Network analysis to understand the labour market. Mobility flows of graduates and PhDs in the labour market of the Friuli Venezia Giulia Region from 2005-2014

PRELIMINARY VERSION. COMMENTS ARE WELCOME

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Abstract

This paper presents an analysis of the regional labour market for graduates and PhDs in the Italian region of Friuli Venezia Giulia. It makes use of Social Network Analysis tools to understand the structure and evolution of the network connecting the firms (nodes in the network) through their hiring flows (links) over time.

The analysis is based on an original data set of individual data coming from three sources: the universities' archives for graduates and PhDs, the data bank of balance sheets for firm characteristics, and hiring data from administrative archives held by the Regional Employment Agency. The analysis includes the period between 2005 and 2014 and two sub-periods (2005-2008 and 2009-2014), which were characterized by different phases in the economic cycle.

The results show a complex structure composed of a number of firms but dominated by a few large hubs, during both the whole period and the two sub-periods considered. Innovative firms show a greater interconnection, particularly in more recent years (2009-2014).
Overall, the study points to the important role of network analysis, a unique tool for jointly considering the labour and industrial policies.

Keywords: hiring flows, labour market for graduates, network analysis, Friuli Venezia Giulia region

1. Introduction

This paper investigates the structure of the labour market for graduates in the Friuli Venezia Giulia region, looking at the inter-firms network determined by the workers mobility flows. The study represents an attempt to analyse a local labour market for graduates in an Italian region by making use of Social Network Analysis (SNA) (Wasserman & Faust, 1994). Ultimately, it has a twofold aim: to better understand the labour market in Friuli Venezia Giulia region and to explore the potential application of network analysis to this field of research.

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SNA has been used extensively within the social sciences to study a wide array of topics linked to the labour market, from migrations to job search to social capital and beyond. In the field of economic analysis, network analysis remains less widespread (see Jackson, 2007 for a review), and has been essentially aimed at modelling the costs and benefits of network formation and at understanding how individual behaviour and outcomes are influenced by networks, so treating the network as an attribute to the individual. This last perspective is adopted in a significant stream of labour literature to assess how much the network influences the labour market outcomes (hiring, incomes, wage differentials and alike) (See, among others, Hellerstein et al., 2011)
Still, the number of studies aimed at analysing the complex network arising from the workers mobility to understand its structural characteristics seems to be very limited (see Giannelle 2014, 2010 and Feri et al., 2006). Beyond the analysis of employment, unemployment and their variations, understanding the functioning of the labour market implies a comprehensive analysis of workers' mobility flows. These flows occur between different occupational statuses and, once employed, among different firms (Davies et al., 2006; Contini & Trivellato, 2005).

In this context, the SNA tools seem to be one of the most appropriate methodologies for tracking the complex array of mobility that connect individuals and firms inside a defined (local) labour market: the firms can be viewed as the nodes of a network, and the hiring flows are the links connecting the different firms.
The pattern of mobility flows and their characteristics, along with the characteristics of the recipient firms, make it possible to identify the role performed by particular firms (nodes) in the local labour market. It also allows us to highlight the possible existence of forms of market segmentation not easily detected with more traditional analytical tools. Moreover, it allows us to ascertain if particular groups of firms – e.g., the most innovative ones – are characterized by a greater intensity of inter-firm graduate's flow. On this respect, an extensive stream of literature has demonstrated the role of inventors' and skilled workers' mobility in firms' innovative performance, particularly in terms of geographical areas (Zucker et al., 2002; Breschi & Lissoni 2009; Moretti, 2013).

One of the main reasons for the lack of empirical analysis making use of SNA relies on the paucity of suitable data. In fact, to perform the network analysis, we need detailed information regarding each firm and worker as well as the single hiring flow linking them. This study is based on a new dataset built on individual data coming from three different sources: the universities' archives for graduates and PhDs, the data bank of balance sheets for firm characteristics, and hiring data from the compulsory notifications to the Regional Employment Agency of Friuli Venezia Giulia

The empirical analysis focuses on firms and on workers' hiring flows connecting them to understand the global network structure. Firms are classified by degree of innovativeness (using Eurostat classification of R&D intensity) and, where possible, by size.

After having considered the network structure and identified the major players inside it, we focus on firms' degree of innovativeness in order to ascertain if this characteristic is coupled with a higher density of links between the firms. The analysis focuses on the years from 2005 to 2014, a period characterized by different cyclical phases marked by the great recession. For this reason, it seems important to consider the two periods of 2005-2008 and 2009-2014 separately to verify the impact of the crisis on the network structure.

The paper is organized as follows. Section 2 presents a brief survey of the possible uses of SNA, as applied to labour market analysis. In section 3, we describe the data set and the main characteristics of graduates, firms and hiring flows (typology of labour contracts). Section 4 presents the results of the network analysis based on the whole typology of contracts (temporary and permanent) discussed.

In section 4, we focus only on the networks created by links deriving from the permanent contracts while presenting a comparison of the network structure in the two sub-periods (2005-2008 and 2009-2014). We then go on to present the network characteristics of firms belonging to groups with different degrees of innovativeness (measured by their sector affiliation and number of patents). Section 5 concludes by summarizing the results and making suggestions for future policies and research.

2. Labour markets flows and network analysis: a few insights.

Labour market flows and their dynamics and structures are fundamental features of labour market functioning (among others, Davies, 2006 and Davis & Haltiwanger, 1999). Several studies on graduates have addressed this point (Biggeri et al., 2001; Brunello & Cappellari, 2008; Pozzoli, 2009; Chies et al., 2015). However, network analysis opens up a new perspective because it jointly accounts for the different characteristics of actors, firms and workers, as well as the intensity of the links between them, as created by mobility flows.

A network is defined by a set of actors and links among them. In our case, nodes of the network are firms and links are defined by the mobility of graduates through them via permanent and non-permanent contracts activated during their working careers.

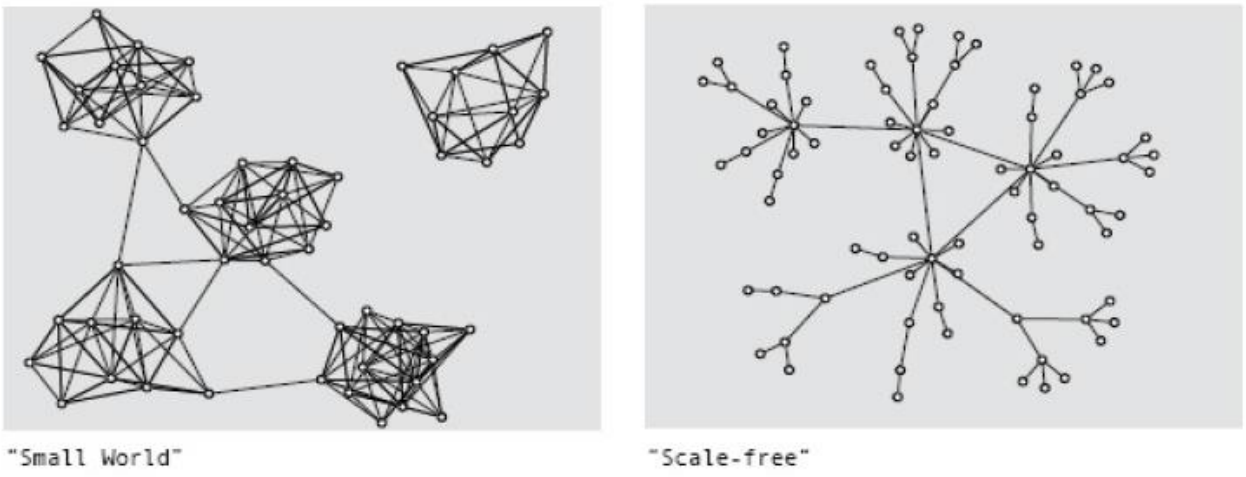
In this contetx, observing the labour market network at a macro-level, it is possible to identify some peculiar structural and dynamic features that can describe the structural functioning of the market itself. In particular, this point can be addressed by identifying if the labour market network looks like a certain theoretical network configuration, that depend on the distribution and on the extent of linkages (examples of network theoretical configurations are: scale-free networks, core periphery). Among the others, one important theoretical configuration, known as small word network, is often observed in real world (Watts and Strogatz, 1998). A small world is characterized by the following condition: a large number of nodes is reachable from many others; nodes are reachable with little effort, the system is parsimonious (see Figure 1 for a comparison between small world and scale-free network). According to a substantial stream of literature a small world seems to be highly efficient towards information (Giannelle 2010) and knowledge diffusion (see among others, Breschi & Catalini, 2010). When such conditions prevail in the labour market, we can say that the system is integrated and permeable: i.e. workers can easily move inside the network. In other words, as far as labour mobility is concerned, a small world configuration seems to represent a benchmark of an integrated and permeable system (Giannelle, 2014).

Furthermore, the results of the network analysis can be interpreted through the lens of the economic approach to the labour market. In particular, the degree of connectivity among actors can be considered as one aspect of the degree of competitiveness inside it. In the same vein, we can infer the existence of labour market segmentation if the network shows disconnected components for firms of similar characteristics. In this case, we can imagine that a mechanism is in place that prevents the flow of labour mobility between those firms; workers in this scenario could be locked inside a disadvantaged segment with detrimental effects on their future occupations. On the contrary, in a relatively open (more interconnected) market, entry into occupations, even in relatively bad conditions, is not prejudicial to future improvements (see, for instance, Kaiser et al., 2011).

Besides a macro-level analysis, we can explore the labour market characteristics by using a micro-level analysis that considers individual node positions and roles inside a network. In particular, looking at the centrality scores, we can describe how the different firms are embedded in the labour market and it is possible to identify the role they play within the system. The simplest centrality

measures – degree, closeness, betweenness – quantify the position taken by each node (firm) counting the number of connections it has to others (degree centrality), the ability to reach other nodes at shorter path lengths (closeness) and the number of shortest paths passing through it, connecting otherwise disconnected subnetworks (betweenness). These measures are able to identify the so-called authorities and hubs. Authorities represent the ability to find the information needed inside the network, while hubs measure how much "knowledge" is held by a node. In a labour market defined through mobility flows, these actors are crucial for the overall integration and connectivity of the whole system. In fact, in the sociological literature at the roots of SNA these indexes are considered measures of the actor's power, however they have been widely used to understand the actor's role in different analytical perspectives. From a labour market perspective, a central actor should perform prominent roles in the selection and training of the labour force and SNA can shed new light on the dynamics of allocation and accumulation of human capital[2].

Figure 1. Small world and scale free network



Considering the nodes' characteristics (i.e., sector of economic activity, size, degree of innovativeness) we can link the functioning of the local labour market to the specific industrial structure of the area taken into consideration, deriving, possibly, policy implications on both industrial and labour market policy. In this context, the issue of industrial classification emerges as crucial. In this paper, firms are classified by sector (ATECO, 2007) and by degree of innovativeness. This choice is explained by the recognized importance of workers' mobility in innovation performance of firms (see, among others, Zucker et al., 2002; Breschi & Lissoni, 2009) and, more in general, by the fact that labour market plays a crucial role in innovative milieu /clusters (see, among others, Feldman, 1994; Boschma & Martin, 2010; Breschi & Catalini, 2010; Kaiser et al., 2011; Braunerhjelm, 2015).

In this paper we present the network analysis of the Friuli Venezia Giulia regional labour market network on the whole period spanning form 2005 to 2014 and separately for two sub-periods 2005-2008 and 2009-2014.

[2] Recently the prominent role a hub has in a cluster (in particular in innovative clusters) as mediator of labour flows has been pointed out in a managerial stream of literature (among others, Dhanaraj & Parkhe (2006).

3. Empirical strategy and dataset

The "firms-graduates' database", from which we derived the regional labour market, is built by merging three administrative archives linked by tax code and VAT. The first is about graduates in the three regional universities (Trieste, Udine and SISSA, International School for Advanced Studies of Trieste); the second includes private-sector hirings collected by the Regional Employment Observatory; the last is the "AIDA" archive and it comprises firms' balance sheets. They enable us to build all the links connecting companies through hiring of high-skilled workers from 2005 to 2014. The universities' dataset registers 105,335 graduates and PhDs from 1970 to 2014, 74.1% of which belongs to the University of Trieste, 25.4% to Udine and the remaining 0.5% to SISSA (only 491 PhDs). The graduates represent a multiple of 92,492 individuals in the database, since 12,521 people achieved other titles during the period, such as further post-reform undergraduates or graduate degrees, pre-reform university courses or PhDs. In our analysis, we consider two periods for the "third level" degrees: 2005-2008 with 21,486 individuals and 2009-2014 with 27,350 individuals. Looking to gender characteristics, we observe that 56.6% are young women. In order to better understand the different kinds of academic titles, it is worth to note that an important university reform took place in 2001, the so-called "Bologna Process". In fact, almost three quarters of the master's degrees and 55.9% of the three-year degrees in the archives were achieved after 2008; at the same time, pre-reform degrees almost disappeared (only 4% of the total).

The universities' database is matched with the administrative register of workers' hires. 201,450 hirings of graduates occurred from January 2005 to April 2014. Between 2005 and 2008, the number of hirings per year was approximately 3,000, but decreased to 2,580 per year between 2009 and 2014. The type of contracts has slightly changed in the two sub-periods. The fixed-term contracts are the most widespread type, in the first period they amount to 41.4% of total, whereas in the second they increase to 51.2%. Other atypical forms of contracts such as the so-called "Continuous and Coordinated Collaborations" (Co.Co.Co) is a sign of the augmenting flexibility in the labour market. Co.Co.Cos represented about 16% of hirings in 2005-2008 and 20% in 2009-2014. Flexible employment forms are used widely as a sort of "stepping stone" into the working world (Booth et al., 2002). Such flexibility allows individuals to improve their next employment prospect while shortening the wait-time for a first job. As expected, of the 32,010 individuals recruited after graduation, the PhDs received proportionally more Co.Co.Co. contracts. Many of these individuals are pursuing research careers, especially at universities, and they often serve as collaborators. Between 2009 and 2014, they amounted to 65% of the first contracts. On the contrary, university graduates more often receive open-ended contracts (26.4% of graduates, 33% of master degrees and only 20% of PhDs), even if the only form of hiring contract really declining is the open-ended with a mean value of 16% of total in the first time and 10.8% in the second one. The decrease in permanent employment has hit particularly young graduates (14.2%) and PhDs (14.8%) in 2009-2014. The type of contract seems to follow the alternating phases in the economic cycle rather than reward the acquisition of higher education with more stable jobs. Keeping in mind this widespread use of flexible contracts, many of the linkages between nodes may be weak.

Secondly, we use the dataset "AIDA" of the Bureau Van Dijk collecting the balance sheets of the Friuli Venezia Giulia companies in 2015 to get information about firms' variables. The original database reports 73,984 companies; however, just in a fraction of the records in the dataset the necessary variables for our estimation exercise are available.[3] In the period considered only 6,039 companies recruited graduates from local universities; among them only 4,973 firms' records contain the number of employees and the information on patent ownership is limited to 417 observations. By

[3] The variables that we consider (those valid in parentheses) are the dimensions measured in terms of the number of employees (43.478 firms), the type of macro sector (71.768 firms) and technology (71.769 firms), as well as the presence and number of patents (813 firms).

aggregating the three types of archives for the period from January 2005 to April 2014, also the number of hirings by companies in FVG decreases. Out of the total 92,492 graduates and/or PhDs remain for the analysis 20,702 individuals corresponding to 53,485 contracts, due to possible multiple contracts. Therefore, in the period under examination local companies recruited only one quarter of graduates from the regional university system at least once.[4] Moreover, the observed sample was reduced in order to compare the two sub-periods considered. In fact, until 2008, only private companies had to report new recruitments. In order to realize the comparison between the two sub-periods consultancy contracts (parasubordinati) and contracts within the public sector have been deleted, thus reducing employment contracts to 25,955, concerning 14,754 graduates and/or PHDs recruited by the remaining 6,039 companies. The economic system of Friuli Venezia Giulia is characterized by the prevalence of small- and medium-size enterprises, and as expected, the flows of hiring contracts of highly qualified personnel are heavily concentrated in the bigger companies. 53% of companies in the first period of observation and 53.8% after 2009 recruited only one graduate. Within a decade, more than 95% of regional companies recorded less than 10 recruitments of graduates and/or PhDs from the regional academic system. The remaining 442 enterprises recruited more than ten individuals in the same period. Table 1 reports the type of contracts representing the links formed between firms and workers. Full-time employment remains the most widespread form throughout the period (72.4%). As previously noted, in the two sub-periods, there was a change in the weight of open-ended contracts for necessity of period comparison as described before. Between 2005 and 2008, open-ended contracts still composed 38.7% of the total, whereas in the subsequent period from 2009-2014 they fell to 29.4%. This sub-period is notable for the increase in flexible contract forms introduced by new labour laws (fixed-term contracts +3% compared to the first period) and traineeships (+9.2% compared to 2005-2008).

Table 1. Graduates by type of contracts (2005-2014)

	2005-2014		**2005-2008**		**2009-2014**		**2005-2014 (Comparable data)**	
	Value	%	Value	%	Value	%	Value	%
Apprenticeship	2772	5.2	1395	11.5	1245	9.0	2640	10.2
Vocational training	64	0.1	53	0.4	10	0.1	63	0.2
Fixed-end contracts	20787	38.9	5388	44.2	6487	47.1	11875	45.8
Open-end contracts	10540	19.7	4715	38.7	4051	29.4	8766	33.8
Traineeships	2907	5.4	632	5.2	1979	14.4	2611	10.1
Atypical contracts	16415	30.7						
Total	53485	100.0	12183	100.0	13772	100.0	25955	100.0

Source: AIDA, Bureau Van Dijk; Universities' Administrative Data; Employment Observatory of Friuli Venezia Giulia

[4] The figure reduces to about 61,000 if we consider only those graduates from 2000 instead of the whole history from 1970. The number of start-ups at work at the local unit of the FVG companies reduces to 18,900 individuals, equal to 31.1% of the total.

The small- to medium-size firms dominate the regional panorama; 94.9% of companies employ less than 20 employees and counts for only 25.9% of hirings in the first period and for 28.6% in the second. It is noteworth that more than the half of these firms has just one employee: only 4% among these latter micro-firms hires graduates during the period considered. Manufacturing and construction activities prevailed in the two sub-periods (34.5% and 32.4% respectively) as well as services to businesses and professions (28.2% to 31.9% respectively) absorbing about two-thirds of the young graduates' hirings. Retail trade, accommodations and food service activities employ a little more than 10% of the total number of young graduates.[5]

In order to perform the SNA analysis, we report in table 2 the variables characterising our dataset for the entire period 2005-2014. This allows us to capture the complete network in a longer time span and considering the maximum number of firms and contracts.

Table 2. Descriptive statistics. Hirings and firms for the period 2005-2014 and the comparable sub-periods

	2005-2014		*2005-2008*		*2009-2014*	
	Value	*%*	*Value*	*%*	*Value*	*%*
HIRES						
Total contracts	53,485	100	12,183	46.9	13,772	53,1
Number of Individuals	20,702	100	7,195	48.8	7,559	51.2
Number of Firms by Individuals						
1	13,256	64.0	6,262	73.3	6,160	82.0
2-5	3,791	18.3	909	26.3	1,316	17.5
6 and more	3,655	17.7	24	0.4	40	0.5
Gender						
Males	9,008	43.5	5,634	46.2	6,041	43.9
Females	11,694	56.5	6,549	53.8	7,731	56.1
Highest Level of Education						
Three-year graduation	8,133	39.29	2,534	35.22	3,160	41.8
Master (2 years)	12,040	58.16	4,552	63.27	4,225	55.89
PHDs	529	2.56	109	1.51	174	2.3
FIRMS						
Number of Contracts by Firms						
1	3,621	49.1	2,002	54.1	2,045	51.1
2-5	2,684	36.4	1318	35.6	1,492	37.3
6-10	554	7.5	223	6.0	267	6.7
More than 10	515	7.0	157	4.2	195	4.9
Total number of firms	7,374	100.0	3,700	100.0	3,999	100.0
Number of Firms by Size (Employees)						
1	679	11.51	243	8.1	283	8.1
2-9	2,755	46.69	1,206	40.3	1,529	44.0
10-19	1,071	18.15	566	18.9	700	20.1
20-49	807	13.68	519	17.4	528	15.2
50-249	492	8.34	380	12.7	359	10.3
250 and more	97	1.64	78	2.6	79	2.3

Source: AIDA Buro Van Dijk; Universities' Administrative Data; Employment Observatory of Friuli Venezia Giulia

[5] The observations derived from the comparison of the active companies are interesting. In the primary sector, they are 15% of the dataset, but just over 3% are hired graduates; in the retail trade sector, the gap is remarkable. Compared to 21% of companies active in the industry, just under 16% are highly trained staff. On the other hand, activities related to catering and leisure reveal a greater presence of graduates, probably also for seasonal reasons (13.2%). Graduates and PhDs are mainly absorbed by ICT, professional and financial activities (about 27% of the total, compared to 18% of total companies) and the public sector (4.7% against an average size of 1.2% in the sample).

Then, to take into account the possible effects of economic crisis and the changes in contract registrations we consider separately the two periods: 2005-2008 and 2009-2014[6].

An analysis of the average technological contents of the manufacturing and service sector returns the expected framework. In the region, the medium- to high-tech innovative companies constitute 2.2% of the total "AIDA" database, to which is added 10% of companies in high technology or high rate of knowledge areas.[7] If we look at the database used in the SNA analysis (Table 2), the results are more encouraging. In fact, over 20 percent of the graduates in the first period and 18.9% in the second found employment in high technology companies as did a further 14.7% between 2005 and 2008 (15.8% after 2008), about a third of the total[8]

In order to understand if also at a local and qualitative level there exist some differences between the two periods, we classify the firms using the Eurostat classification for the technology/knowledge intensity of the economic sectors. In particular, we distinguish three categories: i) manufacturing firms with high and medium-high use of technology (HiT); service firms with high and medium-high use of knowledge (HiK); low and medium low manufacturing and service firms (LoT). Remember that we include in the HiT category also those firms having published patents in the period considered. Table 3 reports the distribution of firms by categories along the two periods.

Table 3. Distribution of firms by the innovation intensity in the two periods 2005-1008 and 2009-2014 (own classification based on the Eurostat classification)

	2005-2008		**2009-2014**	
Category	Freq.	%	Freq	%
HiT	489	13,2	468	11,7
HiK	726	19,6	854	21,3
LoT	2485	67,2	2677	67,0

6. Network results

In this section we apply network analysis tools to analyze the overall structure of the inter-firm network defined by the graduates working mobility. The first aim is to assess the overall network structure, and if its connectivity allows workers to easily move across firms. As in Giannelle (2014) we also want to test if hiring flows give raise to an interconnected networks approximatively similar to well-known network configuartions (for instance, small-world network) or it is composed of many disjoined components, or subnetworks, revealing a segregated market.

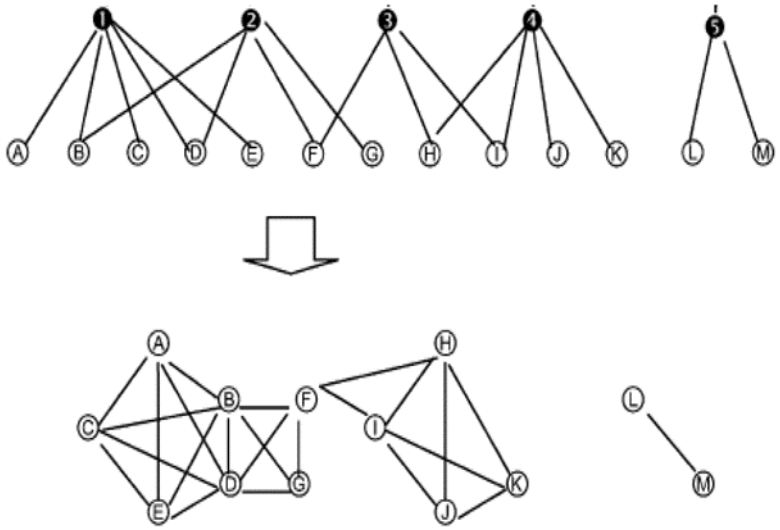
Starting from our dataset of the hiring flows in the Friuli Venezia Giulia region, we obtain the labour mobility network starting from the two-mode network described by the worker×firm matrix, **L**, whose elements are $\mathbf{L}=l_{ij}$ represent the number of contracts the worker *i* had with the firm *j*. We obtain the firm-by-firm (one-mode network) described by the adjacency matrix $\mathbf{A}=\mathbf{L}^{T}\mathbf{L}$ (where T indicates the transpose of the matrix) of elements a_{ij}. Then, for the analysis of the network we consider the dichotomized matrix **A** obtained setting $a_{ij}>1$ to 1 for all a_{ij} in **A**.

[6] In both periods the Public Administration has been excluded

[7] If we consider, however, the total number of companies employing graduates or PHDs, the relative rate increases greatly, almost tripling in the manufacturing sector (6.7%) and doubling in the case of service enterprises (18.4 per cent).

[8] As mentioned before, the high technology and high knowledge sectors include those firms that have registered one or more patents: 222 in the first period and 194 in the second. In the budget register, there were 432 companies showing at least a patent. In our sub-sample, only 416 remain due to the need to make the two sub-periods comparable.

Figure 2. Construction of the one-mode network (firms×firms) from the two-mode network firms (white nodes) by workers (black nodes).



Considering the overall period 2005-2014, the firm-by-firm one-mode network is composed of 7374 nodes (i.e., regional private firms that hired at least one graduated student in one of the three regional universities). Labour mobility flows in the same period determine a total of 15289 firm-to-firm linkages.

As usual in real networks, the density is low (0.001) but the overall structure is quite complex. The low density is partially explained by the absence of links occurring between the largest component (the core formed by the largest part of the node connected in the network) and the other components. In fact, it is clear from the picture that the network is divided in many "island", that are sub-networks composed of a small number of interconnected firms.

It is interesting to note that about the 70% of the firms is connected in the *largest component*, that is 5085 out of 7.374 are linked by a transition of at least one graduate between them. Besides the largest component there exist other 285 much smaller components with an average of 4.5 firms each and 1677 isolated firms (about the 22% of the total). The isolated firms represent those organizations that were never interested in a transition of a graduate from or toward other forms.

The peculiarity of such a structure is that the system of regional labour mobility is characterized by a connected set of core actors. The largest quota of mobility takes place within the *largest component* where the prominent relational role (in terms of number of activated links) is played by the largest regional firms (in terms of stock of workers). In particular, "Danieli & C. Officine Meccaniche SpA" is the most central firms in the largest component having a total of 282 links (consider that the average number of links per firm is equal to 4.15 with a standard deviation of 9.59). The other firms present in *largest component* are mainly (very large) cooperative and social firms. Moreover, we observe a high correlation between *degree*[9] and *betweenness*[10] (r=0.88), which means that the most connected firms played also the role of "hub" (connecting otherwise disconnected region of the network).

Looking at the connectivity within the *largest component*, on average the firms are connected through 6.7 links. This value is much higher with respect to a random network of the same characteristics of our observed network. Therefore, we can affirm that the observed network cannot be considered a

[9] The *degree* of a node *i* is the number of other nodes to which *i* is connected.

[10] The *betweenness centrality* is a centrality measure of a node that indicates its bridging role. In particular, given a node *i*, the higher its betweenness the higher its importance in connecting otherwise disconnected region of a network. That is why nodes with high *betweenness* can be considered as hubs inside a network structure.

small world network (for a definition, see Watts e Strogatz, 1998). This is a different finding from the literature (Giannelle, 2014 and Feri & Currarini, 2006).
A *clustering coefficient*[11] equal to 0.1038 indicates that only the 10% of the triads[12] assumes the form of closed clusters of firms (the so-called triangle configurations).
As general conclusion, the overall network in the whole time span and considering all labour contracts, emerges as a complex structure where a large proportion of firms is interconnected forming a regional labour system with a prominent role of some "hubs" within the *giant component*. This system represent the "core" of the local labour system.
However, in the following in order to study the differences between the two sub-period before and after the economic crisis (2005-2008 and 2009-2014), we just take into account permanent positions and private contracts (we exclude the public sector contract from the analysis), mainly because before 2009 the "Osservatorio regionale del lavoro" did not registered public contracts.
It is worth to note that the overall network, considering this subset of permanent positions and private contracts, presents a very similar structure to the network obtained from the full set of contracts.

Differences between the networks in the two periods

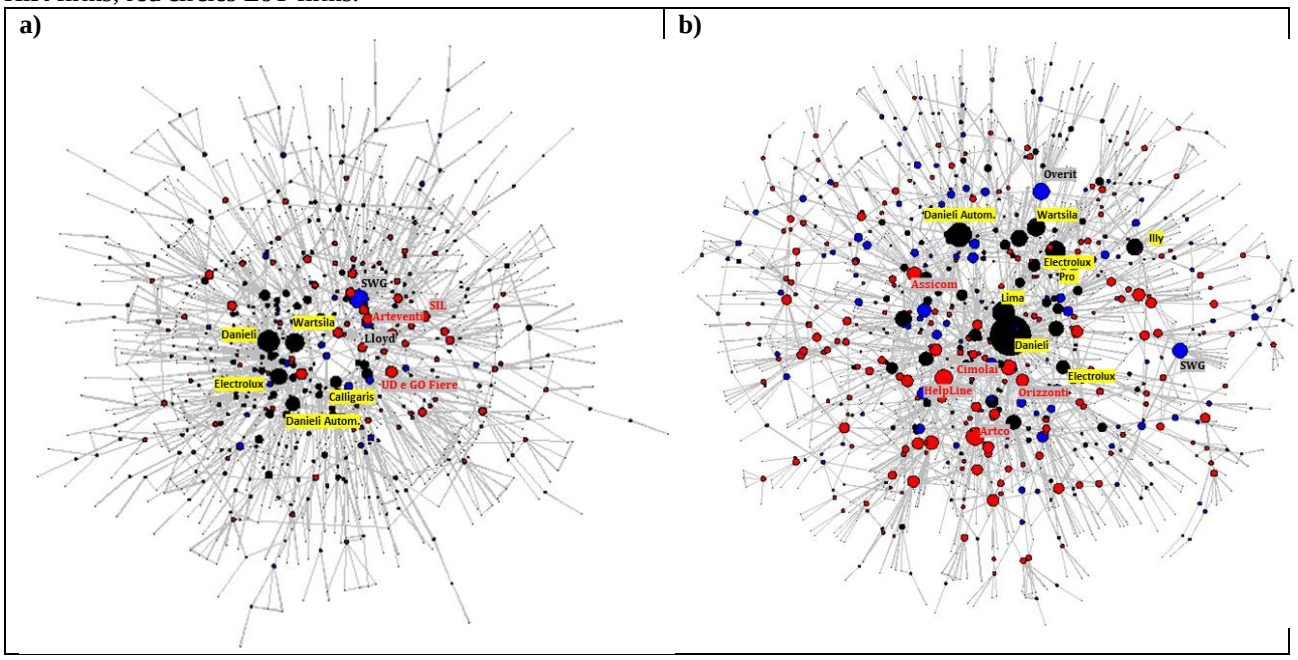
The network in the period 2005-2008 is composed of 3700 firms and 1883 links, with a density of 0.0003. From the structural point of view, the *largest component* in the whole period is already observable. However, in this component we only find 26% (968) of the firms. The hubs relevant for the network connectivity in this period are: Danieli & C. Officine Meccaniche, Wartsila Italia, and SWG. There also are 308 much smaller components and 1973 isolated firms.
The mean degree is 1.02 (with a standard deviation of 2.09). The largest geodesic distance inside the largest component is equal to 29 links and on average 1.95. Clustering coefficient is equal to 0.16 (the 16% of the triads ends up in a closed triangle).
In the subsequent period 2009-2014, the network structure is quite similar (same density 0.0003).
The number of firms (3999) and links (2523) are slightly higher. The largest component now includes 1337 nodes (33.4% of the total on the period).
In the 2009-14 new hubs emerge (Danieli & C. Officine Meccaniche still represents the most central actor with 93 links): Danieli Automation (a firm of the "Danieli" group), Lima Corporate, Electrolux Professional, and some social services companies.
The average degree is 1.26 (standard deviation 2.51). The maximum geodesic distance increases up to 69 links, and the average geodesic distance becomes 2.5.
We observe a slight decrease of the *clustering* that appears to be 0.3.

The general tendency is an enlarged network with longest labour trajectories, and a more fragmented network: in fact, the number of components changes from 308 to 336, whereas isolated firms decreases to 1851. But the main conclusion is that, from a structural perspective, there are not noticeable changes between the two periods. The networks in the two periods can be both considered an instance of "scale-free network" (see figure 1) mainly because of the presence of different hubs that govern the labour market flows.

Considering the structural characteristics of firm, in particular their innovation intensity, new insights emerge.

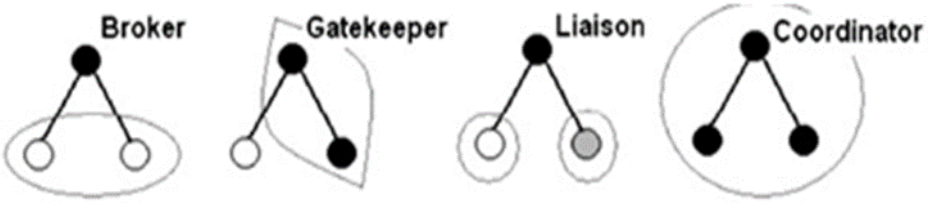
[11] *Clustering coefficient* (or transitivity) is a statistical measure of the tendency of two node to be connected given that they are connected to a third common node.
[12] A triad is a subset of three nodes either connected or disconnected.

Figure 3. Networks in the two periods 2005-2008 (a) and 2009-2014 (b). Black circles represent HiT firms; blue circles HiK firms; red circles LoT firms.



In 2005-2008 we notice that the relevant hubs are mainly HiT firms, whereas in the second period there are several HiK firms in prominent position and even LoT firm (e.g.,mainly in the services sector Arto servizi, Società imprese Lignano, Sms Meer). The most interesting change between the two periods concerns the role of these hubs. In order to understand the occurred change we use the brokerage role analysis, that is the identification of peculiar subnetworks describing different connectivity functions of the hubs either with respect the firms of their category or belonging to different categories.[13]

Figure 4. Graphical representation of the brokerage with respect a focal node ("hub").



Source: Adapted from da Capellari and De Stefano, 2014

From table 4, we observe an increasing tendency for the coordinator role and also hybrid configuration likewise "gatekeeper" and "liaison" roles. This brokerage analysis allows us to affirm that whereas in the first period the hubs mostly connected firms of different sector and in different categories in the period 2009-2014 the brokerage role of our hubs is mainly played with firms of the same technological category.

[13] Coordination involves mediation between members of the same group, brokerage, instead, implies coordination of actors belonging to groups different from the one of the broker. The other two roles describe mediation between members of different groups. In one role, the mediator is a gatekeeper, who regulates the knowledge flow to his group from the outside. In the second, the liaison mediates between members of different groups but who does not belong to these groups himself. Given the objective of our analysis, we focus on the roles that imply mediation between different groups. See Gould e Fernandez (1989) for a detailed definition of the brokerage roles and Capellari and De Stefano (2014, 2016) for an application of this kind of analysis.

In particular the increase of the coordinator roles configurations indicates a homophily effect that is going to take place in the network structure. In the period 2009-2014, both the pre-existing hubs and the new emerging ones tend to connect firms of the same technological category (i.e., HiT and HiT; HiK and HiK; LoT and LoT). This could be interpreted as a general tendency toward a more segmented labour market in the region.

Table 4. Normalized count of the borkerage role in the two periods.

Brokerage role	2005-2008	2009-2014
Coordinator	31.3	45.9
Itinerant Broker	49.1	33.7
Gatekeeper	54.9	76.6
Liaison	71.2	84.8

We have an empirical evidence of this tendency specifying an Exponential Random Graph Model (ERGM)[14], in the networks within the two periods (table 5 reports the estimates).

Table 5. ERGM estimates in the two periods.

2005-2008			
Parameter	**Beta**	**SE**	**p-value**
Edge	-5.99	0.04	0.000***
Homophily (HiT)	1.30	0.09	0.000***
Homophily (HiK)	0.46	0.13	0.001***
Homophily (LoT)	-0.08	0.06	0.21
2009-2014			
Parameter	**Beta**	**SE**	**p-value**
Edge	-6.31	0.03	0.000***
Homophily (HiT)	1.60	0.08	0.000***
Homophily (HiK)	0.50	0.09	0.001***
Homophily (LoT)	0.21	0.05	0.21

From the ERGM results we can affirm that homophily is present in both periods and strongly affects the network structures. In our analysis homophily identifies labour market segmentation, that is graduates tend to flow among the same kind of firms rather than having careers through firms belonging to different categories. Furthermore, in the period 2009-2014 homophily effect is observed also between LoT firms. As general conclusion, we can affirm that graduate flows through firms, passing through the hubs (as the scale-freeness of the network structure) but in the second period these hubs mainly connect firm of their same category (or embedded in hybrid sub-networks likewise those represented by the *gatekeeper* and *liaison* roles).

7. Final remarks

Although preliminary and referring to a labour market of graduates and PhDs inside a regional labour market, the results of the SNA appear to be quite interesting. The application of SNA to the labour flows tools allows us to reach a better understanding of the firms' characteristics that receive entry flows into employment status. SNA also enables a view of the multiple channels of mobility open to

[14] For an introduction to ERGM see Robins et al. (2007).

graduates to change positions once employed. In the meantime, the network, with its nodes and links, allows a representation of the channels through which the formal knowledge built up during university education can be transferred to the local industrial structure.

Looking to the analytical results, we can say that the SNA shows a highly connected network. This evidence is very strong when we consider the whole range of contractual typology; it persists even when only more stable contracts are considered. However, the complete network does not exhibit the features of a small world (even if it doesn't exclude the existence of small world in particular subnetwork areas). Rather, there appears to be a scale-free network dominated by large companies acting as hubs. Innovative firms are more connected than those belonging to the low tech sectors, reaffirming the evidence presented in previous empirical studies.

The comparison between the two periods shows that the network has been rather resilient to the shocks because its main characteristics persisted even in the period following the 2008 crisis. This evidence hinges on the fact that the most important hubs remained in place during both sub periods.

Considering the central role played by different firms in the two sub-periods, we can observe that the labour market seems more segmented in the period of 2009-2014 compared to the previous one. In fact, in the second period, the number of firms acting as coordinators (a bridging role connecting actors with similar characteristics) increased. Meanwhile, the number of brokers (a bridging role connecting actors with different characteristics) decreased. This result highlights the fact that the mobility of graduates and PhDs takes place inside a group of similar firms rather than between groups of firms with different qualities.

Looking at the results, it seems worth mentioning that there is great potential in applying the SNA to the labour market, a topic that deserves further exploration, particularly in terms of searching for the right way to represent the external labour market, and, second to account for the direction of mobility flows.
The usefulness of the SNA in addressing questions of industrial and labour market policy is clear. It can be used for quantitative evaluation of the labour market impact of sectors or company's crises to seek for possible industrial policy interventions or specific labour market policies to ease workers' transitions into new positions. Ultimately, the unique feature of this analysis is reflected in the possibility of jointly analysing the need for industrial policy and labour market policy.

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