

Network Analysis: From Theory to Applications

Analisi Reticolare: dalla Teoria alle Applicazioni

Giulia Rivellini

Università Cattolica del Sacro Cuore, Largo Gemelli 1, 20123 Milano,

giulia.rivellini@unicatt.it

Riassunto: a partire dagli anni '90 l'interesse per l'analisi reticolare è cresciuto notevolmente e diffusamente in molteplici campi scientifici. In questo lavoro si intende documentare tramite una rassegna di contributi e/o progetti scientifici nazionali e internazionali, già diffusi o in corso di realizzazione, come la sintesi teorico-metodologica della network analysis possa favorire un arricchimento della conoscenza nello studio di comportamenti osservati su individui o istituzioni. Le aree tematiche cui appartengono i contributi selezionati toccano principalmente gli ambiti economico – politico, socio-sanitario e socio-demografico.

Keywords: complete networks, egocentered networks, commercial and knowledge relationships, innovation, social integration.

1. Purpose and method of the review

Interest in Social Network Analysis (SNA) has grown massively in recent years. After 1990 an incredible diversity of new substantive quantitative applications for what is now a rather established 'paradigm' characterised the history of SNA. The social network perspective and methods are now widely used in behavioural science, epidemiology, organizational studies, economics, industrial engineering, sex, drug abuse and spread of aids research as well as by criminologists and physicists ("we feel that behind every complex system there is an underlying network with non-random topology and the challenge is to unearth the signature of order from the apparent chaos of millions of nodes and links" Barabasi, 2001). The idea of '*organized paradigm*' is also supported by at least four other elements. 1) Since 1981 every year the International Network for Social Network Analysis has been organising an official international conference (Sunbelt Conference), which now lasts one whole week, where researchers from all over the world have a chance to present methods, models, empirical applications, provisional research projects and even to attend basic and advanced workshops. A brief overview of the Sunbelt Conference preliminary programmes immediately reveals a high increase in the number of thematic sessions (as many as eighty in the XXV Sunbelt) as well as an increasing specificity of the titles given to the sessions. Moreover, for the second year running, the University of Zurich has organised an international conference centred only around the applications of SNA. 2) As many as four peer reviewed and interdisciplinary international journals (*Social Networks*, *Connections*, *Journal of Social Structure* and *Revista Redes*) provide a common forum for representative scientists who share an interest in the study of the structure of relations that may be expressed in network form. 3) The large number of graduate

programmes (14) that offer training or emphasis on SNA, most of them in the USA, with the exception of four that are offered by university centres in four European countries (The Netherlands, France, Austria and Spain). 4) From the overview on software (see Huisman and van Duijn, 2005 and Freeman, 2000) for SNA we learn that up to now the software available for different kinds of network analysis is particularly rich, user friendly and also freeware.

Based on this wealth of scientific literature, the purpose of this article is to illustrate empirical cases of SNA use from a quantitative perspective by presenting a series of national and international contributions and/or scientific projects already widespread or currently underway. The range of topics covered in SNA applications is too wide for a comprehensive overview, even with more space available to introduce results from the research carried out. The criterion adopted was, therefore, to highlight a few specific areas of study where SNA has allowed for progress in knowledge. The selection was made focusing on an interdisciplinary and versatile approach: some examples taken from economic-political (par.4), social-health (par. 5) and social-demographic (par.6) fields are provided. The areas of application were selected among those where interesting projects for Italian researchers are underway, trying to illustrate various types of network data and actors.

2. Recall some definitions for reviewing

On an empirical level there are several ways to define a network. This paragraph will briefly outline some of the main concepts and definitions of network analysis used in the applications illustrated in the following paragraphs.

The *complete or whole network* is obtained by interviewing all the individuals from a closed population collecting information about each actor's tie with all the other remaining actors. By means of example, a question aimed at measuring a closed instrumental support network among the pupils in a classroom could read as follows: "*which one of your classmates do you telephone if you have questions concerning the homework you have been assigned?*". Within the group of complete networks, the structure which is traditionally used to present relational data is known as *one-mode network* consisting of a single set of actors and relationships connecting them. Another possibility is to choose a *two-mode network* or *affiliation network* structure, that consists of two sets of units (e.g. people and events) and relations connecting the two sets, e.g. participation of people in social events (see Wasserman and Faust, 1994). There exist several two-mode networks: membership in institutions (people, institutions, *is a member*, e.g. directors and commissioners on the boards of corporations); '*buying articles in the shop*' where the first set consists of consumers, the second of articles, the connection tells which article was bought by a consumer; *citation network*, where the first set consists of authors, the second set consists of articles/papers, connection is a relation *author cites a paper*. Starting from a *two-mode network*, it is possible to introduce two *one-mode networks*, one giving relationships among the events in terms of the actors they share, the other giving relationships among the actors in terms of the events at which they are co-present (or with which they are co-affiliated).

Generally speaking, based on relational data associated with a complete network (see Wasserman and Faust, 1994), various steps of statistical analysis can be defined (Rivellini and Zaccarin, 2006):

- 1) descriptive analysis of the characteristics of the network and actors, based on measures for a synthetic description of the network properties (density, in-degree, out-degree *dyad census* and *triad census*) and on the search for methods for partitioning networks into subgroups components through the analysis of structure, location, roles and positions (clique detection, structural equivalence, and *blockmodelling*). These analysis types are usually accompanied by graphs to visually illustrate the network;
- 2) analysis of the relationships within the network, that is to say the modelling of the network structure aimed at explaining why connections are present or not based on structural network characteristics, also with reference to individual attributes of the actors and/or to the relationships observed in other networks (see Wasserman and Robins 2005);
- 3) analysis of the network evolution over time in the presence of longitudinal observations of network ties and individual behaviours (Snijders *et al.*, 2005).

In a way which is less innovative, but simpler from the viewpoint of empirical measurement, a network can be defined starting from a single node, measuring the set of relationships an individual has, thus obtaining an *egocentered* or personal network. In this case the network description and analysis are carried out starting from focal individuals, called *ego*. The network is considered starting from an individual and from the indications provided by the latter as regards connections to other individuals around him/her (relatives, friends, neighbours), not necessarily belonging to a closed set from a pre-defined list of names. Every ego reports about a set of others it is connected with and on the type of relationship (emotional or social support, for example) connecting them within that set. Unlike in the complete network, an example of a question generating the nodes in an egocentered network could read as follows: “*thinking of all your relatives, friends and people you know, could you indicate the individuals you think are more important for you and with whom you have relationships on a regular basis?*”. In general, for each node quoted, fundamental attributes can be defined, such as gender, age, the year the relationship started, marital status, place of residence, frequency of telephone conversations, type of support connecting the ego to the individual node, etc. This information is then duly processed in order to measure synthetically the network size and composition; this makes it possible to expand the case (ego) by variables matrix, adding to the individual variable group those pertaining to the personal network.

In the traditional statistical analysis approach, the measurement of egocentered networks entails formulating a model whereby the behaviour of the individual is a function of both the individual status and of a reference system and concrete exchanges, measured through the personal network. Furthermore, it is useful to consider that egocentered networks, observed at a given time t , clearly identify a *nested data structure*, where respondents (egos, level 2 units) are indicated by j and nominees, or relations with nominees (level 1 units), by i . This structure generates a group in correspondence with each ego, given that the observations from the same group are generally more similar than those from different groups, therefore the assumption of independence between all observations is patently violated. It is exactly this “*lack of independence*” which justifies the use of multilevel models.

Moreover, the presence of longitudinal egocentered network data allows for an in-depth study of the causal effects between individual behaviour and personal network types (by way of example, see Fratiglioni *et al.*, 2000).

3. Network analysis for the study of international trade

Initially used by sociologists and anthropologists to study complex interpersonal interactions (see Scott, 1997), SNA has recently been used also by economists to analyse institutional, technological and commercial relationships between agents, industries, regions and countries. The positive estimate of SNA in the economic sector began with the diffusion of the *world system theory* (Wallerstein, 1974) which identifies in the structure of world economic system three precise structural positions where the various countries can be located: *central*, *peripheral* and *semi-peripheral*. Global economic interdependence, according to *world system* theorists, can be represented as a grid of exchanges, an exchange of relationships between countries with structurally different positions: a central state has a strong government apparatus and a solid economy thanks to its diversified production, manufacturing and exporting of goods; its workers are skilled and their salaries relatively high. On the other hand a peripheral country has a weak government, an economy specialising in the production of few semi-processed goods or in raw material extraction and salaries are low. Finally, the position of the semi-peripheral area is intermediate, but equally fundamental in the global economic hierarchy (Uberti, 1998). Regardless of the validity of the theories put forward by the *world system theory*, already starting in the mid-Seventies SNA began to emerge as a suitable tool for the analysis of the world structure because it allows for an analysis of international relations between countries which are grouped according to their structural position. Snyder and Kick (1979) were the first to empirically test the validity of the network approach by defining through the blockmodel analysis carried out for only one year (1965) on a sample of 118 the structure and position of a state within the world economic system. They operationally defined the structure of that system according to four types of international networks: trade flows, military interventions, diplomatic exchanges and conjoint treaty memberships. The four one-mode networks are represented by separate $N \times N$ matrices of countries. The matrices are all coded in binary form where each instance of a tie from one member of a population to another is designated with “1” in the appropriate cell of the matrix, and the absence of a claim coded “0”. The empirical elaboration was integrated and completed by an econometric analysis whose results match those of SNA: structurally different positions (central – semi-peripheral – peripheral) show different levels of economic development. Following this groundbreaking analysis, several other contributions were made to economic studies centred around the use of SNA as regards international trade. A distinction can be made between those which use exclusively the relationships between countries generated by the import and export of material goods (single-criterion approach) and those which also include other types of relations, for example in diplomacy or the military (multi-criterion approach). The methods most frequently used in these studies were clique detection, structural equivalence and blockmodeling (see Knoke and Kuklinski, 1982).

Recently, following the abrupt changes in the technological system (defined in Leoncini *et al.*, 1996 as the result of the interaction of four different components among which the innovative system, made up of knowledge) network analysis has been successfully used also for the study of the impact of knowledge flows on regional economic development. In Maggioni and Uberti (2005) the a. addresses the manifold nature of knowledge through the analysis of four distinct but complementary phenomena that characterise knowledge as an intrinsic relational structure (directly) connecting people,

institutions and (indirectly) regions across five European countries: 1) digital information exchange (transmitted through Internet hyperlinks between 308 universities web pages located in German, Spanish, French, Italian and UK regions at NUTS2 level); 2) participation in the same research networks (funded by the EU Fifth Framework Programme); EPO co-patent applications, one of the most established output indicators of innovative activities, 4) Erasmus students' exchange flows. In this research 110 NUTS2 European regions are treated as nodes, while their different knowledge flows are considered as ties in four one-mode networks. Co-patenting and research networks are symmetric, and Internet hyperlinks and Erasmus exchange flows are asymmetric. NA indexes (density, clustering, isolated nodes, centralisation) have been calculated from a dichotomised version of the original knowledge flows matrices. The empirical analysis shows the existence of a polarised centre-periphery hierarchy of European regions that is reflected in the structure of the knowledge flows: the existence of a very dense core (the network of more advanced regions) on the one hand, and a residual sparse set of relations within the periphery on the other. This type of analysis, complemented by estimates based on econometric models, makes it possible to empirically monitor the progress of the process triggered by EU policies for the purpose of reaching one of the organisation's main targets, the reduction of regional disparities. The network analysis approach can be useful also in trying to measure a globalisation process involving a metropolis. The definition of "global city", indeed, has shifted from a mainly hierarchical concept, where cities were rivals and competing actors, to a "network" concept, where urban centres are connected by economic, financial, cultural and social relations (Taylor and Lang, 2005). This new vision of the global city has led the Milan Chamber of Commerce to plan for the year 2005 monitoring work on Global Milan based on a twofold analysis perspective: the first, more traditional one, focuses on the comparative, and if possible also dynamic, analysis of attributional variables, (i.e. macro-economic standards, social and technological indicators); the second one concentrates more on the network approach, aimed at describing the "geography", as well as the structure, of this global entity, highlighting origins and destinations of the flows analysed. This latter perspective specifically gives the opportunity of graphically representing one-mode or two-mode network data: each node stands for a territorial entity, which also includes Milan; the flows on the other hand are commercial or social-demographic relations (exports or imports in the high-tech sector, presence in the Milan area of one-person companies owned by a foreigner; presence of resident foreigners by country of origin; mixed marriages by nationality of the spouses). When the flows are directed, therefore not necessarily symmetric, this is shown on the graph by specifying both their direction (the arrows) and size; the increased size of the arrows is proportionate to the dimension of the flow also when the latter are of the non-oriented type (Rivellini and Uberti, 2006).

4. Networks and diffusion of innovations

The empirical measurement of the network can be useful also for the purpose of the diffusion of innovations theory whose aim has always been that of explaining how new ideas and practices spread within and between communities. Adapted from epidemiology, the diffusion theory research has been substantially developed also as part of other disciplines, such as anthropology, economics, geography, sociology and

marketing studies. At the basis of every diffusion process, however, there is a common premise which identifies in interpersonal contacts, largely consisting of interpersonal communication, the main channels through which new ideas and practices are spread. Within this theoretical framework, social network analysis offers empirical-methodological support to better understand the factors that lead some members of a population to adopt a new idea or behaviour while others do not. Valente (2005) acknowledges that “diffusion research, peaked in the early 1960s, has been reinvigorated more recently with the advent of more sophisticated network models and technology making it possible to study the diffusion process more explicitly. Network influences are captured by an exposure or contagion model, and each individual’s likelihood of adoption increases as the proportion (or number) of users in his or her personal network increases. Personal network exposure is the proportion of number of adopters in each person’s network that provide information and influence with regard to some behaviours.”

This statement is confirmed by the empirical studies conducted in a variety of domains, but mostly drawn from the *public health field* reviewed by Valente (*ibidem*) in search of evidence for diffusion processes.

Because of the lack of data on complete network and adoption process, most of the empirical research in this field has been based on *egocentered networks*. Moreover, due to the difficulty in collecting data over a time period long enough for diffusion to occur, many of the widespread studies in this sector so far have been cross-sectional and in many cases retrospective, involving only one time point.

Mention should be made of the study by Entwisle and others (1996) which shows how the contraceptive choices in Nang Rong, Thailand, made by early adopters contributed significantly to the contraceptive choices made by later adopters. Modern contraception in this and other research is seen as an innovation. Women’s attitudes toward this new alternative, and their willingness to adopt a temporary method or sterilization are shaped by local family planning accessibility and other structural village characteristics (remoteness measured as obstacles to travelling to Nang Rong town, productivity of rice and involvement in jute production). The results also suggest the importance of other, less easily measured variables, especially those related to the operation of social networks (interpersonal interaction and sharing of information). They find evidence for the importance of the social community, bound together by social interaction. The qualitative data collected through focus group interviews suggest that conversational networks help direct and control the flow of information about contraceptive methods. The structure of these social networks helps to account for method dominance within villages and also for marked differences in popularity of methods between villages.

One year later Kohler (1997), reanalysing the data of a Korean study that surveyed in 1973 twenty-five villages to evaluate the community-based program of family planning, showed that women using modern contraception are noticeably better informed about the practice than other community members. Moreover, as predicted by theories of information diffusion, the method a woman uses has the largest representation among her friends and neighbours.

As regards the measurement of complete networks, it is finally worth mentioning two other studies which help understand how to measure the process of social influence through complete social networks. Valente *et al.* (1997) collected sociometric data on contraceptive use among women in voluntary associations in Cameroon and showed that perception of these friends’ behaviour, and in particular, perceptions that these

friends encouraged contraceptive use, were significantly associated with behaviour. Alexander and others (2001) investigate the effects of popularity, best friends smoking within the peer networks on current smoking of seven-through 12th grade students, using data from a special saturated sample of 13 schools, belonging to the National Longitudinal Study of Adolescent Health, in which all enrolled students were selected for the in-home interview. Information from the in-school questionnaire was used to construct measures of school smoking prevalence and popularity. As a part of the survey, students were asked to identify five male and five female friends from rosters of the high school and the feeder school. These data were used to characterise peer network. A measure of popularity was calculated by adding the total number of friendship nominations received by each student using the in-school survey. This indicator corresponds to the network measure of in-degree centrality that assesses an individual's direct linkages with others. School smoking prevalence was constructed by aggregating the responses of all students in each school to the in-school survey question "During the past 12 months, how often did you smoke cigarettes?". By including in-home adolescent (questions on sensitive topics such as sexual behaviour, drug and tobacco use, asked using an audio computer-assisted survey instrument) and parent interviews for all students along with in-school questionnaire, it was possible to link information across subjects and construct peer influence measures using multiple informants. Within the friendship network the a. constructed two *network exposures*: the *peer network smoking exposure*, as percentage of current smokers within the peer network, obtained by linking in-school survey friendship nominations with responses to the 30-day cigarette smoking question from the in-home interviews; the *best friend smoking exposure* constructed using similarly linked information for the first female and first male friend nominations. Table 1 presents the results from multivariate logistic regression analyses performed controlling intra-school clustering. Adjusting for age, gender, race/ethnicity, parent education, school, and availability of cigarettes in the home, the risk of current smoking was significantly associated with peer networks in which at least half of the members smoked (OR = 1.91), one or two best friends smoked (OR = 2), and with increasing rates of school smoking prevalence (OR = 1.73). In addition (model 2), there was a significant interaction of popularity and school smoking prevalence such that risk of current smoking was somewhat greater among popular students in schools with high smoking prevalence than among popular students in schools with low smoking prevalence.

Table 1: Logistic regression analyses of peer variables associated with cigarette smoking among adolescents*

Variable	Model 1			Model 2		
	Odds Ratio	Adjusted SE	95% CI	Odds Ratio	Adjusted SE	95% CI
Peer network smoking (<50%)	1.07	0.11	0.88, 1.30	1.03	0.11	0.87, 1.30
Peer network smoking (≥50%)	1.91	0.36	1.32, 2.78	1.89	0.36	1.30, 2.75
Best friend smoking (one or both)	2.00	0.19	1.67, 2.41	2.01	0.19	1.66, 2.42
Popularity	1.02	0.07	0.90, 1.16	0.76	0.12	0.56, 1.03
School smoking prevalence	1.73	0.15	1.46, 2.06	1.49	0.15	1.22, 1.82
Popularity school smoking prevalence				1.08	0.04	1.01, 1.15

Source: Alexander and others (2001) - * Adjusted for age, gender race/ethnicity, parental education, school, and availability of cigarettes in the home.

Even though the study presents some limitations clearly outlined by the authors (measures of cigarette smoking constructed using two different time frames and

impossibility of testing selection effects because of the lack of longitudinal data for in-school survey) the step forward made in comparison with previous research that has documented the strength of association between adolescent and friend smoking, is the measure of peer smoking calculated using peer reports of their own smoking behaviour and not constructed from adolescents' descriptions of the smoking behaviour of their friends.

Similarly to smoking, also drug addiction is one of the social phenomena defined as such by Robins and Pattison (2005) "precisely because behaviours by the individuals involved are interrelated". Cocaine consumers (Snijders *et al.*, 1995) constitute the second-level units on the hierarchical data structure, while the individuals (alters) mentioned by the consumers in the egocentered network are units at level one. The outcome variable ("importance of cocaine consumption in relationships, measured on the basis of the assessment given by the respondent") is defined by the authors using an ordinal scale with scores ranging from 0 to 6, aimed at assessing two specific issues related to cocaine consumption: "acquiring the cocaine" and "the frequency of meetings between the respondent and the node mentioned in contexts associated with cocaine consumption". The set of explanatory variables can include both those associated with the respondent (method of cocaine consumption, gender, environment where the drug is mainly taken), and those referring to the person mentioned (main consumption environment, gender) and those measured with respect to the relationship itself (duration of the relationship).

In longitudinal egocentered networks too, "multilevel techniques can also give more specific insight on why personal network change: they allow to distinguish between the influence of individual and of tie characteristics on the stability of personal networks as a whole and of specific ties within a personal network" (van Duijn *et al.*, 1999).

5. Immigrants' children social integration

In the social-demographic field, one of the thematic areas where network analysis can provide a valid and innovative methodology contribution is the study of the integration process, seen as positive interaction between members of the community and their well-being (Zincone, 2000). More specifically, immigrants' children integration has become a phenomenon of increasing importance in Italy as in other new receiving countries. The schools attended by native and foreign students represent a privileged observatory to analyse social relationships: in daily life at school the young immigrants may play the role of "integration vehicles" transferring to their ethnic communities new cultural and social models and at the same time offering to natives important opportunities for enrichment. Friendly, day-to-day contact with classmates of other ethnic backgrounds is argued to break down existing inter-ethnic prejudice and thereby reduce inter-ethnic tension and antagonism. This should reduce pupils' inclination to restrict their personal relationships to people of the same ethnic group, and thus generate more intra-ethnic relationships. But the quantitative research on this topic has not yet been satisfactory partly because most researchers neglected the network aspects in their theory, design and method of analysis. The traditional methods of survey and analysis appear rather unsatisfactory to measure network density, isolated nodes, popularity, activity and centrality degree; the latter can be interpreted as quantitative indicators of social integration, to be used as covariates inside models explaining individual behaviours.

With longitudinal one-mode network data it is also possible to model the interaction between *network* and *behaviour*, with the aim of separating the process of ‘*influence*’ from that of ‘*selection*’ (Steglich *et al.*, 2005).

A group of Dutch researchers tried to overcome some of these problems, showing the added value of a network approach for the study of the existence of ethnic boundaries by comparing the proportion of intra-ethnic to inter-ethnic relationships in 20 pupils’ networks. They therefore present the results of a social network study using a special model for dyadic data, the p_2 model (van Duijn *et al.*, 2004) associated to each network/school. Because of the lack of methods for analysing multiple networks, the a. used a meta-analysis approach to combine the results of different networks.

Table 2: *Meta-analysis of p_2 analyses of emotional support relationships in 20 pupil networks/schools*

Parameter in the p_2 model	Values concerning schools	
	Mean*	S.E.
<i>Density</i> (overall)	-6.12	0.30
Similarity gender (n = 19)	0.63	0.12
Similarity girl (n = 20)	1.01	0.21
Similarity Dutch (n = 19)	0.44	0.10
Similarity Moroccan (n = 7)	1.03	0.31
Similarity Turkish (n = 9)	1.72	0.24
Similarity Surinamese (n = 11)	1.62	0.21
Similarity Turkish/Moroccan (n = 5)	0.90	0.30
Similarity acculturation (n = 20)	0.08	0.10
Similarity low acculturation (n = 9)	0.63	0.37
Similarity high acculturation (n = 11)	0.28	0.35
<i>Reciprocity</i> (overall)	4.32	0.40
Similarity gender (n = 15)	-1.04	0.31
Similarity girl (n = 19)	1.03	0.23
Similarity Dutch (n = 16)	-0.22	0.24
Similarity Moroccan (n = 2)	-1.35	1.39
Similarity Turkish (n = 5)	-1.48	0.62
Similarity Surinamese (n = 5)	-1.06	0.79
Similarity Turkish/Moroccan (n = 2)	-1.82	1.23
Similarity acculturation (n = 16)	-0.34	0.26
Similarity low acculturation (n = 3)	0.13	1.17
Similarity high acculturation (n = 8)	0.92	0.56
<i>Sender</i>		
Gender (n = 20)	0.53	0.17
Relative importance of friends at school (n = 20)	0.26	0.08
High acculturation (n = 15)	-0.42	0.24
Low acculturation (n = 20)	-0.12	0.17
<i>Receiver</i>		
Relative importance of friends at school (n = 20)	0.10	0.07
High acculturation (n = 15)	-0.47	0.21
Low acculturation (n = 20)	-0.49	0.13

Source: Baerveldt C., van Duijn M. A. J. Vermeij L., van Hemert D. A. (2004)

*Bold figures indicate significant ($p < 0.05$) estimates

Table 2 includes the parameter estimates calculated after having carried out the operations necessary to synthesize and ‘generalize’ the results observed in the individual schools, each of which should be considered as level-*j* study. These results help better understand what substantial interpretation should be given to the *network effects* (sender, receiver, density and reciprocity) associated with the innovative modelling of the network structure. The ‘explanatory’ variables are individual characteristics to explain sender (activity) and receiver (popularity) effects, as well as dyadic characteristics (similarity with respect to a certain individual characteristics) to explain density and reciprocity effects. “A positive density effect of similarity with respect to ethnic background means that the probability of a tie between pupils with the same ethnicity is higher than between pupils with different ethnic backgrounds. The positive estimate of the similarity effects of gender and of girls indicate that, in general there were more relationships between pupils of the same gender, and especially between girls. Boys have a higher probability to ‘send’, i.e. to report received support from others, either boys and girls (the positive sender effect of boys, where boys are coded as 1 and girls as 0). The negative overall density effect indicates that the networks were all rather sparse, while a positive overall reciprocity effects indicates that symmetric relationships were more likely than the asymmetric one” (Baerveldt *et al.*, 2004).

The Dutch application carried out using data from the Dutch Social Behaviour Study (DSBS) shows the feasibility of empirical research structured in order to collect complete network data also on non negligible sizes of sample units (1317 pupils). Along these lines, an ongoing national research project (“*I ragazzi figli di stranieri e di italiani*” [Children of immigrants and Italians]) is being carried out on success and difficulties of the integration process for immigrants’ children attending lower secondary school in some Italian regions with the support of the Department of Statistics of Padua University, ISMU Foundation and several other Italian universities. In particular for Lombardy and Lazio a whole section of the questionnaire is dedicated to collecting one-mode network data aimed at studying positive and negative relationships in complete networks.

6. Conclusions

The scientific contributions selected have made it possible to confirm the added value introduced by SNA as to the study of behaviours observed in individuals or institutions. The overview of network analysis theory and methodology can therefore enhance knowledge as regards the international trading of goods and information, the study of processes pertaining to globalisation and the diffusion of innovative behaviours, as well as the empirical analysis of social integration mechanisms for young generation of immigrants, an extremely topical subject in Italy today. Apart from the empirical cases presented, international research, especially in the socio-demographic sector, has confirmed the appropriateness of including in the analysis of the micro production process of the action, not only the macro but also the intermediate level, with respect to the network of relationships individuals have with the people around them in daily life. As regards the technical apparatus used in the research above reviewed, a prevalence of

descriptive analysis of the characteristics of the network and actors, based on measures for a synthetic description of the network properties and on methods for partitioning networks into subgroups components is evident. Most of these descriptive network measures are used as explanatory variables, in order to better understand the role of alters in shaping an individual behaviour or in positioning an institution within a macro system. The diffusion of applications, which also present statistical models for estimating the structural effects, is still limited, even on an international level, not because the methods are unsuitable for the research issue, but simply because collecting data on a complete network is often far from the main aims of large surveys; it is time consuming and requires training, and it is only useful when the entire set of actors can be surveyed. As regards Italy, however, a considerable effort is being made to measure the egocentered network in the ISTAT Multipurpose Survey: these types of data offer some opportunities to analyse kinship networks for instrumental support, which are not exploited enough yet. We should also acknowledge that modelling processes in social space and time requires complex statistical technicalities for dealing stochastically the dependence of network dynamics on network structure. This complexity too could explain the limited diffusion of network models; scholars still need to get to know and appreciate the modelling of this interdependence.

References

- Alexander C., Piazza M., Mekos D., Valente T.W. (2001) Peer networks and adolescent cigarette smoking: an analysis of the national longitudinal study of adolescent health, *Journal of Adolescent Health*, 29, 22-30.
- Baerveldt C., van Duijn M.A.J., Vermeij L., van Hemert D.A. (2004) Ethnic boundaries and personal choice. Assessing the influence of individual inclinations to choose intra-ethnic relationships on pupils' networks, *Social Networks* 26, 55-74.
- Barabasi A. L. (2001) The physics of the Web, *Physics World - Physicsweb*.
- Entwisle B, Rindfuss R.R., Guilkey D.K., Chamrathirong A., Sawangdee Y. (1996) Community and Contraceptive Choice in Rural Thailand: a case study of Nang Rong, *Demography* 33, pp. 1-11.
- Fratiglioni L. Wang H.X., Ericsson K., Maytan M., Winblad B. (2000) Influence of social network on occurrence of dementia: a community-based longitudinal study, *Lancet*, 355, Issue 9212.
- Freeman L. C. (2000) Visualizing Social Networks, *Journal of Social Structure*, Vol. 1, n. 1.
- Huisman M., van Duijn M. (2005) Software for Social Network Analysis, in: *Models and methods in social networks analysis*, Carrington P., Scott J. Wasserman S. (Eds), Cambridge University Press, New York.
- Kohler H.P. (1997) Learning social network and contraceptive choice, *Demography*, 34, pp. 369-383.
- Knoke D., Kuklinski J. H. (1982) *Network Analysis*, Sage University Paper.
- Leoncini R., Maggioni M.A., Montresor S. (1996) Intersectoral innovation flows and national technological systems: network analysis for comparing Italy and Germany, *Research Policy* 25, 415-430.
- Maggioni A.A., Uberti T.E. (2005) International networks of knowledge flows: an econometric analysis, *Papers on Economics & Evolution*, n. 0519, Max Planck

Institute of Economics.

- Rivellini G., Zaccarin S. (2006) I modelli statistici nell'analisi di rete: evoluzione e utilizzo in Salvini A. (a cura di) *Analisi delle reti sociali. Teorie, metodi, applicazioni*, Franco Angeli, Milano (in corso di pubblicazione).
- Rivellini G., Uberti T.E. (2006) Lo schema interpretativo, in: *Milano Globale - Gli Indicatori di Reticolarità*, AA.VV., Camera di Commercio e Artigianato di Milano e Università Cattolica di Milano.
- Robins G., Pattison P. (2005) Interdependencies and Social Processes: dependence graphs and generalized dependence structures in: *Models and methods in social networks analysis*, Carrington P., Scott J. Wasserman S. (Eds), Cambridge University Press, New York.
- Scott J. (1997) *L'analisi delle reti sociali*, Edizione italiana a cura di Enrica Amato, NIS, Roma.
- Snijders T.A.B., Spreen M., Zwaagstra R. (1995) The use of multilevel modelling for analysing personal networks: networks of cocaine users in an urban area, *Journal of Quantitative Anthropology* 5, 85-105.
- Snijders T.A.B., Steglich C.E.G., Schweinberger M. (2005) Modelling the co-evolution of networks and behaviour, in van Montfort K., Oud H., Satorra A. (eds.), *Longitudinal models in the behavioural and related sciences*, Lawrence Erlbaum (in print).
- Snyder D., Kick E.L. (1979) Structural Position in the World System and Economic Growth, 1955-1970: A Multiple Network Analysis of Transnational Interactions, *American Journal of Sociology*, vol. 84, pp. 1096-1126.
- Steglich C.E.G., Snijders T.A.B., Pearson M. (2005) Dynamic Networks and Behaviour: Separating Selection from Influence, *Working Paper, ICS*, University of Groningen, The Netherlands.
- Taylor P.J., Lang R.E., (2005) U.S. Cities in the "World City Network, *The Brookings Institution Survey Series*, Washington D.C.
- Uberti T.E. (1998) *Struttura ed evoluzione del commercio internazionale di beni ad alta tecnologia: un'analisi reticolare*, Tesi di laurea, Università Cattolica di Milano.
- Valente T.W., Watkins S., Jato M.N., Van der Straten A., Tsitsol L.M. (1997) Social network associations with contraceptive use among Cameroonian women in voluntary associations, *Social Science and Medicine*, 45, 677-687.
- Valente T.W. (2005) Network models and methods for studying the diffusion of innovations, in: *Models and methods in social networks analysis*, Carrington P., Scott J. Wasserman S. (Eds), Cambridge University Press, New York.
- van Duijn M.A.J., van Busschbach J.T., Snijders T.A.B. (1999) Multilevel analysis of personal network as dependent variables, *Social Networks* 21, 187 – 209.
- van Duijn M.A.J., Snijders T.A.B., Zijlstra B.J.H (2004) p_2 : a random effects model with covariates for directed graphs, *Statistica Neerlandica*, 58, 234-254.
- Wallerstein I. (1974) *The modern world-system*, Academic Press, INC., New York.
- Wasserman S., Faust K. (1994) *Social Network Analysis. Methods and Application*, Cambridge University Press.
- Wasserman S., Robins G., (2005) An introduction to random graphs, dependence graphs, and p^* , in: *Models and methods in social networks analysis*, Carrington P., Scott J. Wasserman S. (Eds), Cambridge University Press, New York.
- Zincone G. (a cura di) Primo rapporto sull'integrazione degli immigrati in Italia, Il Mulino, 2000.