and the other two in Tuscany and in Puglia, where some of the field research is done. ISE, in collaboration with the other CRA wine specialised institute, the Experimental Institute of Viticulture, also publishes a scientific journal, the "*Rivista di Viticoltura e di Enologia*" (Journal of Viticulture and Oenology), which is one of Italian leading journal in the wine field.

The University of Torino, with its Faculty of Agronomy, is also playing a key role in research and education on wine related issues. With regard to education, the Faculty offers a wide range of courses in viticulture and oenology at both graduate and undergraduate level; among them there is a recently established two-years international master degree in viticulture and oenology, in collaboration with other Italian and European universities.

The leading research position of the Faculty, stressed as a key feature of the regional wine research system by a number of key informers, has also been confirmed by the recent first national research assessment; particularly, the departments involved in wine-related research have obtained a high ranking.[8]

These departments are the Department of Exploitation and Protection of Agricultural and Forestry Resources (DI.VA.P.R.A.) and the Department of Arboriculture and Pomology. In DI.Va.PRA., one sector, Microbiology and Agricultural Industries, is particularly active in wine related research and studies are carried out on issues as microbiological processes affecting vines and soil, biological

controls and pesticides, processing technologies. Complementary to these issues, the interests of research in the Department of Arboriculture and Pomology cover fields such as genetic improvement of plants, harvesting and post-harvesting techniques and their relation with the quality of wines.

Besides the University of Turin, other Italian Universities participate in the wine research projects of Regione Piemonte. Among the institutions which have been more frequently involved, there are in Emilia Romagna the Catholic University of Piacenza and the University of Bologna, the University of Firenze (Tuscany) and the University of Milan (Lombardy). In all these Universities there are Faculties of Agronomy and departments with renowned research teams specialised in wine-related studies.

To conclude, overall the main research organizations involved in the analysed projects show a good record of publications on international recognised journals[9] and besides they are all involved also in other research projects on issues related with wine at national and European level (Table 3).

Extension organisations

Within the wine regional system a key role in knowledge dissemination and technical assistance is played by a number of public or quasi-public organisations (Table 4). Among them, a central actor is *Tenuta Cannona*, a public company owned jointly by Regione Piemonte, some local municipalities and Vignaioli Piemontesi, the main association of wine firms in Piemonte. *Tenuta Cannona* is an experimental farm with its own vineyards and testing laboratories, conducting research in the field of soil defense, analysis of clones, wine making techniques and weather forecast techniques. Moreover, it provides technical services as sensory analysis of wine and microvinification to other regional actors as IIV, ISE and the Faculty of Agronomy in Torino and it offers wine tasting courses. Tenuta Cannona participates, often as a leader, in projects financed by Regione Piemonte.

Another key actor in the extension system is the Regional Advisory Phytopathological Service (*Settore Fitosanitario Regionale SFR*), which is the public body responsible for monitoring sanitary problems in agriculture. The SFR has three laboratories specialised in phytopathology, agrochemical and agrometeorological analysis, which are run by a qualified staff of technicians. These laboratories also work for external actors such as research centres and wine firms.

Associations of producers also play an important role in disseminating technical knowledge and providing technical support for their associates. In particular *Vignaioli Piemontesi*, the largest association of wine and grape producers in Italy, with more than 8000 associates (including 500 wine firms and 49 cooperatives), is a key player in the Piedmont Wine Regional Research System.

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[8] Results are available at www.civr.it
[9] The articles listed in Table 3 are extracted from the Web of Science edition of the Science Citation Index Expanded of the Institute for Scientific Information (ISI).

The mains aims of the association are to empower associates through lobbying activities and to provide them technical and commercial assistance. The association employs a team of technicians, mainly agronomists, who work closely with the associated firms, and particularly, in small firms they are often in charge of the whole agronomic management of the vineyards. *Vignaioli Piemontesi* directly participates in many of the research projects financed by Regione Piemonte, mainly acting as a technical partner of the scientific institutions involved in projects. Its main task is to carry out fieldwork research (e.g. collecting data, monitoring of results), and to disseminate the results of the projects to farmers and wine producers.

Table 4 – The main extension organizations participating in the projects funded by Regione Piemonte

Name	Activity	Main field of research	Number of researchers	Region
Regione Piemonte – Tenuta Cannona	Extension	Viticulture	8	Piedmont
Regione Piemonte - Regional Advisory Phytopathological Service	Extension	Virology/ food safety	5	Piedmont
Vignaioli Piemontesi	Extension	Viticulture	8	Piedmont
Barolo Langhe and Monferrato Consortium	Extension	Oenology	--	Piedmont
Technical high school in viticulture and oenology, Alba	Education	Viticulture and oenology	10	Piedmont
Technical high school for agriculture, "G.Penna", Asti	Education	Oenology analysis	0	Piedmont
Technical high school for agriculture, Cussanio	Education	Oenology analysis	0	Piedmont
Technical high school in viticulture, "Malva Arnaldi", Bibiana	Education	Cultural techniques	2	Piedmont
Cadir lab	Laboratory	Phytopathology analysis	8	Piedmont
Enocontrol lab	Laboratory	Oenology analysis	1	Piedmont
Sagea lab	Laboratory	Phytopharmacy, sensorial analysis	--	Piedmont
Viten lab	Laboratory	Phytopharmacy, sensorial analysis	8	Piedmont

Other institutions sometimes participating in the Regione Piemonte research projects are the different wine consortia established to defend and promote the specific local typology of wines. In Piedmont there are 22 different consortia, providing technical assistance on matters related with all the regulations for wine certification, which concern the production area, the grape varieties that can be used in a

particular regional blend, the vine cultivation techniques, the alcoholic content, the production and aging methods together with a specification of which kind of information should be put on the wine label. Their role is crucial in all the research projects aimed at the improvement of the specific wines under their control as well as to identify vineyards and wineries where to conduct the fieldwork. Besides, they participate actively in the dissemination of results to local farmers and wineries.

A further typology of institutions involved in the research projects are the technical high schools. Among them, the Oenology School in Alba is a very old institution offering a technical high school degree in oenology. Technical schools in most of the cases participate in research projects through the use of their laboratories and their vineyards.

Another category of actors involved in projects are private laboratories. Their main activity is to offer testing services to firms. In some cases, they are run by well-known wine makers who works as consultants for many different firms, not only locally. Their participation in research projects is confined to testing activities.

In the next section, with network analysis we focus our attention on the relationships occurring among all these research and extension actors as well as with the many participating firms. Here, we may anticipate that on the basis of the information collected with some direct interviews to their directors, some researchers and key informers, it appears that all the local research organizations have established a rather dense web of, mainly informal, local ties facilitated by geographical as well as cognitive proximity. Besides, most of the actors have also set up connections with research centres outside the region, both in the rest of Italy and abroad, participating to several research projects at regional, national and European level.

Nevertheless, among our key informers there is a diffused opinion that a drawback of the regional system is the fragmentation of research activities in too many institutes, departments and laboratories and the duplication of results. The Australian wine research system, coordinated by the Australian Wine Research Institute, is often referred to as a successful model to reach scale and scope economies, obtaining considerable results, which other emerging producing countries, as South Africa, are replicating.

4.3   An analysis of the WRRS network

This section presents the results of the network analysis carried out on the R&D projects funded by the Regione Piemonte. This further investigation complements the above discussion on the characteristics of the actors involved in the R&D projects. More precisely, it intends to analyse the structural characteristics of the network of relationships in which research, extension and production organisations are embedded. In order to do so we use a number of indicators, widely applied in network studies (Wasserman and Faust, 1994).

A conventional way to begin the analysis of networks is to assess the degree of connectedness. A first rough indicator is given by the *number of components* (i.e. number of connected sub-graphs in a network), as reported in Table 5. We observe that the network is highly connected, in fact there is only one connected sub-graph that coincides with the network itself. This indicates that each actor involved in the regional projects is, directly or indirectly, connected via collaboration with all the other organisations in the network. A further measure of cohesiveness is *density* (i.e. the ratio between the number of actual links and the maximum theoretical number of possible links). Overall, the density is quite high and high connectedness is also confirmed by the *average degree*, i.e. the number of actors to which a node is directly linked, which is close to 30.

To quantify the efficiency of a network in connecting different actors and facilitating the flows of information and knowledge it can be calculated the *average distance*, which measures the number of steps that have to be taken in order to connect two randomly selected nodes. On average, each actor takes 1.9 steps to reach a randomly selected actor in the network, which is a rather short distance. It is worth to notice that the maximum distance connecting two nodes is also rather low, being 3 steps.

A further interesting characteristic of the structure of the network is *clustering*, which indicates to what extent subgroups of actors form clusters, that is whether they show high local density. The clustering coefficient tells how much of a node's collaborators are, on average, willing to collaborate each other. Table 5 shows that on average almost 15% of the collaborators of a certain actor in the network also collaborate each other.[10]

Table 5 Structural characteristics of the WRRS network (1991-2003)

|	
Number of links in projects	2765
Number of organisations	193
Density (x100)	14,92
Number of components	1
Number of organisations in the largest component	193
- as % of all organisations	100
Average degree	29.95 (24.64)
Average distance	1.924
Maximum distance	3
Clustering coefficient	0.1457 (0.071)

*Standard deviation in bracket

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[10] To be noticed that results are partly reflecting the structure of the bipartite graph, in which all the actors in the same project are by definition connected among each other.

The above analysis indicates that the overall structure of the network is highly cohesive and actors are strongly connected. We can investigate this latter aspect by visualising the research network. The figures 3a, b, c and d, in which nodes represent organisations and ties indicate that actors have collaborated at least once in a project, depict the research network under different hypothesis. The different colours indicate the three categories of actors: blue nodes stand for firms (i.e. PROD), which account for more than 80% of the organisations involved in the regional research programme; red nodes identify extension organisations (i.e. EXT) and green nodes are universities or public research centres (R&D). The first figure shows the network including all the actors that have participated at least to one project during the period examined. As stated above, each actor can reach any other node in the network, which is a pretty good property in this context because it means that each actor, for example entrepreneurs, has several opportunities to get in touch with many different institutions, and furthermore he/she can also reach any given source of information through many possible paths. Thus, at first sight, these projects seem to be rather effective in connecting different organizations and through them the people involved in them (e.g. technicians, entrepreneurs, researchers). It may be worth to add that the existence of personal links among individuals within organizations has been strongly stressed by many key informers interviewed.

The second figure (b) shows the network including only actors that have participated to at least two projects and the third one (c) shows only the ties between actors that have participated to more than three projects. It clearly emerges that connectivity abruptly decreases. In particular, most of the firms remain isolated. What emerges from the visual inspection of these networks consents to better specify what has been stated before that is firms participate in projects occasionally and they are connected with the network mainly through weak (in terms of number of projects in which an actor is involved) ties. This may imply that for firms the participation to a project is an opportunity to accrue information and to meet technicians and researchers but, in general, relations cannot be nurtured and trust among rather different agents, as scientist and entrepreneurs, can hardly be reinforced. Conversely, some extension and research organisations are strongly linked among each other. Figure 3d depicts those organisations with participation rate over the average (i.e. more than 4 projects). The sub-graph includes 4 research institutions and 3 extension organisations, all located in Piedmont. Among the former there are two departments of the University of Turin (Divapra and the Department of Arboricolture and Pomology) and two public research centres (IVV-CNR and Institute of Oenology-CRA), the latter include some of the most relevant actors among extension organisations (Vignaioli Piemontesi, Regional Advisory Phytopathological Service, Tenuta Cannona and Sagea Centro di Saggio).

Figure 3 - The Wine Regional Research System Network

a)

b)

c)

d)
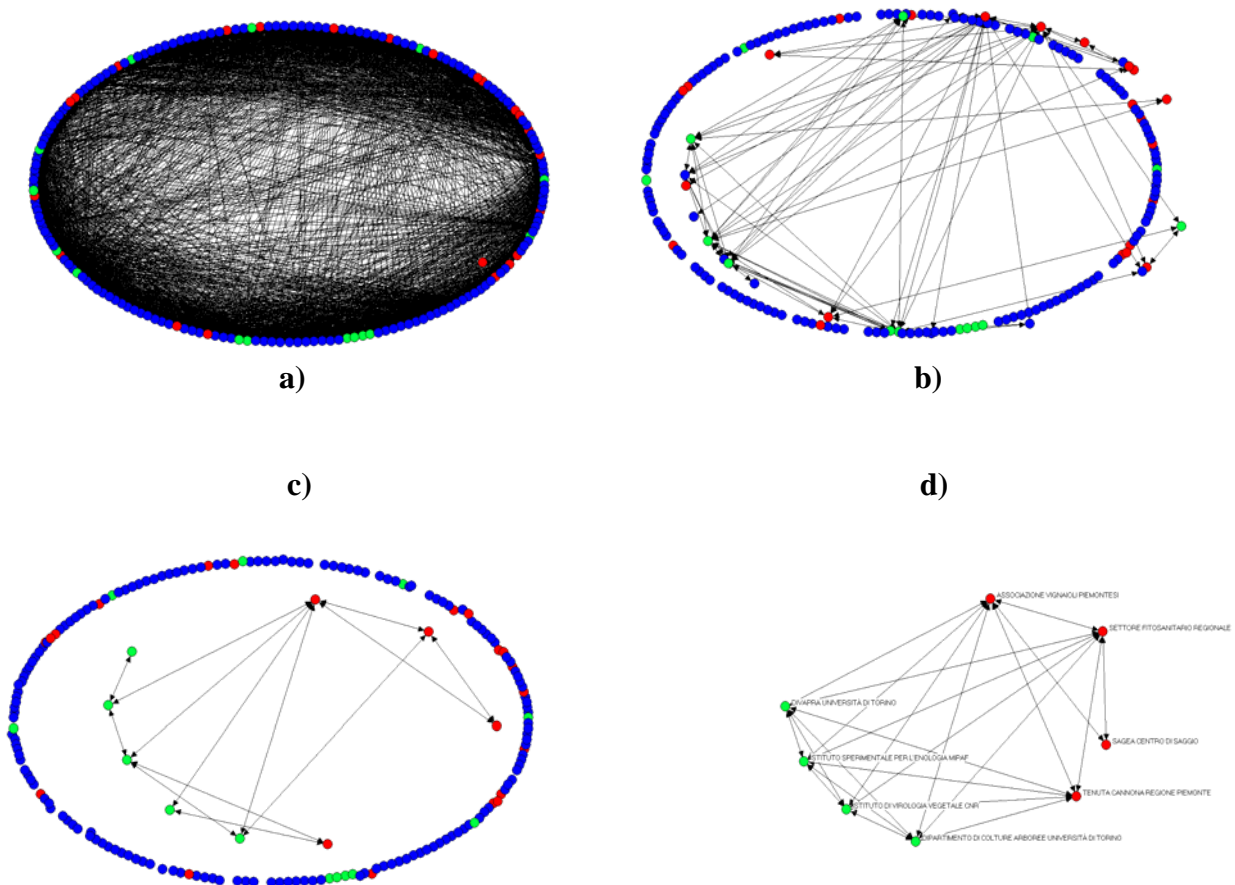
The above analysis suggests that there is a core of organisations in the research programme. We can investigate this latter aspect by assessing the centrality of organisations. In particular, it is extremely interesting to rank organisations according to both their centrality and betweenness to measure their ability to source, disseminate and control knowledge flows within the network. Actors having jointly the highest centrality and betweenness can be identified as *hubs* of the network. Table 6 reports the distribution of hubs according to their activity. We first notice that, as expected, extensions and R&D organisations constitute the largest groups. We also find a rather even distribution between these two groups (38% of hubs are R&D organisations and 35% are extension insitutions) while only 26% of hubs are wine firms (PROD). Above all, extension and R&D

organisations are far more represented as hubs with respect to their rate of participation in the network.

Looking more in details at individual organisations, we find that a relatively small number of research organisations are central (in terms of degree centrality and betweenness) (Table 7). The hub with the highest degree of centrality and betweeness is Vignaioli Piemontesi, the largest association of producers in Piedmont, followed by another extension agency: the Regional Advisory Phytopathological Service. Then, there are the main regional research institutions, together with a few firms. A further result is that all the hubs are located in Piedmont.

A visual representation of hubs is depicted in Figure 4. The size of nodes indicates the value of centrality (given by betweennes and degree centrality) and the hubs are represented as diamonds. Focusing on hubs, we notice that they differ a great deal in terms of their size. Extension organizations are by far the largest, followed by some research institutions (Department of Arboriculture and ISE). This latter finding shows that extension and R&D organisation are well connected among each other and that a few large technical bodies, Vignaioli Piemontesi and the Regional Advisory Phytopathological Service, play the role of hubs between scientific institutions and wineries.

This is indeed an important result if we remember that among the goals of the "Regional Programme for Research, Experimentation and Demonstration" there is the promotion of collaboration between research institutions and technical organisations, which are assumed to be key players in the dissemination of the research findings to end-users (e.g. firms). The empirical analysis presented in this paper suggests that in the wine sector the network of relationships which has emerged from this Programme is highly dense and connected with a core of organizations acting as hubs, a network which, on the basis of its structural characteristics, is apt to diffuse knowledge in an efficient way.

### Table 6 - Distribution of hubs and participants by activity

	1991-2003	
	Participants (%)	Hubs(%)*
EXT	11,9	35,5
R&D	7,8	38,2
PROD	80,3	26,3
Total (%)	100	100
Total (N)	193	10

*Organisation raking higher weight more than those ranking lower. wi $=(max\ r + - ri\ ) / \sum ri$, where wi sums to 1 (see Malerba *et al.*, 2006).

Table 7 - Hubs of the WRRS network

rank	1991-2003	activity
1	Vignaioli Piemontesi	EXT
2	Regional Advisory Phytopathological Service	EXT
3	Department of Arboriculture and Pomology – University of Turin	R&D
4	Experimental Insitute of Oenology – ISE (MIPAF)	R&D
5	DIVAPRA University of Turin	R&D
6	Wine firm 'GOZZELLINO'	PROD
7	Wine firm 'PIANA'	PROD
8	Wine firm 'ACCORNERO'	PROD
9	Wine 'CHIARLO M'	PROD
10	Institute of Plant Virology - IVV (CNR)	R&D

Figure 4 - Hubs and central actors WRRS network
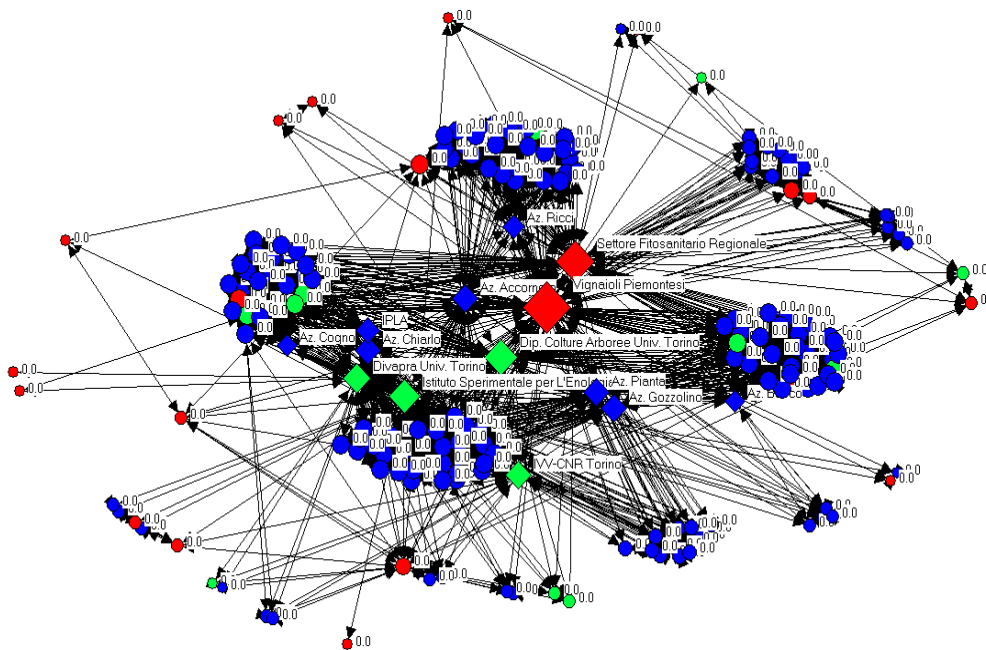
5. Conclusion

This paper is aimed at providing an analysis of the R&D projects funded by the Regione Piemonte in the wine sector, of the institutions involved and of their interactions. With social network analysis, we have mapped the structure of the relations established by all the actors participating in these projects, investigating the structural characteristics of the network and identifying the role played by the different organizations in the wine regional research system.

Our findings show that the wine regional research system emerged from the "Regional Programme for Research, Experimentation and Demonstration" is highly cohesive and all actors are strongly connected. An important feature of the network is the existence of a core of key organizations, characterized by high degrees of centrality and betweeness and defined as hubs, which are mainly R&D and extension institutions and play a key role in diffusing knowledge around the network.

It may be worth to add that our interviews to key informers have widely confirmed the existence of continuous and intensive personal links among researchers and technicians working in the institutions which have been classified as hubs in the network analysis. As a whole, the structure of the emerged network seems to diffuse knowledge, also reaching a large number of firms, in an efficient manner.

Going back to the reason of our interest in investigating the key pillars of the actual wine regional research system in the perspective of the new regional policy aimed at promoting the emergence of a regional system of research and innovation within the general framework set up by the European Research Area, we can conclude that in the wine sector there is already a well established and highly connected network with some key actors, which are important R&D organizations and extension agencies. The existing configuration needs to be considered as starting point for the new regional research area.

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