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Food Supply Chains and Eva.CAN model: a network analytic approach

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Table of contents

Food Supply Chains and Eva.CAN model:

a network analytic approach

1 A brief premise

“In recent years the ideas, concepts and techniques of physics have been applied to different disciplines such as biology, economics and sociology. The results of this interdisciplinary endeavour are interesting and have helped in improving the general understanding of these fields. In particular, in the study of economics, physicists are having an increasingly important role and a new ‘science’ has been born: econophysics (Mantegna & Stanley, 2000).

Central to this work is the idea that meaningful insights can be derived by considering social actors (individuals, groups of people, companies etc.) as ‘particles’ of a physical system and by studying their behaviour and the effects on the whole system under investigation.

This idea is far from new. Since the 17th century many scholars have taken into account the statistical properties of the elements of an economic or a social system to build the theories and models that constitute our current understanding of these (Ball, 2002, 2003). More recently, the usage of physical methods has provided important results such as the modelling of crowd behaviour (Helbing & Molnar, 1995; Henderson, 1971), traffic flows (Kerner & Rehborn, 1996; Nagel & Schreckenberg, 1992) or political elections (Bernardes et al., 2002; Costa Filho et al., 1999), the formation of business alliances (Axelrod et al., 1995; Castellano et al., 2000) and the behaviour of economic markets (Saari, 1995; Sornette, 2003). The application of the most recent developments in the field of complex systems modelling to social systems is also starting to receive ‘institutional legitimacy’ (Henrickson & McKelvey, 2002).” (Baggio R. 2008).

“The general framework in which this study is conducted is known as ‘complexity science’ (Lewin 1999; Waldrop, 1992). This is a rather recently formed corpus of multidisciplinary methods… Nonetheless, the latest results show enormous possibilities in improving our general understanding of social, economic, biological and technological phenomena” (Baggio R. 2008).

The work carried out within of this research is based on network theory, but especially on complex networks theory of the real world, called Scale Free Networks, illustrated by Albert Lazlo Barabasi and Reka Albert in an article published in Science in 1999 and cited directly about 25,000 times by other authors in articles published in other scientific journals.

The features that are proven to belong to complex networks existing in nature, and the meaning of the measurements that can be done on the whole network or on individual nodes of a network, have been further verified and deemed valid by tens of thousands of other research projects in the most various fields carried out by other researchers around the world.

It is impressive the amount of new information that in every area have been obtained from the application of this innovative analysis methodology. Nowadays many companies of all kinds routinely use the information derived from these analyzes to understand complex phenomena of the real world that previously did not found explanation and make more effective decisions for the company and for consumers. This method of analysis has been used successfully in completely different fields, too, such as political or anti-terrorism intelligence, to reconstruct and analyze the relationships between the various entities and to act strategically.

This research is based on the design of a model that reproduces the reality as faithfully as possible. This model has proven to be a complex network of the Scale Free type. As such, its "elective" analysis methodology resides in the application of complex networks theory of the real world whose principles and meanings have already been widely proven to be valid.

In this thesis are presented the results obtained from a first phase of qualitative and quantitative analysis. In fact, compared to what more it is possible to investigate, only the main measurements were made, both on the whole network and on individual nodes. In addition, the absence of a publicly shared database containing all the necessary data, represented in the quantitative analysis a further difficulty in having to rely for some data only on estimated values. This is then a preliminary analysis that can certainly be improved and detailed. It is reasonable to say that, with the necessary time, a lot more can be investigated and studied and in greater detail as has been done in other research fields.

The research work conducted for this thesis has led to the following publications:

- “Modelling the pig supply chain: a network analysis applied to the Italian case” (F. Clemente, P. Nasuelli, R. Baggio), paper for the 10th International European Forum (Igls-Forum) (151st EAAE Seminar) on System Dynamics and Innovation in Food Networks, Igls-Innsbruck, Austria, February 15-19, 2016; presentation and publication in the proceedings (forthcoming) on http://centmapress.ilb.uni-bonn.de/ojs/index.php/proceedings/issue/archive (Feb. 2016).
- “Supply Chains of Products of Animal Origin: a Complex Network Model for Strategic Management” (P. Nasuelli, F. Clemente, R. Baggio, R. Berruto, P. Busato), article, published on International Journal on Food System Dynamics Vol 6, No 4 (December 2015).
- “Formal network analysis of a food supply chain system: a case study for the Italian agro-food chains” (F. Clemente, P. Nasuelli, R. Baggio), article, published on Journal of Agricultural Informatics Vol 6, No 4 (October 2015).
- “Food Supply Chains, a network analytic approach” (Flavia Clemente, Piero Nasuelli, Rodolfo Baggio), paper for the conference “EFITA/WCCA/CIGR 2015”, Poznan, Poland, June 29 – July 2, 2015; presentation and publication in the proceedings of the conference (July 2015).
- "Network Moldels for Supply Chains of Products of Animal Origin" (Flavia Clemente, Piero Nasuelli, Rodolfo Baggio), presentation in the conference at the Museum of Natural History, Verona, Italy, June 5, 2015, and publication in the book of the project "Nutrimentum, art feeds the man"(book: ISBN 978-88-96495-09-4); project sponsored by Expo Milano 2015, affiliated with the project FoodCast of SISSA Trieste, conceived by Studio Chiesa Milano (June 2015).

- “Supply Chains of Products of Animal Origin: a Complex Network Model for the Strategic Management” (Piero Nasuelli, Flavia Clemente, Remigio Berruto, Patrizia Busato), presentation of the paper and publication in the proceedings of the congress “WCCA 2014”, World Congress on Computers in Agriculture and Natural Resources, San Josè, Costa Rica, July 27-30, 2014.
- “Network analysis: the supply chains of products of animal origin in Italy” (Piero Nasuelli and Flavia Clemente), presentation of the paper and publication in the proceedings of the conference "Efita 2013 - Sustainable Agriculture through ICT innovation", Torino, Italy, June 23-27, 2013.
  http://www.informatiqueagricole.org/Efita_2013/final%20pdf%20EFITA/EFITAFullpapers.pdf

2 Abstract

The research work leading to the drafting of this PhD thesis approaches the analysis of supply chains of products of animal origin from various productive species by using network analytic methods. In the studied analysis six supply chains are embedded in a single model which highlights all the interconnections that have little evidence in traditional models. This new model that we called Eva.CAN (Evaluation of Complex Agri-food Network Model) is a new concept model, the first complex network model for the agri-food production, the first to allow the application of Network Theory analysis methods. The initial hypothesis is that the various supply chains of products of animal origin have to be interpreted and analyzed as a whole, as a single complex system. The complex network is studied analyzing the adjacency matrix that constitutes the network with algorithms and methods extensively tested and validated. This analytical approach has already been applied with positive results in many research areas such as social networks, transport networks, the stylistic of writers and musicians, proteomics, pharmacology, medicine, biology, and many others. We apply this methodology to supply chains of products of animal origin and show a series of preliminary results. This method of study of food supply chains could be useful for an observatory, bringing to light slightly evident relations and becoming a strong support for policy-makers. It can also provide useful advices to individual actors on how to optimize their own supply chains. Finally, through an effective enumeration and evaluation of the relationships, a network model could be helpful in design of tracking and traceability systems.

Key words: Agri-food supply chains, Complex Systems, Complex Adaptive Systems, Complex network model, Eva.CAN model, Supply chain management, New Science of Networks, Scale Free networks, Complex Networks Analysis, Network Theory applications

.3 Introduction

The agro-food market dynamics have changed considerably since several years. Food products are the result of a series of complex processes of production and processing involving many actors in many activities who are connected with each other through relationships of various kinds. These relationships constitute the supply chain.

Current models for supply chains of food products are not fully able to describe production and marketing dynamics because they usually do not take into account all the links, vertical and horizontal, in the network of relationships nowadays existing between production, processing, distribution, and even the disposal of food. This makes existing models for supply chains not exactly the most useful tools for a good governance of the players in the food sector. Furthermore, making predictions has become increasingly difficult due to the dynamics of the food market, more and more similar to that of a complex financial market. Existing models of supply and demand are no longer able to serve as useful tools for policy and chain actors to cope with the current behavior of markets. Agro-food production processes have become very complex systems, involving many actors performing activities of different kind and linked by relationships of different nature. Moreover, these relationships are no longer limited to those between the elements most closely linked along the chain but can include stakeholders anywhere in the chain (Yu & Nagurney 2013). The networks of relations include not only manufacturers and processors of raw materials and a number of dealers similar to the retailer generic figure of the past, which distributed the product as it happened perhaps many years ago. Now networks of relations include also packaging companies, companies for disposal of special wastes, companies engaged in the recovery of unsold for humanitarian purposes, activities of rendering from which to derive energy or by-products used in other types of industries, cosmetics industries for example, or also of fertilizers for agriculture. Even the actors involved only in the trade sector are represented by very different job profiles, they exert different roles and carry out distribution with completely different mode from each other, despite being all "traders".

From these observations arises our initial hypothesis on supply chains: we should now consider supply chains as a whole, not separately one by one, and therefore observing and studying them as a single complex system, a single network.

The initial goal of this research was designing a new model for evaluating the network of relationships between the actors of the food supply chains, both to assess the robustness of the organizational structure and to have more accurate measures of the role and the importance of each actor in the system. This can also allow to identify which of the actors occupy strategic positions in the network and which of them have only a redundant function.

In this research we dealt with supply chains of products of animal origin.

The concept of a single network model representing all products of animal origin came to us from our involvement in making network models for the research project “FoodCast” managed by SISSA (International School for Advanced Studies) in Trieste and ISMEA (Institute of Services for the agricultural and food market) and commissioned by the Region Lombardy. The focus of that project was the forecasting of food availability in 2050 given the expected increase in world population, and the risk analysis in the supply chains of major food commodities in Italy (http://foodcast.sissa.it) . FoodCast was a research project designed for Expo Milano 2015 and was thus centered on themes in line with those of the Expo: feeding the planet, availability of food for the world population, energy expenditure for the production and transport of different foods, convenience to consume and therefore to produce a food rather than another depending on the seasons or areas of the planet. It ended with a series of Neurosciences research on perceptions aroused in the consumer by the different types of food, more simple or more sophisticated and vegetable or animal origin, and also on perceptions about the nutritional needs of each person and the real calories provided from each type of food. At the base of each topic studied in FoodCast there were network models for the major food productions. However, although also those network models included relations between actors strictly belonging to food supply chains and actors connected to them but not directly involved in the purely food industry, in FoodCast supply chains were still observed separately. Therefore, although always based on network models, supply chains were not interpreted as a single complex system as we did in our research, and, in addition, the aims of that research were different from what we have autonomously done later.

The objective of this research is to develop a model to analyze in detail the structure (actors and relationships) and the dynamics existing in the supply chains of products of animal origin by providing a mapping of the productions as complete as possible, and as representative as possible of the relationships among the players.

Some authors argue that supply chains should be treated as a Complex Adaptive Systems (CAS) and propose to exploit concepts, tools and techniques used in the study of CAS to characterize and model supply-chain networks. (Surana et al, 2005). Sharing this thought, our hypothesis is that we face a complex system, mainly characterized by the dynamic nonlinear relationships between its elements. Among the many possible methods to approach the problem, the techniques developed in the framework of network science seem to be quite suitable for the purpose. A supply chain, in fact, can be seen as a network of stakeholders involved in primary production, processing, and distributing the products to consumers who are the last link in the chain. In the network actors or actions involved in these stages are the nodes that are connected to each other by some kind of business relationship. These are directed links that can carry a weight which can be valued in different ways.

In this thesis we present a new concept model we designed and called Eva.CAN model, which stands for Evaluation of Complex Agri-food Network model. It is a graph model made of nodes representing the actors of supply chains and links between nodes representing the relationships that bind them. Eva.CAN is a complex network model for products of animal origin, the first model to combine and integrate six different supply chains of animal products, from different animal species, with their fresh and seasoned derived products, in a single complex network. The represented supply chains are milk chains (for cow, goat, sheep and buffalo milk), and meat chains (bovine and pig), along with their fresh and cured products, but it is open to the addition of other supply chains. It is also the first model that despite the stylization of reality characteristic of each model, keeps a wealth of details such as to allow the use of complex networks analysis methods for the study of the structure and relationships along the chains of products of animal origin.

The study of networks, in the form of mathematical graph theory, is one of the fundamental pillars of discrete mathematics. Over the years "network oriented" approaches have been used with positive results in many areas for studying Complex Networks. Examples include spread of viruses or dissemination of a news, catastrophic events in a system and crisis management, usefulness of vaccines, proteomics, pharmacology, medicine, biology, evolution of the writing style of authors in articles or books, the style of music composers, transport networks, communication in social networks, and many others.

Abbasi and Hossain (2012, pp 1 and 2) identified social network analysis (SNA) as "…the mapping and measuring of relationships and flows between nodes of social networks. SNA provides both a visual and a mathematical analysis of human-influenced relationships… Each social network can be represented as a graph made of nodes or actors (individuals, organizations, information) that are tied by one or more specific types of relations (financial exchange, trade, friends, and Web links).… Measures of SNA, such as network centrality, have the potential to unfold existing informal network patterns and behavior that are not noticed before…".

This thesis approaches the analysis of supply chains of products of animal origin from various productive species by using network analytic methods. We propose to look at supply chains as a whole, considering them a single complex system. In the studied analysis the supply chains are embedded in a single model which highlights all the interconnections that have little evidence in traditional models. The complex network is studied analyzing the matrix that constitutes the network with algorithms and methods extensively tested and validated. We apply this methodology to the system of supply chains of products of animal origin and show a series of preliminary results.

The measures that characterize a complex network fall into two categories:

a) measures that characterize the network as a whole and provide information on its structure and,
b) measures on individual nodes which provide information on the importance of each node and its relevance and convenience regarding being linked from other nodes through the shortest possible path.

The analysis can be qualitative or quantitative, providing in both cases outcomes of different nature.

As said this is a first attempt at using network analysis techniques in this field. In the context of animal production network theory has been used to assess the risk of spreading disease (Bigras-Poulin et al, 2006; Natale et al, 2009; Lentz et al, 2016) and therefore aim and research area were different. Network theory has been applied to study the formation of prices in the fish market of Marseille (Vignes et al., 2011), and also in this case the purpose was different. About raw materials, in general, a minimum spanning tree network model was constructed and used to study the relationships and interdependencies of futures contracts for commodities for the period 1998 - 2007 (Sieczka et al, 2009). However, it is the first time that this methodology is applied in the productions of animal origin for purposes of a different type from those of previous studies and to a model different from the existing ones.

This method of analysis of food supply chains could be useful for an observatory, bringing to light slightly evident relations and becoming a strong support for policy-makers. It can also provide useful advices to individual actors on how to optimize their own supply chains. Finally, through an effective enumeration and evaluation of the relationships, a network model could be helpful in design of tracking and traceability systems.

In this thesis will be often used the word "model", supply chains, but also "complex" and "complex system". On the other hand, “Network analysis methods are embedded into the literature of complex and chaotic systems” (Baggio, R. 2008, “Network analysis of a tourism destination”, School of Tourism, The University of Queensland, PhD thesis, p 13). Therefore, a definition of these terms and concepts will be provided.

4 Definitions:

model, supply chain, complex, complex system

4.1 What we mean by "model"

As written in the article “Formal network analysis of a food supply chain system: a case study for the Italian agro-food chains” (Clemente F, Nasuelli P, Baggio R, 2015), using the word "model" it's right to clarify the sense in which this term is used in this thesis. Starting from a citation: "What is a model? Although a model is easily recognizable as such, it is something that virtually defies a formal definition. As the philosopher Max Black pointed out in his classic (1962) study of modeling in science, the term model has as many definitions as it has uses." (Sebeok, T. A. et al., 2000, “The forms of meaning: Modeling systems theory and semiotic analysis”, Vol. 1, Walter de Gruyter, p. 2).

The Business Dictionary provides a definition of “model” that suits our case: “Graphical, mathematical (symbolic), physical, or verbal representation or simplified version of a concept, phenomenon, relationship, structure, system, or an aspect of the real world. The objectives of a model include (1) to facilitate understanding by eliminating unnecessary components, (2) to aid in decision making by simulating 'what if' scenarios, (3) to explain, control, and predict events on the basis of past observations. Since most objects and phenomenon are very complicated (have numerous parts) and much too complex (parts have dense interconnections) to be comprehended in their entirety, a model contains only those features that are of primary importance to the model maker's purpose”
(http://www.businessdictionary.com/definition/model.html).

For our purposes our model is a mapping model, a graphical representation of the structure of the whole system of supply chains of products of animal origin representing relationships among its different components, and traces flows of raw materials, processed food, information and money.

In literature, there are various approach theories to the study of supply chains. Over time, different methodologies have emerged for their analysis. Among the best known, the anglophone Global Commodity Chain (GCC) developed by Gary Gereffi and others within a political economy of development (and underdevelopment) perspective, derived from Wallerstein's (1974) World Systems Theory, and the francophone Filière tradition, developed by researchers at the Institute National de la Recherche Agronomique (INRA) and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD).

A commodity chain is defined as 'a network of labour and production processes whose end result is a finished commodity' (Hopkins and Wallerstein, 1986:159). Among methodologies emerged for their analysis there is Value Chain Analysis, for instance, used to identify which activities are best undertaken by a business and which are best provided by others, or outsourced. The value chain describes the full range of activities required to bring a product or service from its conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use. In this type of analysis, production "per se" is only one of a number of value-added links (Tallec and Bockl, 2005).

Gereffi, theoretician and developer of the Global Commodity Chain during the mid-1990s, and most of his collaborators are concerned specifically with industrial commodity chains. The primary focus of global commodity chain (GCC) analysis is the international trading system and the increasing economic integration of international production and marketing chains. (Raikes, P. et al., 2000, "Global commodity chain analysis and the French filière approach: comparison and critique", pp 3 – 5). The GCC concept was developed within an analytic framework of the political economy of development and underdevelopment, originally derived from world-system theory and dependency theory. It was developed primarily to analyse the impact of globalisation on industrial commodity chains. GCC highlights power relations that are embedded in value chain analyses. It has shown that many chains are characterised by a dominant party (or sometimes parties) that determines the overall character of the chain. This analysis distinguishes between two types of governance: those cases where the coordination is undertaken by buyers ('buyer-driven commodity chains') and those in which producers play the key role ('producer-driven commodity chains') (Tallec and Bockl, 2005).

'Approche Filière', translated as Commodity Chain Analysis, CCA, is applied to the analysis of existing marketing chains for primarily agricultural commodities, assessing how public policies, investments and institutions affect local production systems (Raikes et al., 2000; Tallec and Bockl, 2005). Filière analysts have borrowed from different theories and methodologies, including systems analysis, industrial organisation, institutional economics (old and new), management science and Marxist economics, as well as various accounting techniques with their roots in neoclassical welfare analysis (Kydd et al., 1996: 23).

The empirical aspect of this approach involves mapping out actual commodity flows and identifying agents and activities within a filière, and aims at a measure of inputs and outputs, prices and value added along a commodity chain. In addition, there is an anthropological tradition within filière works which focuses on markets and power in a 'real-world' sense. From this point of view, the approche filière is related to the GCC approach (Raikes et al., 2000)(EJOLT, Environmental Justice Organizations, Liabilities and Trade, http://www.ejolt.org/2012/12/commodity-chains-2/).

"Therefore, while the GCC approach is centred on contributions from a distinct school of thought, the French Filière approach is a loosely-knit set of studies with the common characteristic that they use the filière (or chain) of activities and exchanges as a tool and to delimit the scope of their analysis. The approach is thus a 'meso-level' field of analysis rather than a theory. It is also one seen by most of its practitioners as a neutral, practical tool of analysis for use in 'down-to-earth' applied research." (Raikes, P. et al., 2000, "Global commodity chain analysis and the French filière approach: comparison and critique", p. 22).

These two and other different approaches to the observation of supply chains, each with its strengths and weaknesses, have led to the development of various models, different from each other depending on the purpose of analysis for which they were designed.

The French agronomist Malassis (1973) has defined the supply chain as the set of agents (companies and administrations) and operations (production, distribution, financing) that contribute to the formation and transfer of the product (or group of products) to the final stage of use, as well as all flows connected (Giarè F., Giuca S., “Farmers and short chain: legal profiles and socio-economic dynamics”, INEA 2012, p 12).

In this sense, we can define our model Eva.CAN a French Filiere-inspired. It consists of a set of actors / actions linked by relations drawing the flow of materials, operations, processing, information, up to the final recipient.

Such a network consisting of nodes (set of actors / actions) and links between the nodes (relations among actors) can highlight the relationships between the various supply chains that cannot be considered in models representing singles supply chains, and the nodes of the network common to more than one chain. This offers new points of view and shows the potential to exceed the limits of observation of individual supply chains separated from each other and to observe the various agri-food productions as complex networks given by several supply chains integrated together. Having the ability to observe supply chains all together in a model that integrates into a single complex system means having a vision that is more similar to the reality of facts.

4.2 Supply Chains

To explain the concept of Supply Chain it is necessary to step back and focus our attention first on the term "Logistics".

The Council of Logistics Management defines logistics as: The process of planning, implementation and control of the efficient and effective flow and storage of raw materials, semi-finished and finished goods and related information from point of origin to point of consumption in order to meet customer needs. (AILOG, Italian Association of Logistics and Supply Chain Management, http://www.ailog.it/pagine/logistica_e_scm-20/).

For many years logistics has often been confined to be a control action of specific support activities for supplying processes, production and distribution, considered strategically important for business purposes. Flow management occurred within clearly defined boundaries with the primary goal of meeting the need of a well-defined function. Production, for example, until the 50s represented for manufacturing companies the load-bearing function, while little attention was given to the movements of materials and products. Connections were needed between different generic functions since each, although belonging to the same system and sharing common resources, was conceived independently from the others.

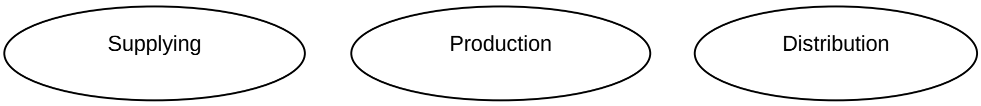

Fig. 1: Generic independence between functions

A proliferation of products and the reduced demand of the 60s made the sale of products strategic, focusing companies attention on the distribution activities of logistics. Companies began to conceive the concept of logistics, however, limited to the management of stores and delivery to customers (outbound transports), therefore only for partial physical distribution issues. During this period, therefore, the physical distribution of the goods produced assumes an important role for the companies as a result of the occurrence of some significant events.

It occurs in the 60s the transition by companies from a simple market orientation to a marketing orientation. Customer demand is increasingly exigent, problematic and personalized. Companies no longer use the strategy of trying to sell what they produced, but they try to produce what they already know they will sell. The ability to provide the customer what he requires, in the times and places required, can allow the realization of a competitive advantage that finds its driving force in marketing. The company tries to understand in advance the needs of potential customers and to develop products able to satisfy them.

The process thus takes origin from the consumer. Consumers needs and behaviors are examined, the company starts from this to conceive the product. In this way the company tries to adapt its offerings to the characteristics of demand. However, the differentiation of the offer by the company cannot take place only on the basis of the qualitative characteristics of the product but also of the service connected to it.

Logistics therefore assumes not only a tactical role aimed at containing costs, but also an essential strategic role, aiming to differentiate precisely the goods with customer service elements. Logistics to customer service, such as physical distribution of finished products, transportation, and packaging tend to take on more importance. For the customer, in fact, the same product can have a lower value if it is not available at the time and place in which is needed.

The goal becomes to implement a logistics system able to guarantee a predefined level of service to customers at lower cost. There was, thus, a change in the vision of the market, from the "product demand" to "customer demand", reflecting the fact that the customers' choices are influenced, in a significant way, by service quality offered in terms of punctuality, reliability and customization of the same.

The value created can be to offer both lower prices than those offered by competitors, and also a high level of service. Competitive advantage comes from the firm's ability to perform more effectively and efficiently the complex tasks making the operating process. The fragmented approach to logistics, resulted from functional excellence, it is thus to be rejected to make way for a new conception of the logistics system (integrated logistics) based on the coordination between physical distribution, production and supplying.

Logistics now, after this reorganization, describes the overall management activities, organizational, managerial, financial, strategic, that are closely integrated at the system level, connected to the flow of materials (raw materials from the supply source, semi-finished, other materials, spare parts, finished products until final consumption). Therefore, logistics includes both the area of materials management and that of physical distribution. This is therefore a combination of many functions none of which alone is the logistics, but on the contrary must be organized, directed and managed as an integrated system.

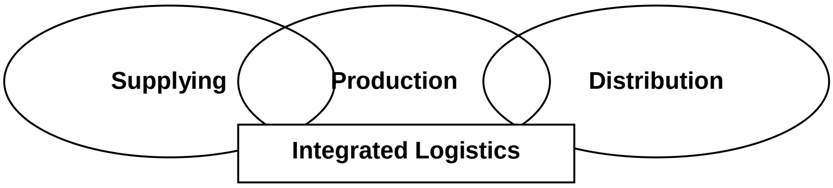

Fig. 2: Integrated Logistics

The concept of integrated logistics identifies, therefore, the set of activities that take place within the enterprise and playing a key role in the acquisition of competitive advantages. In this way, the logistics is intended as a whole form a system that is a coherent set of elements or variables in relation of a multilateral interdependence between them. The general assumption of the concept of system is that not so much on the individual variables you must focus but rather, on their mode of interaction.

The last stage of the evolutionary process, leading to the birth of the concept of supply chain management, is characterized by the growing awareness by enterprises that the improvement in the management of the flow within the logistic chain cannot disregard from the active involvement of the outside actors, especially those that can help maximize the value perceived by the customer.

The loss of competitiveness due to wastes generated in the purchase of materials and in the sale and distribution of products induced some companies to manage in strategic perspective of collaboration the relations with partners in the chain and design a logistic system whose components are: suppliers, customers, transports and information.

In fact, the competitive capability comes from management's ability to integrate and coordinate not only internal activities, but also those with the upstream suppliers and downstream distributors, converting, thus, integrated logistics in channel logistics.

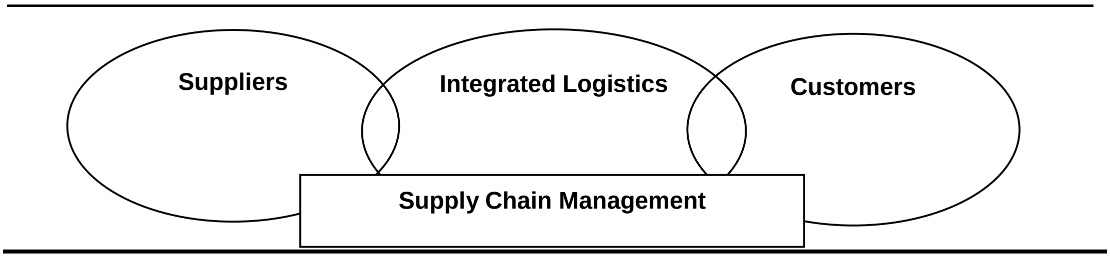

Fig. 3: from Internal integration to external integration

The systemic approach spreading has therefore helped to develop the concept of SCM according to which the integration extends to outside the enterprise to understand all those systemic entities in the environment with which are established appropriate cooperative relations.

In other words, these organizational entities (suppliers, manufacturers, distributors, contractors) turn out to be highly interconnected and coordinated in relation to the common tendency to pursue the objective of the system, namely provide customers with products, services and information with high added value. The synergic activity between all the components generates a final result that is greater than the one achievable from the sum of the individual performances of the individual components.

Over the last decade there has been a renewed and growing interest around issues concerning the strategic management of the supply chain, where this expression refers to the management of the entire value system, from the supply, to production and delivery in order to provide a service more responsive to the complex and different needs of the today's consumer.

The reasons for this special care are to be found in the importance that supplying and distribution processes have assumed in the operational practice of companies, due to the continuous pressure towards increasing efficiency, effectiveness, flexibility and innovative capacity of firms themselves.

The final consumers continue to demand more and more different products, customized, and available at lower prices in the short term. Companies keep up thanks to the development of information and communication technologies that reduce the costs of buying, handling and transmit data. This makes it more economically possible to achieve greater integration of information on every aspect of business processes both internally to the individual company and at intra-organizational level between a company and the others with a consequent reduction of transaction costs.

The Supply Chain Management stands as a new management approach in which the individual company becomes part of a network of organizational entities integrating their business processes to provide products, services and information that create value for the end customer.

Supply Chain must be conceived as a value system to which generation all organizational actors contribute to, each according to well-identified skills. In this context, the success of the system depends on the interaction capabilities of the individual nodes of the network and on the intensive use of interactive technology. Continuous connection with customers, suppliers, employees of the company becomes essential and indispensable basis of the new business model, in which the physical and information flows must be extended outside the organization in order to connect together the various subjects of the system, the center with its suburbs.

The success of a business is therefore more and more conditioned by the competitiveness of the value system in which it is positioned. In other words even if the company is efficient and effective in pursuing its goals, it can be in trouble if upstream and downstream has to interact with subjects inefficient and far from the real needs of the market by importing inefficiencies and inability.

The concept of Supply Chain emphasizes the importance to get out from the firm boundaries to manage in unified way not only the flow of an individual company, but also the one crossing several enterprises. Along the channel that links the production to the consumer is held a variety of activities that concern from time to time those who produce, those who distribute, those who sell.

The concept of Supply Chain is, therefore, wider than that of logistics. It refers to all those activities that should not only be carried out integrated and coordinated within the company but also with all the systemic entities involved in the management of the chain flows.

Supply Chain is represented by a network of companies that work together to make available to the end customer the product and / or service requested. It aims to unitarily manage the flows of goods and information through the single systemic entities located along the chain in order to exploit the synergies between operators and to avoid carrying out unnecessary activities, doubles and without added value, sources of waste and inefficiency.

The decision-making process leading to the definition of the supply chain model is characterized by the presence of four closely interrelated key moments:

- Identification and analysis of strategic processes, or activities that produce a specific output value for the end user and for which it is necessary to achieve a strong integration between the different partners;
- external environment analysis and definition of organizational boundaries, identification of external entities, potential suppliers of inputs and buyers of output;
- definition of the structure of relationships between the various external selected entities making the Supply Chain;
- analysis of the operational and organizational components necessary to achieve an appropriate level of integration between the various processes and systemic entities in the supply chain. It is to identify some important mechanisms for coordination among the members of the chain making possible the achievement of both individual and system goals.

The supply chain design activities is therefore influenced to a significant extent on the capabilities and skills that the company needs to have to perform the necessary processes, and also by the characteristics and capacities of systemic entities in the environment of reference. These entities have the obligation to provide, in an organized and conscious way, to refocus their strategy in the direction of greater flexibility and compatibility with various network nodes.

In the just outlined context the emerging organizational model under the current business evolution dynamics is characterized by development based on inter and intra-systemic logical relationships. For this purpose are studied and intertwined stable relations between companies committed to achieve common goals through the coordinated shared and synergic use of processes and skills.

Distinctive features of the concept of Supply Chain:

- cooperative system developed and managed within a unified strategic plan;
- aimed at the end-customer satisfaction;
- it works through the integration of business processes of each unit and the development of appropriate relationships of interdependence;
- a supply chain must be governed by appropriate coordination mechanisms.

The first attribute primarily highlights the fact that each entities in the Supply Chain is a node characterized by its operational and strategic autonomy, but each node cooperates with all other entities in the network, sharing with them resources and skills, in order to achieve specified levels of efficiency and effectiveness.

The network coordination model implies, in fact, a long term relationship between a plurality of participant units interdependent but autonomous on one or more areas of activity, according to which they regulate their future conduct ex ante through contractual mechanisms. They make available structures and processes to take decisions together and to integrate their efforts to design, build, produce and exchange information and other resources in a stable and guaranteed form.

The customer and the satisfaction of his expectations represent both the trigger of the exchange processes and interaction between the actors in the chain, and the result for which these processes develop and the actors act and interact. The satisfaction of customer needs should be the goal of every company wishing to win the competitive comparison.

The integration between different business realities addressed to form a single business system is one of the essential conditions for the government of the Supply Chain: to create added value for customers it is necessary to transform a group of isolated and fragmented processes into something coherent and able to contribute to the achievement of this objective. It is not an integration for its own sake, but welded around a common set of goals oriented to improving the competitive position on the market both of the system and of its individual components.

In fact, only through greater integration of all activities which are located upstream and downstream of the chain is possible to create more value for all entities in the network. It is no longer the individual enterprise to compete, but the whole supply chain in which relations are not only of logistics and commercial nature, but mainly the mutual exchange of information, knowledge, skills, services, helping implementation of activities and processes.

Another element that enhances the Supply Chain compared to the old Logistics is the amplification of the added value generated. An optimized and rationalized chain expresses an overall value that is higher than the sum of the contributions of the single subjects interacting. This is an important competitive factor for the companies included in an advanced collaborative model.

In order to further highlight the qualifying aspects of a supply chain, it seems useful to refer to some elements characterizing the supply chain, namely centralization, connectivity and stability.

Centralization is the expression of the role played within the supply chain from a particular actor. In fact, the set of inter-relations developed inside the channel, although negotiated between a number of organizational units, is developed and managed by a guide enterprise on which all other players in the system depend.

In accordance of the position that an actor assumes in the network, its centrality is characterized by various parameters, including: a): the number of direct relationships; b): being the passing through node for many organizational entity, a high index of interposition that is to say it acts as an intermediary in the relation between the other nodes of the network; and, c): for a high index of proximity as it is able to reach the greatest number of other nodes through the shortest path. These three parameters are called Centrality Measures and in order they are the Degree Centrality, the Betweenness Centrality and the Closeness Centrality.

Connectivity expresses the extent to which relationships exist between all nodes belonging to the network. A Supply Chain has high levels of connectivity to the extent that the reports are disseminated to all stakeholders without exception. The analysis of relational density allows to measure the degree of connectivity within a Supply Chain. In essence, once identified the actors, one counts the number of relationships of that type existing in the channel in front of the total possible.

It is possible argue that neither the influence processes based on power and contractual regulations, nor the only economic incentives are sufficient as a coordination tool in this multipolar reality. Beside this intense communication processes are required as well as the development of relations based on information sharing, decision-making sharing and the presence of roles of integration and connection. These are the main methods of coordination between the different systemic entities in the Supply Chain. The success is related to the focal firm's ability to coordinate this complex network of actors in order to promote a single stream of activities that, on the basis of inputs from the end customer, has its origins from a supplier and ends at the customer.

Finally, stability can be considered as the measure of the persistence in time of a given configuration of relations between actors.

Two are, therefore, the main dimensions: the actors, or the specialized systemic entities that have their own autonomy, and the relationships between them.

Another aspect to consider is the analysis perspective because the analysis and organizational design of the SC is conducted by one of the network companies - focal company - which, given its goals, has the capacity and capability to act in design and plan the relationships with the other organizations.

The analysis begins with the identification of the entities available in the environment and the definition of the structure of relationships. The organizational design activity aims to analyze the possible relationships between the selected companies, but also the inter-organizational relationships whether actual or potential.

The classification of the entities of the system available within the environment of the focal company allows, on the basis of the identified critical attributes, to guide the management choices about the inter-system relationships to be activated.

Operating within an supply chain involves a strategic change in scale and difficulty that requires a radical rethinking of the company's operating methods from the method of supplying from providers up to relationships with customers. The implementation of the Supply Chain model leading to a real integration of the physical and information flows between companies that are part of it, requires a strong integration of some important operational processes.

It seems appropriate to highlight the fact that based on James Thompson's Theory of Contingencies, you cannot formulate general principles applicable to organizations regardless of the characteristics of time and place in which they operate.

This theory attributes great importance to the variety and variability of organizational forms and problems.

Fundamental consequence of this methodological approach is that not only there is no one best way of organizing and that not all are equally efficient ways to organize, but also that the best way to organize depends on the nature of the environment in which the organization must relate.

It is possible to say that there is no single organizational formula since the uncertainty that characterizes this transition period does not allow for definitive choices, but only temporary solutions.

We can therefore say that the achievement of a competitive performance can be performed by various organizational solutions, but functionally equivalent. In fact, the different organizational solutions have to be assessed on the basis of their ability to ensure the realization of the focal firm's goals (effectiveness); to minimize production costs, the focal firm's transaction (efficiency) and to meet the specific interests of the actors involved in the process of cooperation governed by the network (equity). (Pinna, R., 2006. ”The Evolution in Organizational Dimension of Supply Chain. From the management of a flow to the management of a network”, p.34 – 100).

4.3 Complexity & Complex Systems

First of all, what is meant by "system"? The term system is in traditional uses both in ordinary language and in that of many disciplines, such as mathematics and philosophy. The system concept has a long history. However, a strict definition of the term has only recently been attempted, when the technological and scientific developments have required the need for an explicit and conscious definition, able to subtract the word to its ideologically misuse, and a misleading semantic interpretation.

The birth, so to speak, official of an explicitly theory dedicated to the study of systems must be traced back to 1954, when in Palo Alto a group of European and American scholars of different origins - as the economist Kenneth Boulding, the bio-mathematician Anatol Rapoport, the physiologist Ralph Gerard and the father of systems theory, the biologist Ludwig von Bertalanffy - founded the Society for general system research. Their original purpose was to develop a theory able to create a match between traditionally separate cognitive areas. The concept of system in fact offered the opportunity to relate to each other areas traditionally studied according exclusively specialized mode. A globalizing approach, that is, oriented to develop the rules of empirical totality, defined as wholeness, was underlying the project whose interdisciplinary vocation was certainly influenced by the biological studies of von Bertalanffy. From his idea of organismic totality, where it's not individual causality operating individual but entire interdependent causal complexes, derives in fact the so-called principle of equifinality, according to which a system is able to achieve the same final state of homeostasis, ie dynamic equilibrium, regardless by the intervention of individual causal factors. This principle was developed by von Bertalanffy just to show how much deterministic explanations were insufficient in the analysis of complex phenomena: no individual causality, but entire causality complexes between them interrelated drive the evolution of systems. The organism metaphor, as an autonomous totality and able to self-organize into the attempt to achieve a final state characterized by dynamic balance, is established as fundamental model to be used for other forms of thought, especially in the social sciences.

Subsequent advances in information technology and cognitive science have provided the general theory of the additional opportunities for development systems, allowing it to transform the organismic-totalizing insight of von Bertalanffy in a practical way to access the solution of particularly chaotic knowledge and operational issues, irreducible to monocausal explanatory charges.

The destiny of the general systems theory will be, from the sixties onwards, not so much to provide an isomorphic metalanguage for hyper specialized sciences but rather to deal with the complexity, ie the emergence of phenomena that, cognitively and operationally, have high degrees of uncertainty and indecisiveness.

With the contribution of Norbert Wiener, Claude E. Shannon and Warren Weaver, we arrive at a definition of system claiming that, in general terms, a system is an organized set of relationships between objects resulting from a selective reduction process of the disorder, ie entropy.

Talcott Parsons and Edward Shils define the system: "The most general and fundamental properties of a system is the interdependence of parts or variables. Interdependence is the existence of certain relationships between the parties or variables" (v. Parsons and Shils , 1951, p. 107).

A more precise definition it is that provided by A.D. Hall and R.E. Fagen (v., 1956, p. 18): "A system is a set of objects and relationships between objects and between their attributes."

In all the above definitions is common lack of a defining element that the current systems theory considers fundamental: it is absent any reference to the criterion of choice both objects and the relationships to which is given a systemic nature, ie is lacking the observer of the system.

The criterion of choice, typical of the observer, seems instead appear in the definition of James Grier Miller (v., 1971, p. 52), according to whom the system is "a region bounded in the time-space", where the term 'bounded' obviously refers to an observer that delimits and then chooses. Of dependence on the observer's perspective, observer-dependence, in turn speaks Alessandro Pizzorno (v., 1973), interpreting it as a limit.

In contemporary systems theory no one refuses to introduce the observer in the arguments of the theory itself, and such now accepted observer-dependence is considered not so much a flaw as a constructivist 'virtue'. (Pardi F, 1998).

The general definition given by Encyclopedia Treccani of system in the scientific field is: any object of study which, although composed of several elements that are mutually interconnected and interacting with each other and with the external environment, reacts or evolves as a whole, with its own general laws. (http://www.treccani.it/enciclopedia/sistema/).

About the concept of complexity, in natural language, it has several meanings, usually related to the size and number of components in a system. There is still no universally accepted definition, nor a rigorous theoretical formalisation, of complexity. Nonetheless, it is currently a much investigated research topic (Baggio, R 2008, “Network analysis of a tourism destination”).

By intuition we can define a complex system such as “a system for which it is difficult, if not impossible to reduce the number of parameters or characterizing variables without losing its essential global functional properties” (da Fontoura Costa et al., 2007; Pavard & Dugdale, 2000).

The parts of a complex system interact in a non-linear manner. There are rarely simple cause and effect relationships between elements, and a small stimulus may cause a large effect, or no effect at all. The non-linearity of the interactions among the system’s parts generates a series of specific properties that characterise its behaviour as complex. (Baggio, R 2008).

The two words "complicated" and "complex" have not the same meaning in this context and important is highlighting the difference between a complicated and complex system.

“A complicated system is a collection of a number of elements (often very high) whose collective behaviour is the cumulative sum of the individual behaviours. In other words, a complicated system can be decomposed into sub-elements and understood by analyzing each of them. On the contrary, a complex system can be understood only by analysing it as a whole, almost independently of the number of parts composing it”. (Baggio, R 2008).

A very high number of entities comprising the system is not absolutely necessary condition to classify that system as "complex." In fact, “a 'simple' school of fish, composed of a few dozen elements, is able to adapt its behavior to the external conditions but without apparent organization following a few simple rules regarding local interaction, spacing and velocity” (Reynolds, 1987).

Bar-Yam (1997) defines a complex system as a mesoscopic structure, composed of a number of interacting elements which is neither too low nor too high.

Therefore it is not the high number of constituent units that makes of a system a complex system, but its behavior as a whole, the adapting reaction of the system to the stimuli it receives, which does not correspond to the simple sum of the actions of the units constituting it.

In one special class of complex systems, the complex adaptive system (CAS), interactions among the elements are of a dynamic nature and are influenced by, and in turn influence, the external environment. In this type of system, the parts “interact with each other according to sets of rules that require them to examine and respond to each other’s behaviour in order to improve their behaviour and thus the behaviour of the system they comprise” (Stacey, 1996: 10; Baggio, 2008).

A central property of a CAS is the possible emergence of unforeseen properties or structures termed self-organisation. This is one of the most striking features characterizing a complex system. A consequence of this is the robustness or resilience of the system to perturbations (or errors); the system is relatively insensitive and has a strong capacity to return to a stable behaviour in the absence of external inputs. This property is the one which may be considered to have been exhibited on several occasions after crises, for example in 1996 in occasion of the diffusion of Bovine Spongiform Encephalopathy (BSE) in Europe, which caused a huge drop in sales and the sector crisis, effect that has been repeated for chicken meat on the occasion of avian influenza cases in the East, Middle East, Africa and Europe in 2004/2006.

For a CAS, the main characterising features may be summarised as follows (Baggio, 2008; Levin, 2003; Waldrop, 1992):

- *non-determinism*. It is impossible to anticipate precisely the behaviour of such systems even knowing the function of its elements. The dependence of a system’s behaviour from the initial conditions is extremely sensitive and appears to be extremely erratic; the only predictions that can be made are probabilistic;
- *presence of feedback cycles* (positive or negative). The relationships among the elements become more important than their own specific characteristics, and the feedback cycles can influence the overall behaviour of the system;

- *distributed nature*. Many properties and functions cannot be precisely localised, in many cases there are redundancies and overlaps; it is a distributed system;
- *emergence and self-organisation*. A number of emergent properties are not directly accessible (identifiable or foreseeable) from an understanding of its components. Very often, in a CAS, global structures emerge over a critical threshold of some parameter. Typically, a new hierarchical level appears that reduces the complexity. In continuing the evolution, the system evolves, increasing its complexity up to the next self-organisation process;
- *limited decomposability*. The dynamic structure is studied as a whole. It is difficult, if not impossible, to study its properties by decomposing it into functionally stable parts. Its permanent interaction with the environment and its properties of self-organisation allow it to functionally restructure itself;
- *self-similarity*. It implies that the system considered will look like itself on a different scale, if magnified or made smaller in a suitable way. The self-similarity is evidence of a possible internal complex dynamic. The system is at a critical state between chaos and order, a condition that has been also called a self-organised critical state. A self-similar object, described by parameters N and z, has a power-law relationship between them: $N = z^k$. The best known of these laws is the rank-size rule which describes objects as varied as population in cities, word frequencies, and incomes. A power-law means that there is no ‘normal’ or ‘typical’ event, and that there is no qualitative difference between the larger and smaller fluctuations.

Examples of CAS include the patterns of birds in flight or the interactions of various life forms in an ecosystem, the behaviour of consumers in a retail environment, people and groups in a community, the economy, the stock market, the weather, earthquakes, traffic jams, the immune system, river networks, zebra stripes, sea-shell patterns, and many others.

Complexity is a multidisciplinary concept derived from mathematics and physics that has been applied to the world of economics. As Saari (1995: 222) writes, “even the simple models from introductory economics can exhibit dynamical behavior far more complex than anything found in classical physics or biology."

Arthur et al. (1997: 4) quoted a number of features of an economy that present difficulties for the 'linear' mathematics usually employed in economics:

- *Dispersed Interaction:* what happens in the economy is determined by the interaction of many dispersed, possibly heterogeneous, agents acting in parallel. The action of any given agent depends upon the anticipated actions of a limited number of other agents and on the aggregate state these agents co-create.
- *No Global Controller:* no global entity controls interactions. Instead, controls are provided by mechanisms of competition and coordination between agents. Economic actions are mediated by legal institutions, assigned roles, and shifting associations. Nor is there a universal competitor—a single agent that can exploit all opportunities in the economy.
- *Cross-cutting Hierarchical Organization*: the economy has many levels of organization and interaction. Units at any given level—behaviors, actions, strategies, products—typically serve as 'building blocks' for constructing units at the next higher level. The overall organization is more than hierarchical, with many sorts of tangling interactions (associations, channels of communication) across levels.
- *Continual Adaptation Behaviors:* actions, strategies, and products are revised continually as the individual agents accumulate experience—the system constantly adapts.
- *Perpetual Novelty:* niches are continually created by new markets, new technologies, new behaviors, new institutions. The very act of filling a niche may provide new niches. The result is ongoing, perpetual novelty.
- *Out-of-Equilibrium Dynamics*: because new niches, new potentials, new possibilities, are continually created, the economy operates far from any optimum or global equilibrium. Improvements are always possible and indeed occur regularly.

Always W. Brian Arthur wrote in 1999 about complexity and the economy:

“After two centuries of studying equilibria—static patterns that call for no further behavioral adjustments— economists are beginning to study the general emergence of structures and the unfolding of patterns in the economy. When viewed in out-of-equilibrium formation, economic patterns sometimes fall into the simple homogeneous equilibria of standard economics. More often they are ever changing, showing perpetually novel behavior and emergent phenomena. Complexity therefore portrays the economy not as deterministic, predictable, and mechanistic but as process dependent, organic, and always evolving”. (Arthur, 1999).

The supply chains of food products being a complex set of economic activities involving companies producing and processing foods as well as companies providing services, and therefore very different business from each other, share many of these characteristics.

5 Network Theory

5.1 Brief history of Network Theory and evolution of fields of application

A number of tools have been developed in recent years to try to best describe a complex systems. Many of them come from the work of scientists of the 19th century, but only modern computers have made it possible to make complicated calculations taking advantage of work done by scientists of the past.

One of these tools, according to the review made by Amaral and Ottino in 2004 is identified in Network Theory.

Most complex systems can be described as networks of interacting elements. Irrespective of the individual characteristics of each element, interactions lead to global behaviours that are not observable at the level of each of them. The collective properties of dynamic complex systems composed of many interconnected elements are influenced by its topology namely by the structure assumed by the relationships between elements.

As Havlin et al. (2012) write, within the span of a decade, network theory has become one of the most visible theoretical frameworks that can be applied to the description, analysis, understanding, design and repair of complex systems and in particular in strongly coupled multi-level complex systems.

Complex networks occur everywhere, in man-made systems and in human social systems. We may recall examples in cellular and molecular structures, climate networks, communication and infrastructure networks, but also social and economic networks. They have been used to understand and explain structure and dynamics of complex phenomena, and study solutions to crises, about epidemic spreading, immunization strategies, social percolation and opinion dynamics, citation networks, structure of financial markets, structure of mobile communication network, networks of all types of transports and many others. Network science has hugely evolved in the past fifteen years, with an explosion of interest in network research, becoming at present a leading scientific field in the description of complex systems, which affects every aspect of our daily life.

"An understanding of the growth, structure, dynamics, and functioning of these networks and their mutual interrelationships is essential in order to find precursors of changes, to make the systems resilient against failures, to protect them against external attacks or, as in the case of terroristic networks and misleading social manipulation strategies, to be able to fight them in the most efficient way, while supporting objective public information and opinion formation. The interrelationship between structure (topology) and dynamics, function and task performance in complex systems represents the focus of many studies in different fields of research with important scientific and technological applications. Because of their enormous potential to represent the intricate topology of numerous systems in nature, complex networks have recently been used as a framework to describe the behavior of physical, chemical, biological, technological and social networks. As such, and taking into account the multitude of disciplines in which network science is needed, such research requires intimate interdisciplinary cooperation." (Havlin et al. 2012, p. 2).

"Social network theory provides an answer to a question that has preoccupied social philosophy since the time of Plato, namely, the problem of social order: how autonomous individuals can combine to create enduring, functioning societies." (Borgatti et al. 2009, p. 3). Between 1940 and 1950 the research on social networks made progress on several fronts: the use of matrix algebra and graph theory to formalize some basic concepts of sociology, and later the development of a program of laboratory experimentation on networks. Researchers at the Group Networks Laboratory at the Massachusetts Institute of Technology (MIT) began studying the effects of different communication network structures on the speed and accuracy with which a group could solve problems. They found that in decentralized networks, such as a series of nodes connected in a circle, no one acts as an integrator of information. Although the appearance of the circle structure could have the shortest problem solving time, actually the trend in social networks is that the decentralized nodes send information to a central node, which shall decide which is the correct answer and send it back to other nodes. The work done by Bavelas and his colleagues at MIT captured the imagination of researchers in a number of fields, including psychology, political science, and economics.

Always about social and communication studies, in the 70s Stanley Milgram tested empirically on the population of those time of the United States a question raised previously (in 1950s) by other two researchers tackling what is known today as the "small world" problem. Basing their hypothesis on mathematical models, they posed a question: If two persons are selected at random from a population, what are the chances that they would know each other, and, more generally, how long a chain of acquaintanceship would be required to link them? In the 70s Stanley Milgram tested their propositions empirically, leading to the now popular notion of “six degrees of separation”.

In those years, scholars were dedicated to the study of the change of the social fabric of the city. It was the period of urbanization and the general belief was that urbanization was responsible for the destruction of communities. Representation and analysis of community network structure remains at the forefront of network research in the social sciences today. Interest is even growing, given that this type of analysis reveals characteristics and dynamics of virtual communities supported by social networks like Facebook, Instagram, Twitter, LinkedIn or Google Scholars.

Due to the fact that in the ‘70s the main interest of the research in network structures was the social sciences Lorrain and White studied the ways of building reduced models of the complex algebras created when all possible compositions of a set of relations were constructed.

“By collapsing together nodes that were structurally equivalent—i.e., those that had similar incoming and outgoing ties—they could form a new network (a reduced model) in which the nodes consisted of structural positions rather than individuals.” (Borgatti et al. 2009, p.4).

This technique of "collapsing together" structurally equivalent entities to derive nodes representing structural positions rather than individuals, is the same used in designing the model Eva.CAN.

“This idea mapped well with the anthropologists’ view of social structure as a network of roles rather than individuals, and was broadly applicable to the analysis of roles in other settings, such as the structure of the U.S. economy. It was also noted that structurally equivalent individuals faced similar social environments and therefore could be expected to develop similar responses, such as similar attitudes or behaviors." (Borgatti et al. 2009, p. 4).

By the 1980s, social network analysis had become an established field within the social sciences, with a professional organization (INSNA, International Network for Social Network Analysis), an annual conference (Sunbelt), specialized software (e.g., UCINET), and its own journal (Social Networks). In the 1990s, network analysis multiplied and diversified enormously its fields of application. Much progress has been made and great successes have been achieved with the application in areas such as transports, economics, management consulting, public health, solutions to critical situations already existing systems (in all areas) and crime / war fighting.

In management consulting, network analysis is often applied in the context of knowledge management. The goal is to indicate to organizations how to make better use of information, knowledge and skills distributed through its members. (see Cross, R et al. 2002).

This, having an accurate mapping of the supply chains would be possible also in an agri-food system, both in a general context, that is, macroeconomic, and within a single company.

In the field of public health, network approaches have been important in human medicine but also in veterinary medicine both in stopping the spread of infectious diseases by acting directly on the strategic nodes of the network, both in making predictions about the diffusive dynamics in order to implement extraordinary measures and in providing better health and social care support. (see Bigras-Poulin et al. 2006; Lentz et al. 2016).

"Of all the applied fields, national security is probably the area that has most embraced social network analysis. Crime-fighters, particularly those fighting organized crime, have used a network perspective for many years, covering walls with huge maps showing links between "persons of interest." This network approach is often credited with contributing to the capture of Saddam Hussein. In addition, terrorist groups are widely seen as networks rather than organizations, fueling research on how to disrupt functioning networks. At the same time, it is often asserted that it takes a network to fight a network, sparking military experiments with decentralized units." (Borgatti et al. 2009, p. 4).

This statement by Borgatti et al. on how network analysis has been used in the fight against terrorism confirms once again the validity of this type of analysis as a study tool for the realization of an effective strategic plan.

Obviously, the progress that has been made in the application of network theory have been achieved for some sort of parallelism, borrowing and collaboration between disciplines. What in an area, such as physics, was discovered and established, it was used in parallel even in biology, or sociology or other fields. This is because, physicists and mathematicians, being more interested in the properties of the networks as a whole and not just the properties of individual nodes, they immediately tried to categorize networks in various typologies depending on their properties, coming for example to determine that the Random Networks have different properties from real-world networks. In 1999 Barabasi and Albert published an article on Science in which they explained the differences between the Random and the Scale Free Networks (the ones of the real world) after having analyzed the properties of real-world networks through a very precise mapping of various existing systems and having found common features. (see Barabasi & Albert, 1999, "Emergence of Scaling in Random Networks"). Through a precise mapping of many real-world networks, studying the properties of these networks and making global measurements on their structure, finding always the same features they have been able to say that these networks show the same global features and they all behave in the same way regardless of the characteristics of individual nodes.

Studying the structure of a system has become an important step in the field of the social network analysis, in which now the concept that the structure matters is a fundamental axiom, as it is for example in the chemistry for the isomers. For example, teams with the same composition of member skills can perform very differently depending on the patterns of relationships among the members. (Borgatti et al. 2009).

Mutualism between different disciplines in the field of network analysis has the sense of being able to share and use each in his own context the established principles of the theory. Social scientists have been more concerned than the physical scientists with the individual node than with the network as a whole. This focus on node-level outcomes is probably driven to at least some extent by the fact that traditional social science theories have focused largely on the individual. “At the node level of analysis, the most widely studied concept is centrality—a family of node level properties relating to the structural importance or prominence of a node in the network. For example, one type of centrality is Freeman’s betweenness, which captures the property of frequently lying along the shortest paths between pairs of nodes (Freeman 1977). This is often interpreted in terms of the potential power that an actor might wield due to the ability to slow down flows or to distort what is passed along in such a way as to serve the actor’s interests. For example, Padgett and Ansell analyzed historical data on marriages and financial transactions of the powerful Medici family in 15th-century Florence. The same example is reported by Jackson on his book "Social and Economic Networks" (2008, p. 19 – 21). The study suggested that the Medici’s rise to power was a function of their position of high betweenness within the network, which allowed them to broker business deals and serve as a crucial hub for communication and political decision-making.

This is the study done on the achieving of power by the Medici in Florence. In fact the question of the "centrality" has different assessment parameters. As I will say later, there are various measures of centrality that assess different types of centrality. As the same Freeman observes in his article "Centrality in Social Networks. Conceptual Clarification" (1978/79): “In effect, these three kinds of centrality imply three competing “theories” of how centrality might affect group processes. If it is proposed that perceived leadership, for example, depends on centrality, we are now obligated to specify whether we mean centrality as control, centrality as independence, or centrality as activity. Any one or any combination of these three kinds of centrality might be appropriate in a given application". He meant in fact that the Degree centrality measures the activity or communication activities, the Betweenness centrality measures the potential for control of communication, and the Closeness is an indication either of independence or efficiency (p. 23 – 24). Also the fact that there are several evaluation parameters of the centrality in a network often leads to the result that is not a single node that governs and conditions all the others, but maybe a group of network nodes conditioning for one reason or the other the whole system.

5.2 Models of network structure: from Graph Theory to the New Science of Networks

Mathematical models of network structures have been developed in Graph Theory. A graph is a stylized representation of a group of entities (individuals or communities) linked by relationships. The entities are called nodes or vertices. The relationships between them are called links or arcs. The relations can have a specific direction from one node to his neighbor (but not vice versa), or may not have direction. In the first case the graph is called directed. In the second case it is an undirected graph. The directed graphs allow us to track and follow in the correct direction the path of materials, information, production processes, movements by means of transport, from beginning to end. Links may be associated with numeric values called weights. They may represent monetary exchange, information exchange, distances, amounts of various kind measured in the most appropriate unit of measurement.

In recent years, many researchers have thoroughly studied some topological aspects of many types of social, natural and technological networks revealing their distinctive features (collaboration networks, networks of words, metabolic networks, proteomics, economic agents, trade networks, transports, WWW, power grids).

Graph Theory has ancient origins. Scott, Cooper and Baggio (2008) trace the birth of graph theory in “Solutio problematis ad geometriam situs pertinentis” written in 1736 by the Swiss mathematician Leonhard Euler, stating that Graph theory is one of the few areas in mathematics with a definite date of birth.

Euler proposes a mathematical formulation of the renowned Königsberg Bridge Problem:

“Is it possible to plan a walk through the town of Königsberg which crosses each of the town’s seven bridges once and only once?”

The English translation of the original Latin paper can be found in Biggs et al., 1976. Of course Euler found the solution to the question posed to him by the town's inhabitants, but “the importance of Euler’s paper for the history of mathematics does not lie, obviously, in the solution of the game. It is related to the approach taken, the one stated in the very first paragraph of the paper:

In addition to that branch of geometry which is concerned with magnitudes, and which has always received the greatest attention, there is another branch, previously almost unknown, which Leibniz first mentioned, calling it the geometry of position. This branch is concerned only with the determination of position and its properties; it does not involve measurements, nor calculations made with them. It has not yet been satisfactorily determined what kind of problems are relevant to this geometry of position, or what methods should be used in solving them. Hence, when a problem was recently mentioned, which seemed geometrical but was so constructed that it did not require the measurement of distances, nor did calculation help at all, I had no doubt that it was concerned with the geometry of position - especially as its solution involved only position, and no calculation was of any use. I have therefore decided to give here the method which I have found for solving this kind of problem, as an example of the geometry of position.

Geometria situs, as Leibniz had called it, is today known with the name of topology, and Euler’s solution is the first of this kind formally stated and solved”. (Baggio R. 2008).

[Gottfried W. Leibniz (1646-1716) used the expression *Geometria situs* in a letter to C. Huygens dated 8 September 1679. (Biggs et al., 1976: 20)].

Despite the numerous but sparse works on this topic in the second part of the 18th and in the 19th centuries (Cauchy, Kirchoff, Hamilton, Poincaré, to quote just the most famous authors), a formal setting of these theories came only exactly 200 years after the Königsberg bridges paper.

In that period there was the transition from abstraction to application. Social scientists realized that a group of individuals, a community or communities in relation with each other, could be represented by the enumeration of their mutual relations. Therefore they began using the graph theory and its methods for studies in sociology.

“Jacob L. Moreno (1934) introduced sociometry. By using a sociogram (a diagram of points and lines used to represent relations among persons) he aimed at identifying the structure of relationships around a person, group, or organisation in order to study how these configurations may affect beliefs or behaviours” (Baggio R. 2008).

Modern social network analysis which replaced the sociometry is concerned with analysis of the relationships between entities in part by using graphical methods. It deals with friendship between people (many studies in recent years on virtual relationships on social networks like Facebook or Twitter and on dissemination of information), of various kind of relations in the communities, business relations between companies and also trade agreements between nations, to give just a few examples.

In '67 Milgram published his experiments on the smallness of our world of acquaintances, it became famous the experiment that led to the phenomenon known as six degrees of separation, and in '73 Granovetter spoke of the strength of weak ties in social context.

The next extremely important progress made in the field of network theory took place between '59 and '61. Two Hungarian mathematicians, Erdös and Rényi, published three articles on a particular type of graphs, Random Graphs, which were later called ER model, by their initials.

The problem addressed was a fundamental question in the quest for understanding graphs, networks and interconnection phenomena: how these objects form, what is the connectivity strength in a random graph and how they evolve over time.

They used a statistical and probabilistic approach. Their model became a standard model and for almost 30 years the only available of this kind and able to explain many of the characteristics, not all, of the networks encountered in the real world. Many researchers used it to investigate developing it further.

In the last years of the 1990s a big propulsion to the research was provided by two main factors: a) the Internet that allowed the availability of a huge mass of data and the fast spread of research already done making them available by anyone around the world, and, b) the advances in information technology, for computing power of the machines and the rise of many specialized software in the representation and analysis of complex networks that have helped greatly to speed up any type of operation.

In 2004 Watts officially enshrines this new beginning with the name "New Science of Networks". The New Science of Networks owes a lot to three papers written between '98 and '99:

- “Collective dynamics of ‘small world’ networks”, by Watts and Strogatz (1998);
- “On power-law relationships of the internet topology” by M. Faloutsos, P. Faloutsos, and C. Faloutsos (1999);
- “Emergence of scaling in random networks” by Barabási, and Albert (1999).

These works have provided proof that the ER model was only a generic approximation and only for a particular class of networks, but many of those existing in the real world, technological networks, physical, biological, social or technological networks, showed properties of a different nature. (Baggio R. 2009).

Based on these new findings many phenomena have been modeled and have found explanation. Furthermore, new studies have greatly strengthened the idea that the collective properties of dynamic systems composed of a large number of interconnected parts are strongly influenced by the topology of the underlying network (see the reviews by Albert & Barabási, 2002; Boccaletti et al., 2006; Newman, 2003).

One more aspect of this work is also worth noting: the contributions to this new science are, probably for the first time in the history of science, truly and absolutely interdisciplinary. Physicists, mathematicians, computer scientists, biologists, economists, and sociologists are all equally contributing to the growth of the knowledge in this field. (Baggio R. 2009).

5.3 Supply Chains and Network Analysis

The networks of relationships that the food industries intertwine during the production processes are very complex. Some authors argue that supply chains should be treated as a Complex Adaptive Systems and propose to exploit concepts, tools and techniques used in the study of CAS (Complex Adaptive Systems) to characterize and model supply-chain networks. (Surana et al, 2005).

The networks of relations include not only manufacturers and processors of raw materials but also packaging companies, companies for disposal of special wastes, and trade and distribution including large-scale retail and deliveries to other companies such as the ones of the group “HO.RE.CA” (hotels, restaurants and catering). From a food chain view the relationships constitute an inter-organizational collaboration of many companies that may be completely different from each other. (Nasuelli et al. 2015).

Apart from the obvious difference between the manufacturers of raw materials, milk and meat (live animals), the companies processing raw materials and those of trade sector, even within each of these segments of the supply chain many companies very different from each other work together. For example, in the segment of processing there are real processors but also companies providing services such as packaging, and likewise in the trade segment there are very different figures, from the agents / intermediaries to the actors of the chain of supermarkets, to those of Hotel - Restaurant - Catering, to the actors recovering unsold for humanitarian purposes. Therefore in a food supply chain are involved very different companies even within the same segment of chain and some of them do not produce food but provide services, sometimes even the same service but in very different ways.

Supply Chain Analysis (SCA) and Network Analysis (NA) (Lazzarini et al., 2001) have so far been treated separately, as two different and distinct types of analysis suited to studying bonds of different nature in the context of interorganizational collaboration. SCA studies the vertically organized sequential transactions which represent the successive stages of creating value along the supply chain. NA is not particularly concerned with vertically organized links, but rather with horizontal bonds between companies belonging to particular industries or groups. The NA provides several tools for mapping the structure of inter-organizational relationships or links between different companies (De Benedictis et al., 2011; Jackson, 2008). It is based on the acknowledgment that the structure of the network constraints is formed by the actions of the network companies (Lazzarini et al.,2001).

Lazzarini et al, (2001) introduce the concept of Netchain Analysis: "…a netchain is a set of networks comprised of horizontal ties between firms within a particular industry or group, which are sequentially arranged based on vertical ties between firms in different layers. Netchain analysis interprets supply chain and network perspectives on inter- organizational collaboration with particular emphasis on the value creating and coordination mechanism sources. We posit that sources of value and coordination mechanisms correspond to particular and distinct types of interdependencies: pooled, sequential, and reciprocal. It is further argued that the recognition and accounting of these simultaneous interdependencies is crucial for a more advanced understanding of complex inter-organizational relations…".

A Netchain is a network formed by a set of networks composed of horizontal bonds between firms within a particular segment and arranged sequentially according to vertical ties between firms in different layers, or in different segments. Netchain Analysis makes explicit distinction between horizontal bonds (in the same layer) and vertical links (in different layers), mapping how agents in each layer are related to other agents and to agents in the other layers.

Some authors apply the NA in contexts that involve the supply chain (Uzzi 1997, Burt 1992; Dyer and Nobeoka 2000; Swaminathan et al., 2000), but the simultaneous assessment of vertical and horizontal relationships was not the main purpose of their study. (Lazzarini et al).

A Netchain approach could merge SCA and NA for providing information to actors in policy in food chains and the literature on supply chain management emphasizes the role of managerial discretion in coordinating the flow of products, information, and decision making in the supply chain.

Through the SCA, the manager may coordinate the supply chain in order to minimize transaction costs, optimize production flows, capture value along the supply chain. In literature on NA, inter-organizational collaboration is focusing on the development of social links in which the activities are adjusted to each other and not just planned. It supports managerial initiatives towards pursuing flexibility in positioning the company in value networks, benefitting from new information and knowledge. (Lazzarini et al. 2001).

Considering the fact that our intention was to design a model that would represent many supply chains together, and that these supply chains have points of contact because they share some interactions with common stakeholders, and in light of the observations about Netchain Analysis, we decided to design a network model.

6 Eva.CAN model:
Evaluation of **C**omplex **A**gri-food **N**etwork model

6.1 Aim of the research

The case study presented here, as being said at the beginning of this thesis in the short preface, was presented in conferences and articles.

The French agronomist Malassis (1973) defined the supply chain as the set of agents (companies and administrations) and operations (production, distribution, financing) that contribute to the formation and transfer of the product (or group of products) to the final stage of use, as well as all flows connected (Giarè F., Giuca S., "Farmers and short chain: legal profiles and socio-economic dynamics", INEA 2012, p 12).

"…while the GCC approach is centred on contributions from a distinct school of thought, the French filière approach is a loosely-knit set of studies with the common characteristic that they use the filière (or chain) of activities and exchanges as a tool and to delimit the scope of their analysis. The approach is thus less a theory than a 'meso-level' field of analysis. It is also one seen by most of its practitioners as a neutral, practical tool of analysis for use in 'down-to-earth' applied research." (Philip Raikes, Michael Friis Jensen & Stefano Ponte, "Global commodity chain analysis and the French filière approach: comparison and critique", Economy and Society, Vol 29, Issue 3, 2000, p. 13).

In this sense, we can define our model Eva.CAN a French Filiere-inspired model.

For our purposes our model is a mapping model, a graphical representation of the structure of system of food supply chains that depicts relationships among its different components, and traces flows of raw materials, processed food, information and money.

The objective of this research is to develop a model to analyze in detail the structure (actors and relationships) and the dynamics existing in the supply chains of products of animal origin by providing a mapping of the productions as complete as possible, and as representative as possible of the relationships among the players. Some authors argue that supply chains should be treated as a Complex Adaptive Systems (CAS) and propose to exploit concepts, tools and techniques used in the study of CAS to characterize and model supply-chain networks. (Surana et al, 2005).

Sharing this thought, our hypothesis is that we face a complex system, mainly characterized by the dynamic nonlinear relationships between its elements. Among the many possible methods to approach the problem, the techniques developed in the framework of network science seem to be quite suitable for the purpose.

The innovation presented in this study is to make use of a social network analysis model for evaluating the economic relationships between the actors of the supply chains of products of animal origin, which all together constitute a network.

Abbasi and Hossain (2012, pp 1 and 2) identified social network analysis (SNA) as "…the mapping and measuring of relationships and flows between nodes of social networks. SNA provides both a visual and a mathematical analysis of human-influenced relationships…Each social network can be represented as a graph made of nodes or actors (individuals, organizations, information) that are tied by one or more specific types of relations (financial exchange, trade, friends, and Web links).…Measures of SNA, such as network centrality, have the potential to unfold existing informal network patterns and behavior that are not noticed before…".

A supply chain, in fact, can be seen as a network of stakeholders involved in primary production, processing, and distributing the products. In the network actors or actions involved in these stages are the nodes that are connected to each other by some kind of business relationship. These are directed links that can carry a weight which can be valued in different ways.

The model realized is a new concept model we called **Eva.CAN** model which stands for **Eva**luation of **C**omplex **A**gri-food **N**etwork model. If we want to classify this model in a specific category, Eva.CAN is a directed weighted complex network model. The first model to combine and integrate six different supply chains of animal products, with their fresh and seasoned derived products, in a single complex network, the first model allowing the use of these methods of analysis on the network of animal productions sectors seen as a single complex system. This allows to represent the complexity of the chain network, with nodes shared by several supply chains, and also the nodes of products born in a chain and passing into another. In addition, it allows to evaluate the importance of a network node in single chain or in the entire system. This means, for nodes in common between several supply chains, to have sectoral assessments and also assessments related to the whole system, according to the double role played by that node. Eva.CAN is open to the addition of other supply chains of other products too.

Various would be the potentiality of a model of this type. It could be an interesting and new analytical tool for an observatory on products of animal origin thus becoming a strong support to decisions for policy-makers. Moreover, it can also provide the useful advices to individual actors on how to optimize their own supply chains and improve efficiency. Finally, through a full and effective enumeration and evaluation of the relationships between all the actors, a network model can be highly helpful in developing policies and tracking and traceability systems. (Clemente et al. 2015).

6.2 A Network Analytic Approach

At this point it seems useful to recall briefly the key features of a complex network.

According to Newman (2003, p. 168), "…a network is a set of items, which we will call vertices or sometimes nodes, with connections between them, called edges. Systems taking the form of networks (also called "graphs" in much of the mathematical literature) abound in the world. Examples include the Internet, the World Wide Web, social networks of acquaintance or other connections between individuals, organizational networks and networks of business relations between companies, neural networks, metabolic networks, food webs, distribution networks such as blood vessels or postal delivery routes, networks of citations between papers, and many others".

The various terms used in the definition of components of a network may differ between fields of study (Newman, 2003, p. 173). A Vertex describes the basic constituent unit of a network which is sometimes also called a site (Physics) or node (in Computer Science) or actor (Social Science). An edge describes the line that connects two Vertices. It is also known as bond (in Physics), link (in Computer Science) or tie (Social Sciences).

Nodes in a network can be single entities (people) or communities (groups of people, companies, etc.). The links represent some form of relationship (business, friendship etc.) existing between nodes. Furthermore, a link can have a specific direction from a node to its neighbor (but not vice versa), or may also have no direction. Directed links, which are sometimes called arcs, can be represented by arrows indicating the direction. A graph is directed if all of its links are directed. A model with directed graphs represents a directed complex network, and this one is our case. If the links have no direction the model will be an undirected complex networks.

Links can be associated with a weight that differentiates the different relationships (importance, cost, speed etc.).

Eva.CAN is a directed weighted complex network.

The shape of the network (its topological characteristics), as demonstrated in numerous cases (da Fontoura Costa et al., 2011, pp. 212-215; Baggio et al., 2010, pp. 819-821), offers useful insights into the structure of the system and its dynamic characteristics.

As many studies show (see e.g. the reviews contained in the books by Easley & Kleinberg, 2010, and Newman, 2010), topological characteristics play a crucial role in determining the functioning of the system under investigation. The analysis can be qualitative or quantitative, providing outcomes of different nature, but in both cases significant findings.

A complex network can be described by using a wide series of measurements that underline the different features of the system. The most important and widely used measures are reported as following (Boccaletti et al. 2006, pp. 180-185) :

- *degree*: the number of direct relations that a particular node has with others;
- *assortativity*: the correlation coefficient between the degree of a node and that of its neighbors, it shows the preference for a network's nodes to attach to others that are similar in some way;

- *closeness*: the inverse of the sum of the distances between any two nodes;
- *betweenness*: the number of times a given node is interposed on shortest path between two nodes, it allows to highlight bottlenecks in the network;
- *clustering coefficient (also termed transitivity)*: a measure of the local inhomogeneity of the density of links.

Average values and statistical distributions of these quantities, mainly that of the degrees, typically depict the global characteristics of the network, while the single nodal values (often called centrality metrics) render the role or the importance of the single elements of the network.

The following metrics are commonly used for characterizing the global properties of a network:

- *density of links*: the ratio between the number of links present in the network and the maximum possible number;
- *Gini coefficient for the degrees*: measures the inequality among the values of the link distribution (1 is maximum inequality)
- *average path length, largest minimum path (diameter)*: the average or largest series of links that connect any two nodes;
- *modularity*: the extent to which a network can be partitioned into groups of nodes that are more densely connected between them than with other parts of the network. In a socio-economic setting these can be identified as collaborative groups.

Why complex networks are suitable for representing supply chains? For several reasons:

- they allow a visual (qualitative) and a quantitative analysis both at a global (whole system) and local (individual actors) level;
- they allow highlighting possible substructures such as hierarchies or communities and measure the effects they have on the overall functioning of the system;
- they allow comparing different configurations and highlight associated advantages and disadvantages, and
- they allow performing simulations thus giving the possibility to examine how global or local modifications can affect the system, and what

configurations are the most effective with respect to some dynamic process unfolding on the network (Barrat et al. 2008, Newman 2010, pp. 589-704).

The model we propose here is a network with topological (structural) characteristics defined by the connections between the vertices, to which we assign a weight that represent the monetary value of the exchange occurring.

6.3 Methods and Materials

The case study presented here as being said at the beginning of the chapter was presented in conferences and articles.

We designed the model with the idea of representing the entire scenario of the products of animal origin. The model examines the Italian supply chains of milk and dairy products (cow, goat, sheep and buffalo milk), and beef and pork meat along with their fresh and cured derived products.

The peculiarity of the Italian food supply chains and also of some other countries, such as France, is the large number of PDO products (Protected Denomination of Origin) and PGI (Protected Geographical Indication). The products having these awards have production lines since the beginning separate from those of products that are not PDO and not PGI. For its construction the model is open to the addition of other supply chains (i.e. poultry sector). Before extending the model to other supply chains we wanted to represent the supply chains of products of animal origin more closely related. In fact the whey deriving from the production of cheese is used in the feeding of pigs.

The model takes into account some business choices such as that of the direct selling of products, as well as some aspects concerning the recovery of waste through rendering activities for the production of energy or by-products that are used in other industries.

It also considers issues currently under the spotlight for their social valence such as the recovery of the unsold for humanitarian purposes. In our model single nodes represent categories of actors in the supply chains, or activities that take place along the chains (thus a company performing different activities may be represented by different nodes).

For an initial graphical representation of the model, we used yEd Graph Editor, (available at: http://www.yworks.com/en/products/yfiles/yed/) a graphical software also providing a first qualitative assessment.

The total number of the elements is 228, the number of nodes that represent the single products is 184, linked by 491 directed relationships. The network has been assembled by taking into account the four main segments of a chain: production, processing, trade and consumption. These segments contain several sub-segments that contain the nodes of the network.

The sub-segments are useful for a graphical representation of the network, but also for the assessment of data aggregated on the basis of product typology. For example in the sub-segment that represents cheese factories there are distinct groups for PDO cheeses and cheeses which are not PDO. We must keep in mind that both organic products and PDO products have production lines distinguished from those of other products since the origin of raw materials and for animal feeding, too. In addition some products exist exclusively in PDO version. Therefore, they differ from the other both for the production methodology constrained to the production disciplinary, both for the product obtained that will be by definition different from any other. Always remaining in the segment of processing a group apart is reserved for organic products. Also for the meat supply chain certain types of products have been collected in groups. This because there is interest by some operators to know the aggregate data more than the data of the individual product.

The relationships present in the network have a precise direction from one node to the next. They trace the path followed by raw materials along each segment of the chain from production to the processing into processed or matured products, to the packaging, and after trade activities, to the consumption.

In addition to a total transformation of raw materials into a multiplicity of very different products from the original ones, each passage from one node to the next along the network is characterized by an economic transaction.

The links among the nodes of supply chains network therefore are complex relationships that can be measured (weighted) by adopting an homogeneous metric: money (Euro in our case). The resulting network is then a directed weighted network. The following figures show different views of the supply chains network.

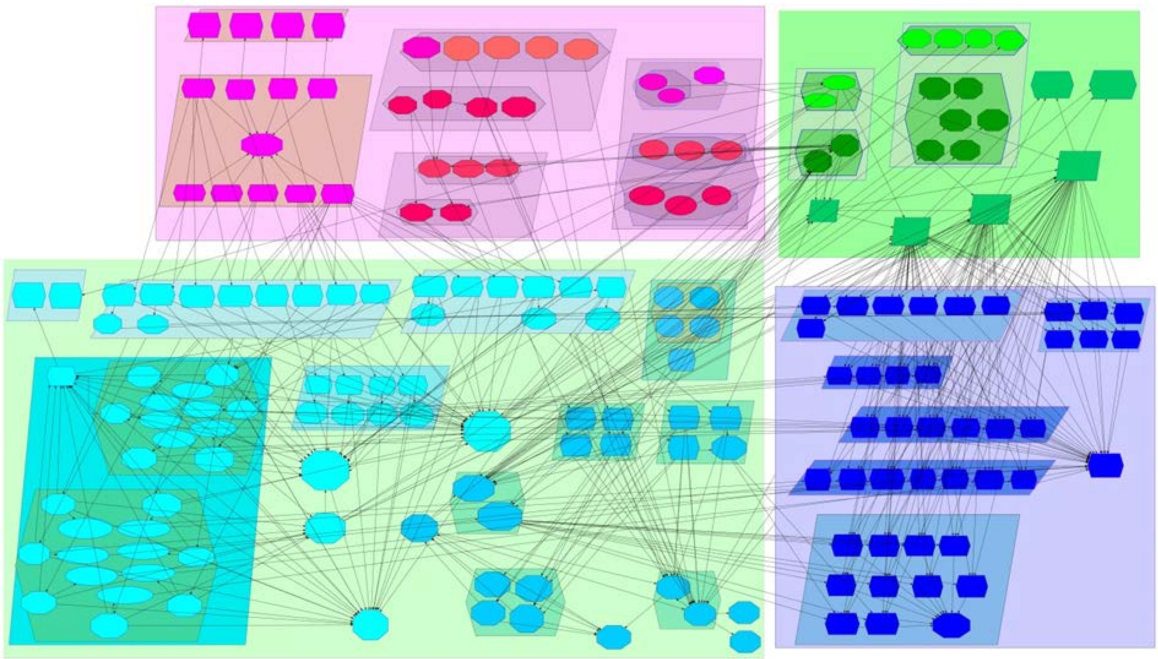

Fig. 4: The complex network model of supply chains of products of animal origin in Italy.

The four segments are represented as rectangles, within which are contained the sub-segments which are the next level of the supply chain and are represented by parallelograms. Each change of shape marks the passage from one level to the next, more specific, of the representation.

Legend for figure 4:

Different colors are used for showing the different segments of the supply chain:

- pink = production; (fuchsia: milk producers; red: live animals producers)
- turquoise = processing; (clearer: milk chain; darker: meat chain)
- green = trade; (clearer: milk import and export; darker: meat import and export; medium green: distribution on national territory)
- blue = consumption.

Geometric shapes: used to distinguish the level of particular described:

- rectangles = 1st level (the more generic): segments (production, processing, trade, consumption);
- parallelograms = 2nd level (grouping large groups of products in the same category): sub-segments;
- hexagons = 3rd level (grouping most specific): for example products which differ in the fact of having a production protocol;
- octagons = 4th level: individual nodes;
- ellipses = 5th level: represent companies that make direct sales.

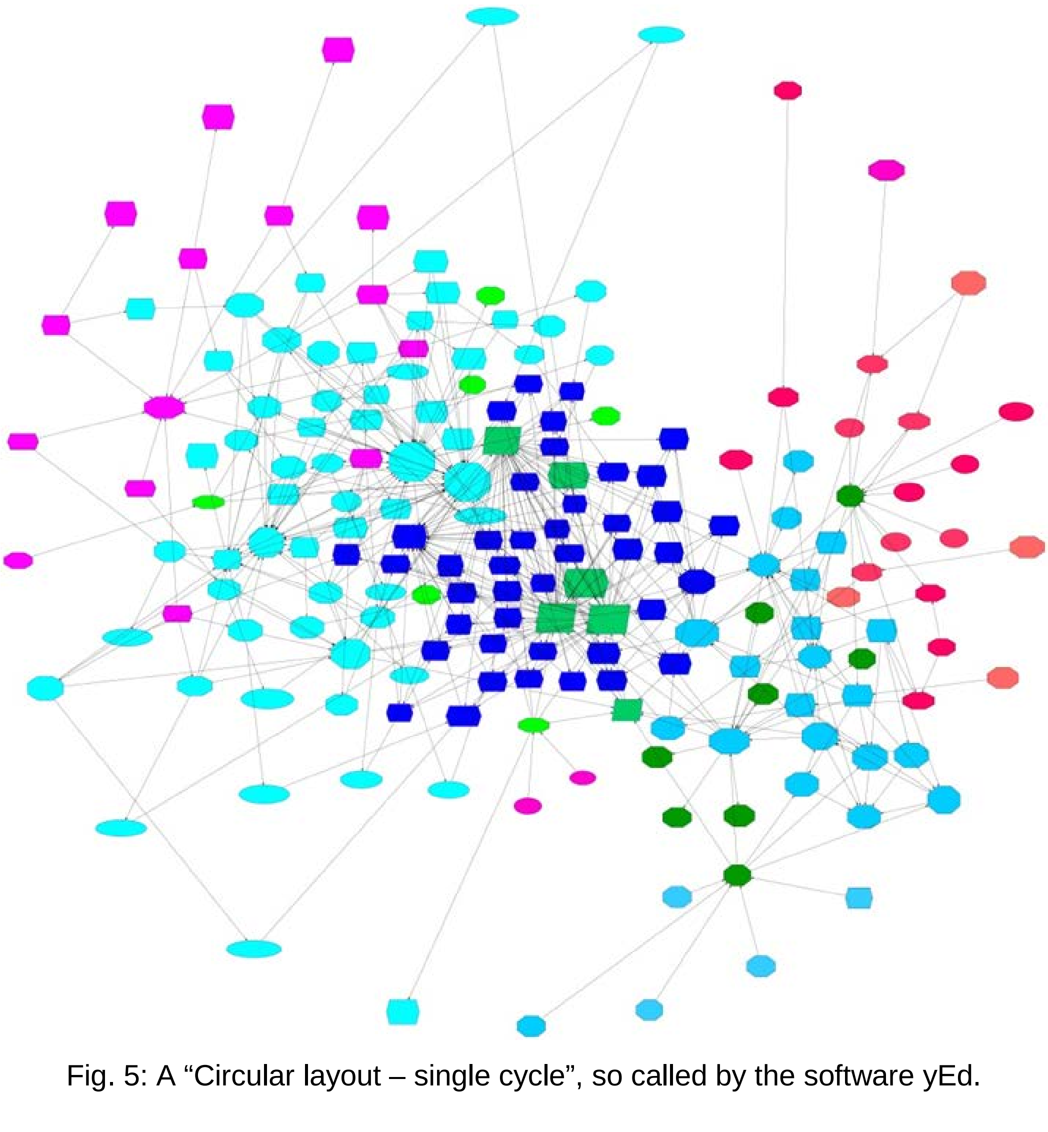

Fig. 5: A "Circular layout – single cycle", so called by the software yEd.

This figure shows the entire network in a circular arrangement of its nodes. As can be seen in the center of this layout there is the portion of nodes most tightly connected with the others, while less connected nodes remain on the edge.

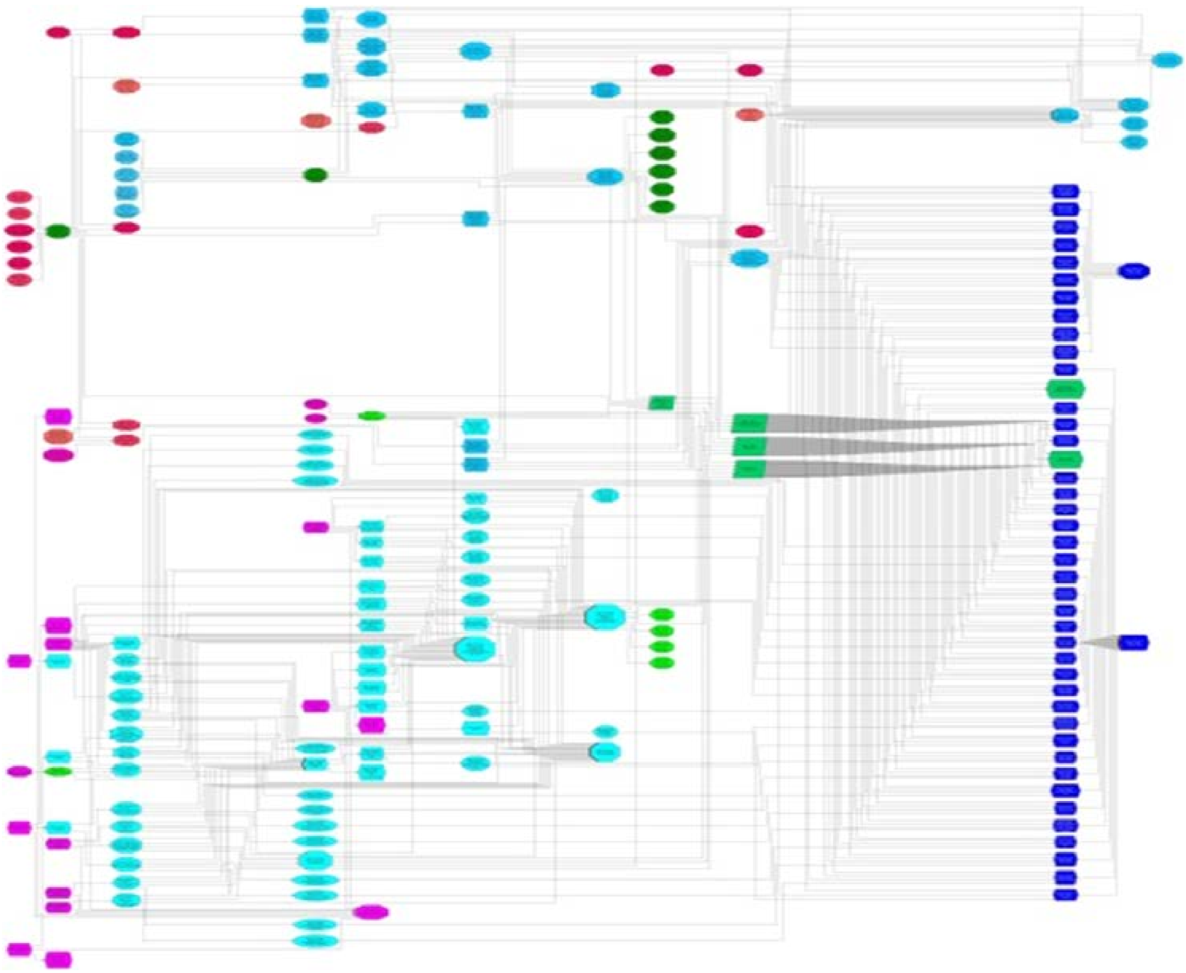

Fig. 6: Hierarchical structure layout from left to right

This layout style “flow chart” makes clear the direction of the links between a node and its neighbor and the sequence of the "key actions" taking place along the network of chains.

This is perhaps the most similar representation to the classically one is made of a supply chain. In this case, however, the model represents a supply network (not a chain) with 6 different supply chains integrated together in the nodes in common to all or to some of them. For this reason, despite being the most classic representation, it appears in any case different to what we usually see.

The nodes where entering or leaving more links (the most connected ones) are recognizable from the thicker lines of links.

This layout also retains a good level of separation between the four segments of the supply chain (production, processing, trade, consumption), as is endorsed by the 4 different colors assigned to the nodes depending on the segment to which they belong.

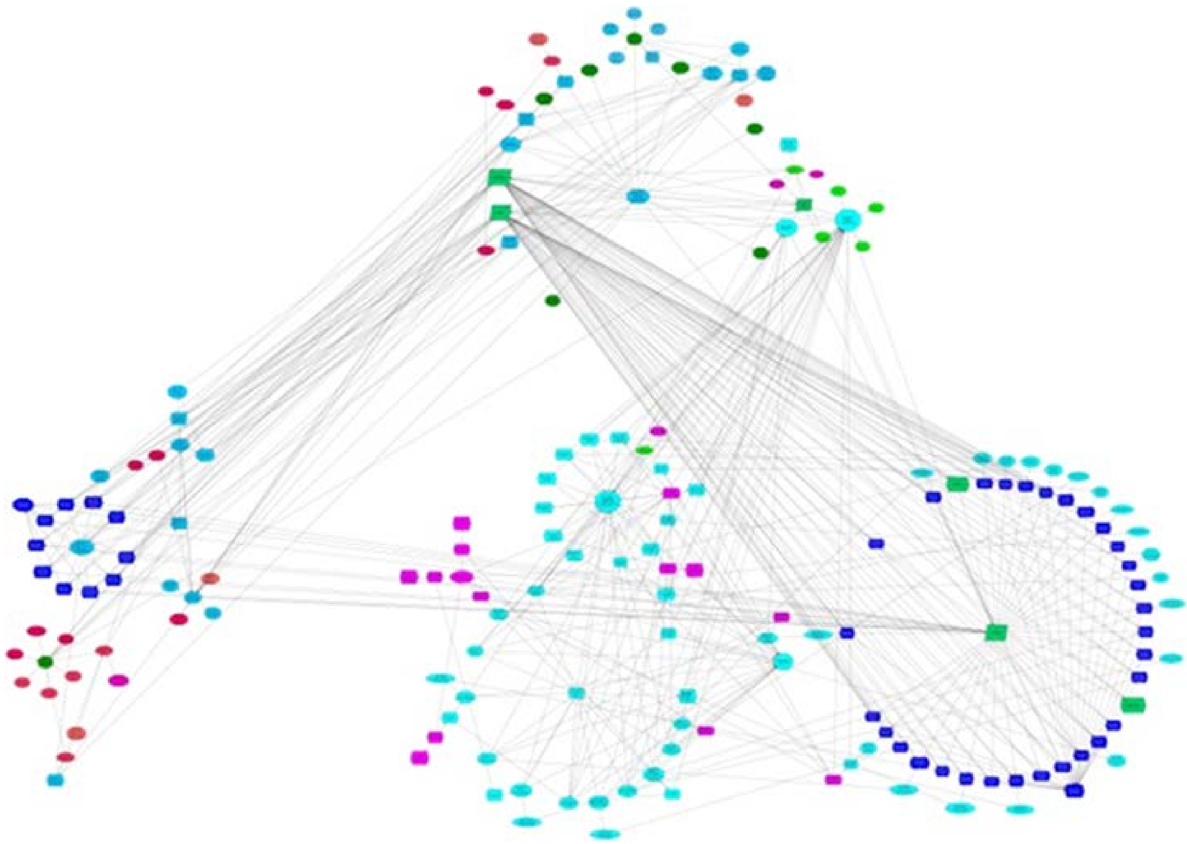

Fig. 7: Circular layout with custom groups highlighting “subnetworks”.

This "custom groups" layout allows to appreciate various network substructures, subnetworks, with one (or more) central "main" node (or nodes) of that subnet.

7 Qualitative analysis and Quantitative analysis

7.1 Qualitative analysis

The most important metrics in an economic network, with reference to the measurements we can calculate at the level of individual nodes are Degree, Betweenness and Closeness centrality measures.

Briefly recall the meaning of each of the three centrality measures evaluated, as described by Lentz H. et al. (2016):

- Degree centrality: Number of neighbors of a node. Normalized to the number of nodes in the network.
- Betweenness centrality: Frequency that a node lies on a shortest path between other nodes.
- Closeness centrality: Reciprocal average shortest path length between a node and all other nodes.

Each measure of centrality is useful depending on the circumstances and what aspect of the network and the relationships between the nodes one want to investigate (Baggio et al., 2010). For assessing economic aspects, the meaning of centrality concepts such as “popularity” has to be "translated" into its economic relevance (Boccaletti et al., 2006, pp 180-185).

Thus, summarizing and shifting in the economic sphere the meaning of these measures:

- Degree centrality, the number of direct link (in and out) of a node with the others, is a measure of the ability of communication of a node in the network (Freeman L, ‘78/’79). In our case (an economic network) this is the number of incoming and outgoing direct economic relations.
- Betweenness centrality, the number of times a given node is interposed over the shortest path between two nodes (for all the pairs of nods in the network), measures the role of crucial crossroads in the network, a

key point for the supply chain, “the potential for control of communication” (Freeman ‘78/’79), “the potential power that an actor might wield due to the ability to slow down flows or to distort what is passed along in such a way as to serve the actor’s interests” (Freeman ’77).

- Closeness centrality, the distance of a node from all the others in number of steps, gives the measurement of the capacity of a node to reach all the others in the network, “an indication either of independence or efficiency” (Freeman ‘78/’79); in economic terms this is the influence of a node over the rest of the system, the measure of its independence.

The issue of centrality is not addressed only by the science of networks and complex network models, but also from other disciplines and other models. Also the science of supply chain management addresses this question.

As reported by other sources quoted in a previous chapter of this thesis, centralization is the expression of the role played within the supply chain from a particular actor. In fact, the set of inter-relations developed inside the channel, although negotiated between a number of organizational units, is developed and managed by a guide enterprise on which all other players in the system depend.

In accordance of the position that an actor assumes in the network, its centrality is characterized by various parameters, including: a): the number of direct relationships; b): being the passing through node for many organizational entity, a high index of interposition that is to say it acts as an intermediary in the relation between the other nodes of the network; and, c): for a high index of proximity as it is able to reach the greatest number of other nodes through the shortest path. These three parameters are called Centrality Measures (Pinna, R., 2006. ”The Evolution in Organizational Dimension of Supply Chain. From the management of a flow to the management of a network”).

Their definitions match those provided by network science.

Therefore, the parameters of the evaluation of centrality are the same. Obviously, being based on 3 different characteristics, the result will be that we will have 3 different charts of which is the node, or the nodes, most important or strategic in the network, depending on the measured parameter.

The following figures (Fig. 8,9 and 10) show qualitatively how the network settles when considering these metrics. The nodes with the highest values of these three measures are shown and compared in Table 1.

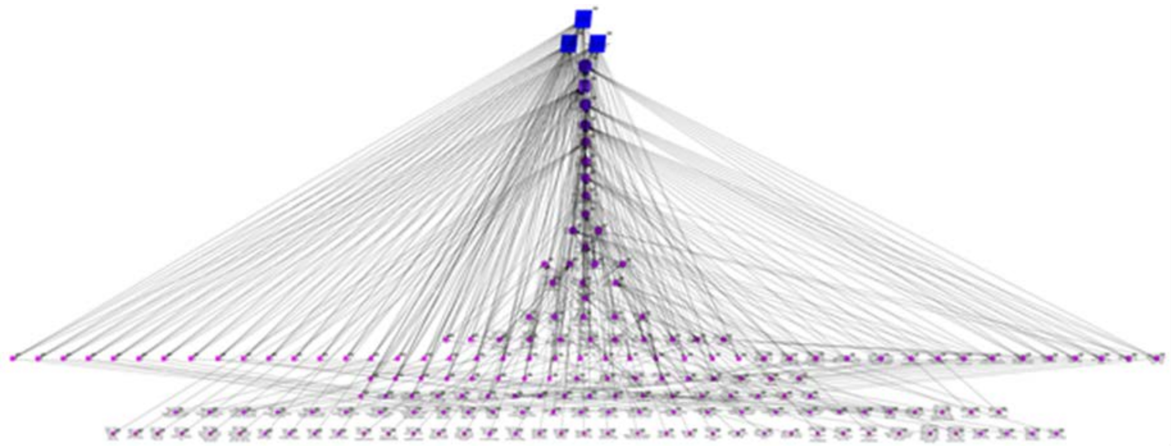

Fig. 8: Degree centrality

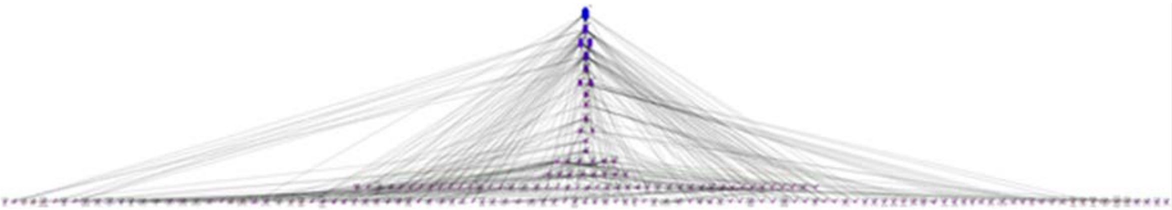

Fig. 9: Betweenness centrality

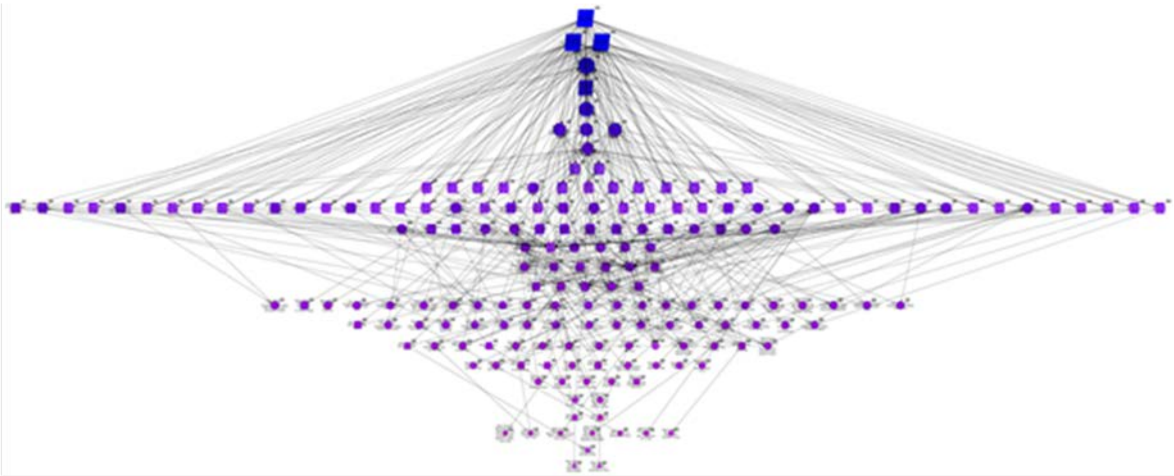

Fig. 10: Closeness centrality

As can be observed, we got 3 completely different graphics, because the scores are completely different as well as the ranking of the nodes for each measure. The figures make clear the fact that a strong hierarchy exists in the system, and that the ranking of the network nodes changes depending on the measure of centrality used. Some nodes are placed in the top positions of the network as seen in all the figures. They belong (Table 1) to the segment of Trade (supermarket chain, hotel-restaurant-catering companies commonly called HO.RE.CA., and the retail sales), and to the segment Processing such as packaging and sales through traditional channels (therefore no direct sales). In must be noted, however, that in this first qualitative inspection, weights are not considered and therefore the figures are based only on the number and arrangement of the links existing in the network.

Ranking	Degree Centrality	Betweenness Centrality	Closeness Centrality
1	Segm. Traders, Retail Sales: 1.00	Segm. Processors, Milk S. C., Packaging and Selling through Conventional channels: 1.00	Segm. Traders, Retail Sales: 1.00
2	Segm. Traders, a)HO.RE.CA.; b)Supermarket chain: 0.98	Segm. Traders, Retail Sales: 0.61	Segm. Traders, a)Supermarket Chain; b)HO.RE.CA.: 0.99
3	Segm. Processors, Milk Supply Chain, Packaging & Selling trough Conventional channels: 0.69	Segm. Traders, a)HO.RE.CA.; b)Intermediaries/ Agents: 0.60	Segm. Processors, Milk S. C., Packaging and Selling through Conventional Channels: 0.92
4	Segm. Consumers, Milk Supply Chain, Losses and Waste: 0.62	Segm. Traders, Supermarket Chains: 0.59	Segm. Traders, Intermediaries/Agents: 0.89
5	Segm. Processors, Milk Supply Chain, Conversion into processed products (ice cream, desserts, gelled milk, other): 0.54	Segm. Processors, Meat S.C., Packaging and Selling through Conventional Cahnnels for Meat of all the types: 0.42	Segm. Processors, Dairy S. C., Cheese Maturers: 0.85

Table 1: Ranking of the first 5 position for Centrality Measures – Qualitative analysis with yEd

7.2 Quantitative analysis

The quantitative analysis of a complex network model of supply chain requires the availability of data of the supply chain of a company, and the evaluation of the weight of all the relationships between network nodes.

Not wanting to perform a quantitative analysis of the activities of a particular company, we decided to demonstrate the applicability of the quantitative analysis to the whole system of productions of animal origin as shown in Eva.CAN model, remembering that it's made of six supply chains of animal production integrated into a single network.

This has led to considerable difficulties during data collection because while any company that requires analysis is itself to provide the necessary and required data, in this case we have had to rely on a basis of official data which did not complete our needs for the analysis of the whole network. Unfortunately in the agri-food sector we do not have a publicly released complete data set and only for a part of products we have data collected by the authorities, or at least, the databases from official sources do not contain all the data that we needed. In addition, for many products such as the buffalo Mozzarella cheese, data are recorded by the relevant authorities only for the last few years. Having arrived at this point, however, an attempt to quantitative analysis must be done. How to solve this problem?

Data were collected from official sources (ISTAT) when available, or from production or processing consortia. For the nodes without official data, the amounts were estimated by resorting to an estimation using standard coefficients of transformation of raw materials into processed products. The idea is that considering the total sum of the relationships between network nodes (total amounts), the sum of the weights from official sources with those estimated should be consistent. The total sum of the relationships between the nodes of the network amounts to about 60 billion euro. This amount was obtained by computing the average over three years: between 2010 and 2012.

The choice of the nodes was performed by inserting the network nodes that represent the fundamental stages of supply chains and the most representative products of production, import, export, and of PDO products and non-PDO products of Italian supply chains. The network covers more than 99.5% of the 6 supply chains examined. In essence, the choice of the nodes to be represented has been made with the same logical methodology used by Lorrain and White (1971): collapsing together entities / representative figures that were structurally equivalent, by designing a network in which the nodes consist of structural positions, actions along the chains, rather than individuals.

To weigh the network we performed the following operations:

- collecting data of the weight of relationships in a database.
- establishing an alphanumeric code to be assigned to each node. The code allows to identify even at first sight: segment, supply chain (milk or meat), animal species;
- listing of all pairs of nodes connected in a direct way. In the current model they are 491;
- building the adjacency matrix of all the nodes.

As seen, the first step in the analysis was performed inspecting visually the graphics. As said, they provide only a visual representation, but does not allow calculating the whole series of measures characterizing the network.

Therefore, as further step, more accurate and precise measurement of the network and its features was accomplished by using the Python programming language and the NetworkX library (available at: https://networkx.lanl.gov/) specialized in network analysis measurements. In this second phase we used for the graphic network display a specialized software for representation of complex networks, Pajek.

7.3 Outcomes of the Quantitative Analysis

Given the directed nature of the links the nodal measurements are divided into in- and out- metrics where in- refers to the connections arriving at a node and out- to those departing from a node. Moreover we compare also the unweighted and the weighted versions of the network.

The topology of the network (Fig. 11) is dominated by a relatively small number of highly connected nodes that join the rest of the less connected system.

The degree distribution is highly in-homogeneous as shown by the Lorenz curves (Fig. 12, the diagonal is the line of full equality), and follows a power law (Fig. 13).

This behavior is typical of many phenomena in the world of nature, sociology and economics, represented by networks "Scale Free". Important consequence of this is that the removal of nodes at higher connection leads to the disintegration of the network in different isolated clusters and to the increase in diameter of what remains of the network, while the removal of the less connected nodes does not have particular effects.

As to the diameter it is a measure of the efficiency of a network. Great efficiency corresponds to small diameters, and then to a compact size.

The different individual (nodal) measurements allowed identifying the most central actors as well as those whose position is critical for the connectedness of the whole system, and those whose neighborhood is of particular value.

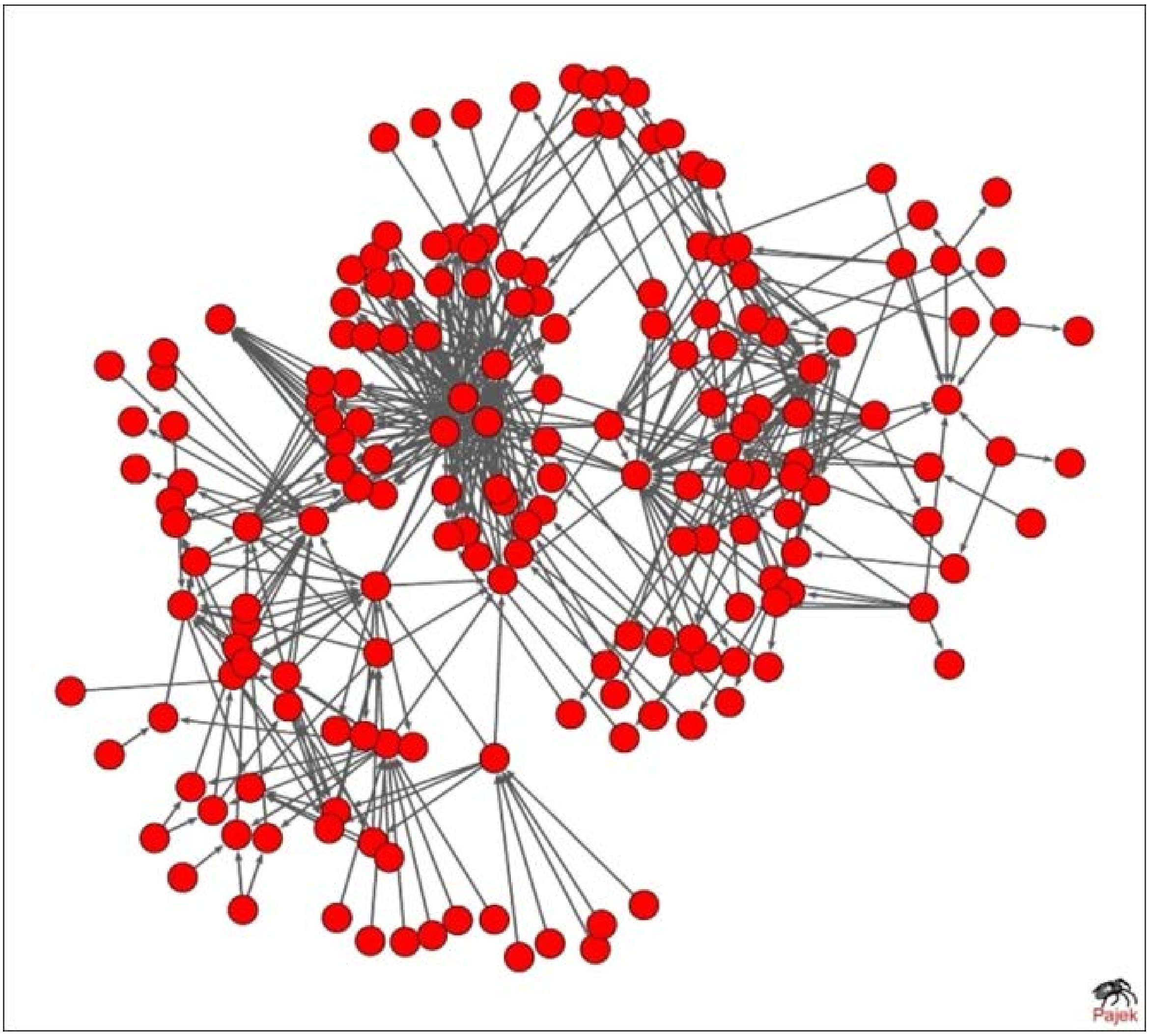

Fig. 11: The topology of the network. Representation made by Pajek.

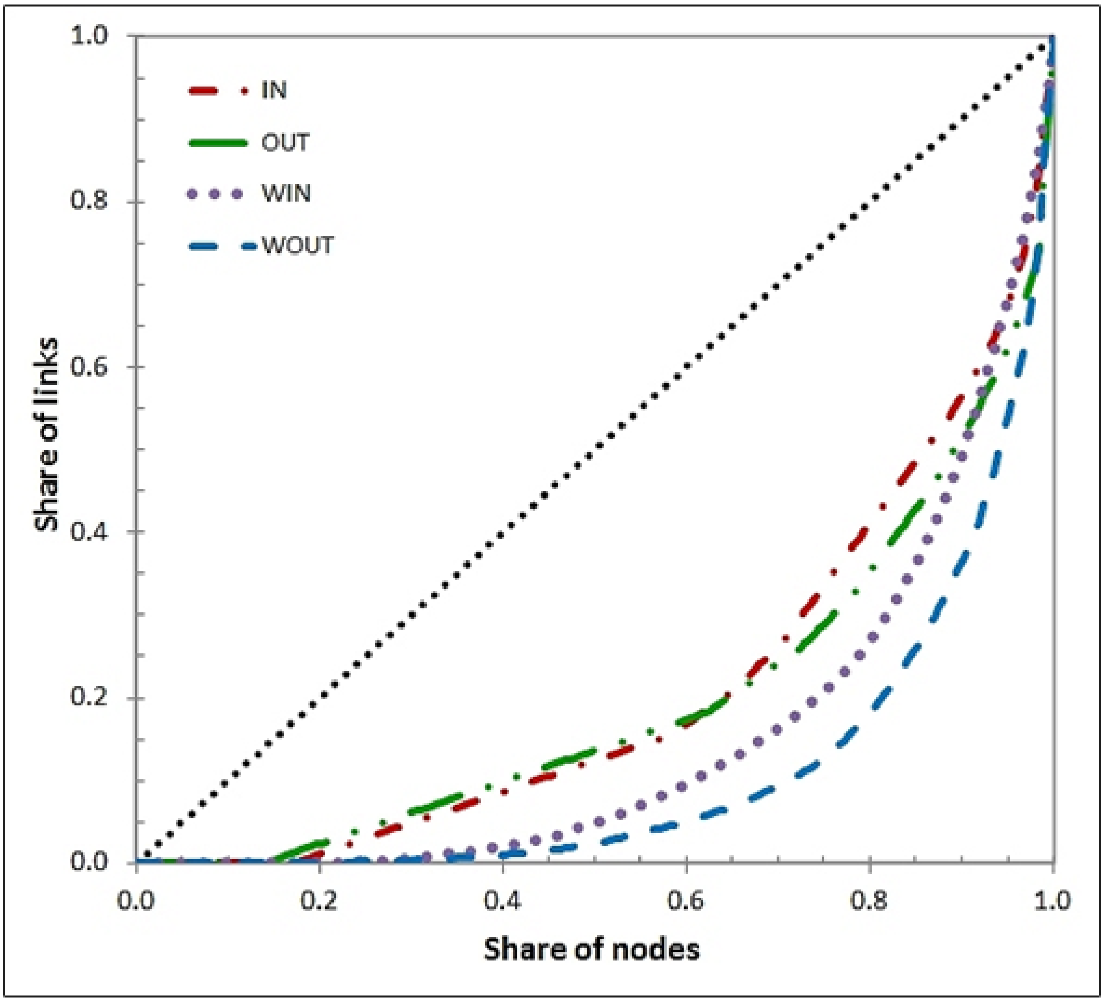

Fig.12: Lorenz curve for the network degrees. Weighted versions of the curve signaled by a W.

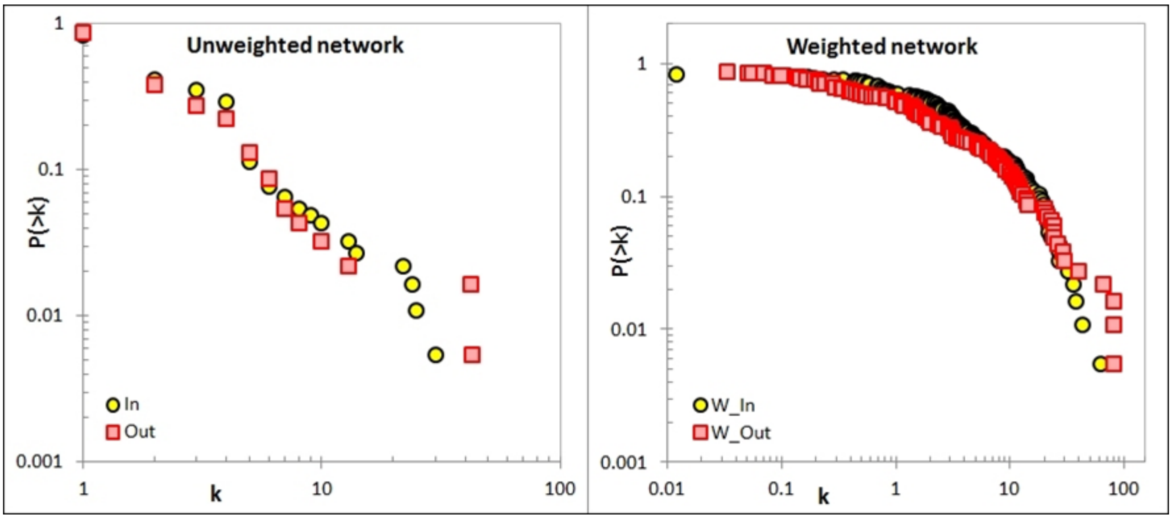

Fig. 13: Degree distribution in the unweighted network and in the weighted network

Tables 2 and 3 show the main quantities calculated for the supply chain network.

Measurements	Unweighted network	Weighted network
Node count	184	184
Link count	491	---
Sum weights	491	997,85
Density	0,015	---
Average path length	0,545	1,576
Diameter	7	21,256
Average transitivity	0,015	
Modularity (infomap)	0,553	0,562
Degree Gini coefficient	in: 0.582	in: 0.695
	out:0.603	out: 0.779

Table 2: main metrics of the whole network

Node Levels Measures	**Unweighted network**			**Weighted network**		
	min	max	mean	min	max	mean
In-Degree	1.000	30.000	3.209	0.000	61.460	5.423
Out-Degree	1.000	43.000	3.088	0.000	80.215	5.423
Betweenness	0.000	0.057	0.003	0.000	0.053	0.002
Closeness	0.002	0.147	0.038	0.147	0.033	0.029
Min. Path	1.000	1.000	1.000	0.000	21.256	0.921
Transitivity (symmetric)	0.004	1.000	0.206	0.000	1.000	0.070

Table 3: Node Levels Measures for the nodes in the whole network

Table 4 reports the parameters calculated for the degree and strength (weighted degrees) distributions. The parameters are the exponent (and associated statistical error) for a power-law distribution (in the following P(k) is the probability that a node has degree k):

$$P(k) \sim k^{-\alpha},$$

and mean (μ) and standard deviation (σ) for a lognormal distribution:

$$P(k) \sim (1/2\pi\sigma k)\cdot\exp(-(\ln k-\mu)^2/2\sigma^2)$$

Calculations were performed by using a maximum likelihood fit (as done in Baggio et al 2010, p.814) of the distributions as described by Clauset et al. (2009). The software used is the Python package available at: https://pypi.python.org/pypi/powerlaw.

Table 4 reports the results along with the errors calculated. Here we notice that the weighted version is better fit by a lognormal distribution, which is quite common among many real networks and is barely distinguishable from the power-law, thus assuming the same meaning for all practical purposes (Mitzenmacher, 2004, p. 244).

	Type	Measures	In	Out
Degree distribution	power-law	α	4.25	3.44
		error	0.44	0.38
Strength distribution	lognormal	μ	-2.07	1.09
		σ	1.38	1.39

Table 4: Degree distributions parameters

A modularity analysis was performed on the network by using the Infomap algorithm (Fortunato, 2010) which is particularly suitable in the case (like ours) of weighted directed networks. Here the modules are identified as groups of nodes more strongly connected between them than to other parts of the network. The property is then measured by a modularity coefficient which shows how well "separated" are the modules identified (the coefficient ranges from 0 to 1, where 1 is the case of completely separated modules).

In this network we found 19 clusters, some consisted of high number of nodes (46 nodes), while others composed of few or very few nodes. The 4 larger groups contain respectively 46, 46, 20 and 17 nodes for the weighted network.

When looking at which nodes belong to which cluster we noticed that they do not depend on the segment of the supply chain, nor the type of chain (dairy or meat), not even to a possible distinction in PDO or products which are not PDO. The full list of the nodes that constitute the different clusters, detailed analysis and commentary on the composition of the clusters will be subject to a future next research: as mentioned at the beginning of this paragraph this is only a preliminary quantitative analysis, but nevertheless we want to give some broad indication also about this part of quantitative analysis.

One of the two largest groups (46 nodes each) consists largely of milk and meat producers of raw materials (milk and live animals), and then of processors, traders and consumers of fresh meat and cured meat products. In this cluster there are nodes of the milk and of the meat supply chain in much the same number.

The 2nd group is composed mainly of consumers of milk and dairy products, of many of the cheeses (both PDO cheeses and non-PDO cheeses), the relative processors operating direct sales of these products, and traders of milk and dairy products. Only 3 nodes belong to the segment producers of raw materials, 2 nodes to milk producers and one node belongs to the producers of live animals (breeders animals for meat).

The 3rd and 4th group (20 and 17 nodes respectively) are composed primarily of producers, processors and consumers mainly from meat and meat products chain, both fresh cuts and cured products. A lower number of nodes belongs to the milk chain.

The smaller clusters put together producers of raw materials (milk and dairy products, and of live animals), processors and consumers, but of course being composed only by few nodes theese small clusters are certainly not the most appropriate to try to understand what is the criterion by which clusters are composed.

The general suggestions regarding these first results say that the composition of the clusters does not follow, if not in part in the major clusters, the division between the milk and the meat supply chain, nor the logic of the separation of a precise type of products, for example PDO products, or the organic ones, from others. Another highlight is that the clusters which result effective from this mathematical analysis do not match those decided during the planning of the model for the classification requirements of the nodes according to certain categories and for representative need.

Two pictures of the modularized networks are shown in Fig. 14 and 15. The diversity of elements making a single module is evident by the different colors. Two different arrangements of the formation and composition of the clusters are shown because different layouts allow to appreciate different features. In this case, in the second figure it is easier to see thanks to the differences of colors to which segment of the supply chain or type of chain (milk or meat) cluster nodes belong.

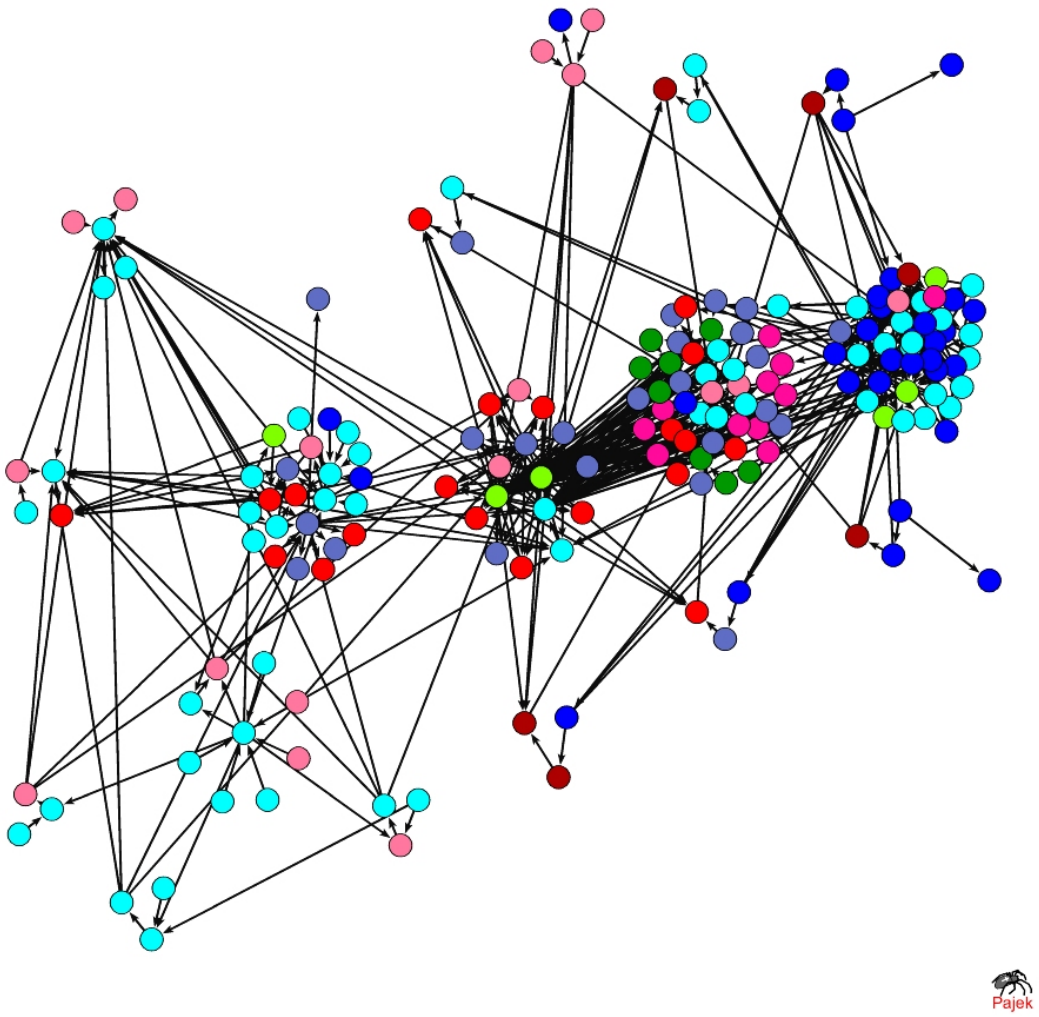

Fig. 14: Weighted network modules and clusters composition: layout grouping the clusters

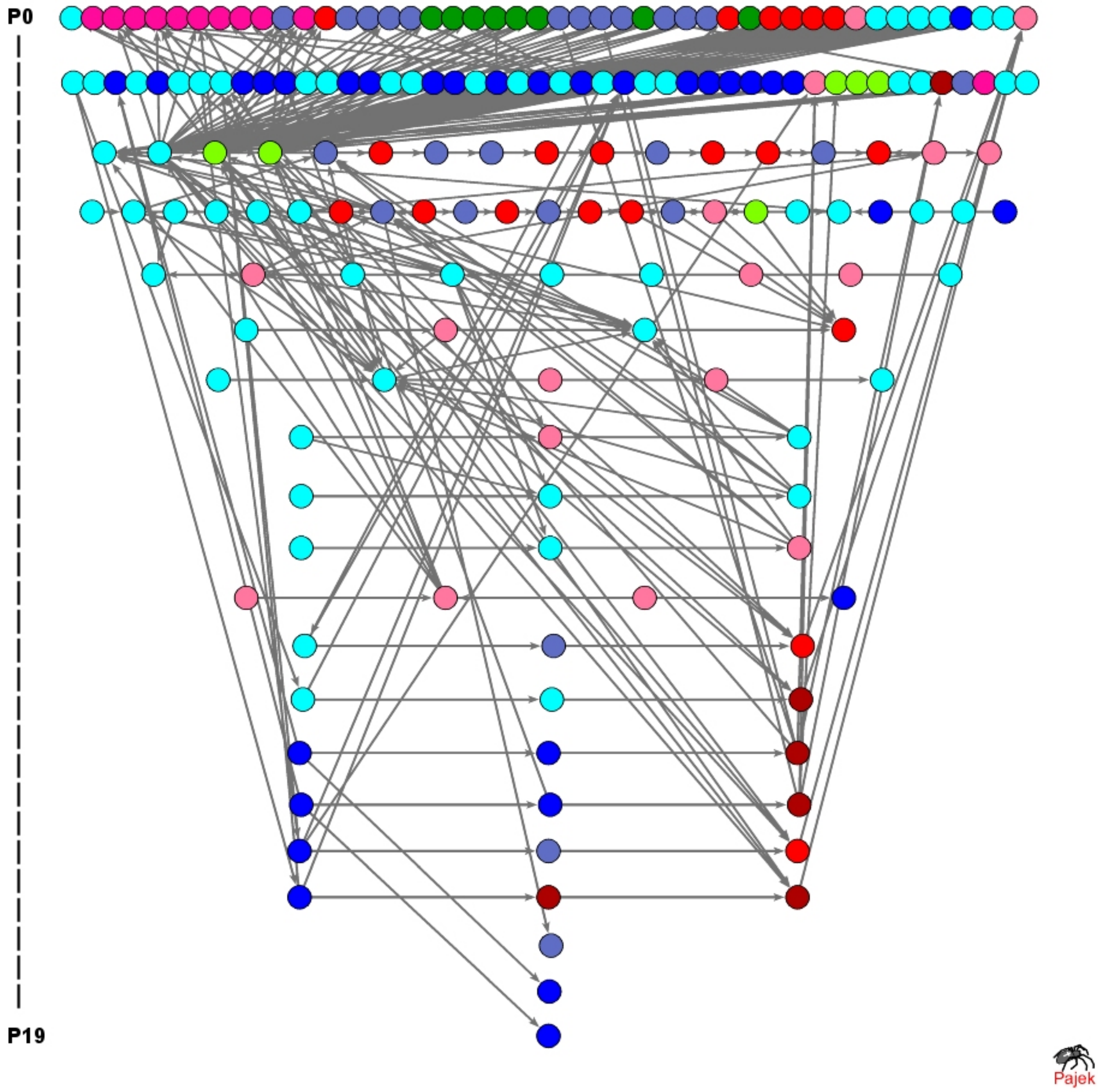

Fig. 15: Weighted network modules and clusters composition: linear layout of the clusters

The important conclusion here is that, contrary to some common intuitive belief, the network self-organizes in collaborative groups that are composed of actors belonging to different types. Thus the results suggest that the topology generated by the system of connections between the different organizations in the supply chains goes beyond predetermined differentiations and provide indications that in order to optimize some performance, for example optimal communication channels or even productivity in collaborations, policy makers should take into account the spontaneous characteristics of the complex system, and embrace the ideas and practices of an adaptive approach to the management of supply chains. Otherwise, the dynamic characteristics of this complex system risk preventing an effective and efficient application of policy measures.

7.4 Individual nodes: ranking

The ranking of individual nodes for centrality measures which we consider most important: degree (in and out) and betweenness, in the qualitative analysis (unweighted network) do not perfectly match those derived in the quantitative analysis. However, we can see that although the precise ranking is not exactly the equivalent, the group of nodes to be considered "strategic" is practically the same. The weights, in fact, modify many of the metrics. The importance of each node in the weighted network no longer relies only on the number of links, but on a combination of links and weights.

The top five nodes for each measurement, for the unweighted and the weighted networks are shown in Table 5 and 6..

Briefly commenting the results it must be said that nodes losses / waste in the first places in the ranking of the unweighted network in-degrees fortunately disappear in the top ranked nodes of the weighted network.

It can be noted further the importance in every measure in the weighted network of many nodes of processors segment, especially packaging, but also maturers for cheeses, and hams and sausages.

Moreover, many nodes of trade segment rank top in all measurements.

The only PDO product with a high in-degree rank is PDO ham.

We remember that it is still a first preliminary quantitative analysis.

Ranking Nodes measurements Unweighted Network			
InDegree	1	Segment Consumers, Dairy Supply Chain, Losses and waste	30.000
	2	Segment Processors, Dairy Supply Chain, Packaging and Selling through conventional channels	25.000
	3	Segment Processors, Dairy Supply Chain, Conversion into Processed products (ice cream, desserts, gelled milk, other products)	24.000
	4	Segment Processors, Dairy Supply Chain, Losses and waste	22.000
	5	Segment Processors, Meat Supply Chain, Slaughterhouse waste destined for Rendering	14.000
OutDegree	1	Segment Trade (Dairy&Meat), Retail Sales	43.000
	2	a) Segment Trade (Dairy&Meat), HO.RE.CA.; b) Segm. Trade (Dairy&Meat), Supermarket Chains	42.000
	3	Segment Producers, Dairy Supply Chain, Cow Milk for Processing	13.000
	4	a) Segment Processors, Meat Supply Chain, Packaging and Selling through conventional channels for meat of all the types; b) Segm. Processors, Meat Supply Chain, Packagin and Direct Selling for Beef/Veal and all the types of Processed/Matured products	10.000
	5	Segment Processors, Dairy Supply Chain, Packaging and Selling through conventional channels	8.000
Betweenness	1	Segment Processors, Dairy Supply Chain, Packaging and Selling through conventional channels	0.057
	2	Segment Trade (Dairy&Meat), Retail Sales	0.038
	3	a) Segment Trade (Dairy&Meat), HO.RE.CA.; b) Segm. Trade (Dairy&Meat), Supermarket Chains	0.037
	4	Segment Processors, Meat Supply Chain, Packagin and Direct Selling for Beef/Veal and all the types of Processed/Matured products	0.033
	5	Segment Processors, Dairy Supply Chain, Cheese Maturers	0.018

Table 5: Ranking of nodes according to measurements on the unweighted network

Ranking Nodes measurements Weighted Network			
InDegree	1	Segment Processors, Meat Supply Chain, Packaging and Selling through conventional channels for meat of all the types	61.460
	2	Segment Processors, Dairy Supply Chain, Packaging and Selling through conventional channels	42.493
	3	Segment Consumers, Meat Supply Chain, PDO cured ham	37.415
	4	Segment Processors, Dairy Supply Chain, Cheese Maturers	36.195
	5	Segment Consumers, Meat Supply Chain, Cuts of Beef	31.866
OutDegree	1	Segment Trade (Dairy&Meat), Retail Sales	80.215
	2	Segment Trade (Dairy&Meat), Supermarket Chains	80.015
	3	Segment Trade (Dairy&Meat), HO.RE.CA	79.848
	4	Segment Trade, Meat Supply Chain, Live Animals	64.754
	5	Segment Processors, Dairy Supply Chain, Packaging and Selling through conventional channels	40.187
Betweenness	1	Segment Processors, Dairy Supply Chain, Packaging and Selling through conventional channels	0.053
	2	Segment Trade (Dairy&Meat), HO.RE.CA	0.051
	3	Segment Trade (Dairy&Meat), Retail Sales	0.031
	4	a) Segment Trade (Dairy&Meat), Supermarket Chains; b) Segm. Trade (Dairy&Meat), Intermediaries/Agents	0.026
	5	Segment Processors, Meat Supply Chain, Maturers of Meat products	0.024

Table 6: Ranking of nodes according to measurements on the weighted network

8 Conclusions

This research thesis provides here the preliminary analysis of the network built considering the Italian supply chains of products of animal origin.

The name given to this model is Eva.CAN model which stands for Complex Evaluation of Agri-food Network model. A new concept model designed as an integrated complex network of 6 Italian supply chains of products of animal origin. Eva.CAN model can also support the addition of other supply chains. This model has allowed to apply for the first time Network Science and network analysis methods to food chains and to understand the topology of the complex network they form, and how it affects the functions of the system. It also has highlighted which nodes occupy most strategic positions and what direct connections are the most convenient.

The resulting network is a directed weighted network exhibiting a skewed (i.e. shows long tails) distribution of the links following an exponential shape (power-law or lognormal), that makes it similar to many other complex natural networks, called Scale Free.

Measurements on individual network nodes show those who occupy strategic positions, with which it is convenient to be connected directly or otherwise in shortest possible paths.

The mechanism of formation of modules (clusters) provides a view into the mesoscopic structure of the network by highlighting more densely connected groups of nodes between them than with other parts of the network thus underlining the self-organization characteristics of the supply chain system, which it is also a distinctive feature of the real-world networks.

Moreover, these clusterings, which can be interpreted as collaborative groupings, can be of great importance for policy actions directed towards an optimization of the whole system and, for individual stakeholders, in order to look for possible new relationships with the aim of improving operational and strategic activities.

The logic with which the nodes come together to form clusters suggests also, at a first glance, an almost total separation of dairy supply chain and meat supply chain only in the largest groups, while maintaining some rare exceptions which will need deeper investigation. The separation does not depend on whether the products in a cluster are or not PDO products, nor the fact that they are fresh or cured, nor the fact that they are or not organic.

Actually it occurred that the really existing clusters according to this mathematical analysis does not correspond at all to the groups that had been formed in the process of designing the model for classification requirements of the nodes in certain categories or representation needs. But this means that it is not who designs the model that determines with his own design choices a composition of a cluster or another different composition. It is a confirmation once again of the capability for self organizing of the networks Scale Free, those of the real world. This could mean that probably what we would previously have considered to be clusters, ie collaborative forms, or even groups that require common policies, perhaps they are not and that the clusters are composed in a completely different way, as shown by this analysis.

This may suggest, for example, that it makes little sense to promote a policy of help for a specific product or a precise category, such as the PDO products, but that the activities have to consider the whole dairy supply chain or the whole meat chain. The topology generated by the system of connections between the different organizations in the supply chains goes beyond predetermined differentiations and seems to suggest that in order to optimize some performance, for example optimal communication channels or collaborations, policy makers should adopt an adaptive approach to the management of the whole system. Otherwise, the dynamic characteristics of this complex system risk preventing an effective and efficient application of policy measures.

As said this is a first attempt at using network analysis techniques in this field. In the context of animal production network theory has been used to assess the risk of spreading disease (Bigras-Poulin et al, 2006; Natale et al, 2009; Lentz et al. 2016) and therefore aim and research area were different. Network theory has been applied to study the formation of prices in the fish market of Marseille (Vignes et al., 2011), and also in this case the purpose was different. In addition to this, supply chains used in those cases were very general and not as punctual as in this model. About raw materials, in general, a minimum spanning tree network model was constructed and used to study the relationships and interdependencies of futures contracts for commodities for the period 1998 - 2007 (Sieczka et al, 2009).

However, it is the first time that this methodology is applied in the productions of animal origin for purposes of a different type from those of previous studies and to a model different from the existing ones.

9 Limitations and future work

As already mentioned, a major limitation in the context of the research about the products of animal origin is that there is no official and public database as complete as it should be. A lot of data about many products are collected from the relevant authority only since a few years, and, worse, many are not collected or are collected only in aggregate form with other products. Private companies clearly do not provide data to external researchers. In addition the data of a company can only serve to make an accurate analysis exclusively of that company system. The hope is that, as in other disciplines, will arrive one day a public sharing agreement by each researcher of the data at his disposal so that can be positioned the greatest number of missing pieces of the puzzle. Of course this presented here, for all the difficulties of collecting and estimation of missing data, is only a first exercise in the application of the methodology about the valuations on weighted networks. It is already planned a second phase of the research with a series of more accurate data and more accurate estimates and compared with other carried out by other methodologies.

This new model falls within the Multilayer type models, it is a network of networks. In the last few years many Multilayer and Multiplex models have been designed and studies on these types of new models have multiplied, although these studies mainly concern the transport sector. For our model we are thinking of a study in this and in other directions too that will be investigated in the future. Many more investigations are, obviously, needed before being able to make this an operational tool. Apart from the deepening of the analysis and the possible implementation of other dedicated metrics, one of the most interesting ideas is that with a model like the one presented here it will be possible to simulate different configurations and find ways to optimize the supply chain with respect to different parameters such as time, costs or other quantities of interest.

Bibliography

Abbasi, A & Hossain, L (2012), "Hybrid Centrality Measures for Binary and Weighted Networks". 3rd workshop on Complex Networks. Available at: http://works.bepress.com/alireza_abbasi/10 .

AILOG (Italian Association of Logistics and Supply Chain Management) http://www.ailog.it/pagine/logistica_e_scm-20/ (definition of "Logistics").

Albert, R & Barabási, A. L (2002), "Statistical mechanics of complex networks". Review of Modern Physics, 74, 47-91.

Amaral, L. A. N & Ottino, J. M (2004), "Complex networks - Augmenting the framework for the study of complex systems". The European Physical Journal B, 38, 147-162.

Arthur, W. B & Durlauf, S. N & Lane, D (Eds.). (1997). The Economy as an Evolving Complex System II. Reading, MA: Addison-Wesley.

Arthur, W. B (1999), "Complexity and the Economy". SCIENCE VOL 284 2 APRIL 1999.

Axelrod, R & Mitchell, W & Thomas, R. E & Bennett, D. S & Bruderer, E (1995), "Coalition formation in standard-setting alliances". Management Science(41), 1493-1508.

Baggio, R (2008), "Symptoms of complexity in a tourism system". Tourism Analysis, 13(1), 1-20.

Baggio, R (2008), "Network analysis of a tourism destination". School of Tourism, The University of Queensland, PhD thesis http://www.iby.it/turismo/phd.htm .

Baggio, R & Scott, N & Cooper, C (2010), 'Network science - a review with a focus on tourism', Annals of Tourism Research, vol. 37, no. 3, pp. 802-827.

Ball, P (2002), "The physics of society". Nature 415, 371.

Ball, P (2003), "The Physical Modelling of Human Social Systems". Complexus 1, 190-206.

Barabasi, A. L & Albert, R (1999), "Emergence of Scaling in Random Networks". SCIENCE VOL 286 15 October 1999.

Bar-Yam, Y (1997), "Dynamics of Complex Systems". Reading, MA: Addison-Wesley.

Barrat, A & Barthélémy, M & Vespignani, A (2008), "Dynamical processes on complex networks". Cambridge University Press, Cambridge.

Bernardes, A. T & Stauffer, D & Kertész, J (2002), "Election results and the Sznajd model on Barabasi network". The European Physical Journal B, 25, 123-127.

Biggs, N. L & Lloyd, E. K & Wilson, R. J (1976), "Graph Theory 1736-1936". Oxford: Clarendon Press.

Bigras-Poulin, M & Thompson R.A & Chriel, M & Mortensen, S & Greiner, M (2006), "Network analysis of Danish cattle industry trade patterns as an evaluation of risk potential for disease spread". Preventive Veterinary Medicine 76, pp 11-39 Available online at www.sciencedirect.com .

Boccaletti, S & Latora, V & Moreno, Y & Chavez, M & Hwang, D. U (2006), "Complex networks: Structure and dynamics". Physics Reports, 424(4-5), 175-308.

Borgatti, S. P & Mehra, A & Brass, D. J & Labianca G (2009), "Network Analysis in the Social Sciences". Science 323, 892 (2009).

Business dictionary http://www.businessdictionary.com/definition/model.html (definition of "model").

Castellano, C & Marsili, M & Vespignani, A (2000), "Nonequilibrium phase transition in a model for social influence". Physical Review Letters, 85, 3536-3539.

Clauset, A & Shalizi, C R & Newman, M.E.J (2009), "Power-law distributions in empirical data", SIAM Review, vol. 51, no. 4, pp. 661-703.

Clemente, F & Nasuelli, P & Baggio, R (2015), "Formal network analysis of a food supply chain system: a case study for the Italian agro-food chains". Journal of Agricultural Informatics Vol 6, No 4 (October 2015) doi: 10.17700/jai.2015.6.4.205.

Costa Filho, R. N & Almeida, M. P & Andrade, J. S & Moreira, J. E (1999), "Scaling behavior in a proportional voting process". Physical Review E, 60, 1067-1068.

Cross, R & Borgatti, S. P & Parker, A (2002), "Making invisible work visible: Using social network analysis to support strategic collaboration". California management review, 2002 - cmr.ucpress.edu .

da Fontoura Costa, L & Rodrigues, A & Travieso, G & Villas Boas, P. R (2007), "Characterization of complex networks: A survey of measurements". Advances in Physics, 56(1), 167-242.

da Fontoura Costa, L & Oliveira, ON, & Travieso, G & Rodrigues, FA & Villas Boas, PR, & Antiqueira, L & Viana, MP & Correa Rocha, LE (2011), 'Analyzing and modeling real-world phenomena with complex networks: A survey of applications'. Advances in Physics, vol. 60, no. 3, pp. 329-412.

De Benedictis L & Tajoli L (2011), "The World Trade Network", The World Economy, 34(8): 1417-1454.

Easley, D & Kleinberg, J (2010), "Networks, crowds, and markets: Reasoning about a highly connected world". Cambridge University Press, Cambridge.

EJOLT, Environmental Justice Organizations, Liabilities and Trade, http://www.ejolt.org/2012/12/commodity-chains-2/ .

Erdös, P & Rényi, A (1959), "On random graphs". Publicationes Mathematicae (Debrecen), 6, 290-297.

Erdös, P & Rényi, A (1960), "On the evolution of random graphs". Publications of the Mathematical Institute of the Hungarian Academy of Sciences, 5, 17-61.

Erdös, P & Rényi, A (1961), "On the strength of connectedness of a random graph". Acta Mathematica Academiae Scientiarum Hungaricae, 12, 261-267.

Faloutsos, M & Faloutsos, P & Faloutsos, C (1999), "On power-law relationships of the Internet topology". Computer Communication Review, 29, 251-262.

Fortunato, S (2010), "Community detection in graphs". Physics Reports, vol. 486, no. 3-5, pp. 75-174.

Freeman, L. C (1977), "A Set of Measures of Centrality Based on Betweenness". Sociometry Vol. 40, No. 1 (Mar., 1977), pp. 35.

Freeman, L (1978/79), "Centrality in Social Networks. Conceptual Clarification". Social Networks, 1 (1978/79) 215-239.

FoodCast project, http://foodcast.sissa.it .

Giarè, F & Giuca, S (2012), "Farmers and short chain: legal profiles and socio-economic dynamics", INEA 2012, http://dspace.inea.it/bitstream/inea/770/1/Farmers_short_chain.pdf .

Granovetter, M (1973), "The strength of weak ties". The American Journal of Sociology, 78(6), 1360-1380.

Havlin, S & Kenett, D. Y & Ben-Jacob, E & Bunde, A & Cohen, R & Hermann, H & Kantelhardt, J. W & Kertész, J & Kirkpatrick, S & Kurths, J & Portugali, J & Solomon, S (2012), "Challenges in network science: Applications to infrastructures, climate, social systems and economics". Eur. Phys. J. Special Topics 214, 273–293 (2012).

Helbing, D & Molnar, P (1995), "Social force model for pedestrian dynamics". Physical Review E, 51, 4282-4286.

Henderson, L. F (1971), "The statistics of crowd fluids". Nature, 229, 381-383.

Henrickson, L & McKelvey, B (2002), "Foundations of ''new'' social science: Institutional legitimacy from philosophy, complexity science, postmodernism, and agent-based modeling". Proceedings of the National Academy of the Sciences of the USA, 99 (suppl. 3), 7288-7295.

Hopkins, T & Wallerstein, I (1986) "Commodity chains in the world economy prior to 1800". Review X (1) 157-170.

ISTAT (Italian National Institute of Statistics), http://www.istat.it/it/ .

Jackson, M. O (2008), “Social and Economic Networks”. Princeton University Press (book). ISBN: 9780691148205.

Kerner, B. S & Rehborn, H (1996), “Experimental features and characteristics of traffic jams”. Physical Review E, 53, R1297-R1300.

Kydd, J., Pearce, R. and Stockbridge, M. (1996) “The Economic Analysis of Commodity Systems: Environmental Effects, Transaction Costs and the Francophone Filière Tradition”. presented at the ODA/NRSP Socio-Economics Methodology (SEM) Workshop, ODI: London, 29-30 April 1996.

Lazzarini S. G & Chaddad F. R & Cook M. L (2001), “Integrating Supply Chain and Network Analysis: The Study of Netchains”. Journal of Chain and Network Science 1 (1).

Lentz, H & Koher, A & Hovel, P & Gethmann, J & Sauter-Louis, C & Selhorst, T & Conraths, F. J (2016), “Disease spread through animal movements: a static and temporal network analysis of pig trade in Germany”. Cornell University Library, arXiv:1602.09108 [physics.soc-ph] .

Levin, S. A, (2003), “Complex adaptive systems: Exploring the known, the unknown and the unknowable”. Bulletin of the American Mathematical Society, 40(1), 3-19.

Lorrain, F & White, C (1971), “Structural Equivalence of Individuals in Social Networks”. Journal of Mathematical Sociology 1971, Vol. 1, pp 49 – 80.

Mantegna, R. N, & Stanley, H. E (2000), “Introduction to Econophysics: Correlations & Complexity in Finance”. Cambridge: Cambridge University Press.

Milgram, S (1967), “The small world problem”. Psychology Today, 1, 60-67.

Mitzenmacher, M (2004), “A brief history of generative models for power law and lognormal distributions”. Internet mathematics, 1(2), 226-251.

Nagel, K & Schreckenberg, M (1992), “A cellular automaton model for freeway traffic”. Journal of Physics I, 2, 2221-2230.

Nasuelli, P & Clemente, F & Baggio, R & Berruto, R & Busato, P (2015), “Supply Chains of Products of Animal Origin: a Complex Network Model for Strategic Management”. International Journal on Food System Dynamics 6 (4), 2015, 248-258.

Natale, F & Giovannini, A & Savini, L & Palma, D & Possenti, L & Fiore, G & Calistri, P (2009), “Network analysis of Italian cattle trade patterns and evaluation of risks for potential disease spread”. Preventive Veterinary Medicine, 92: 341-350. Journal homepage: www.elsevier.com/locate/prevetmed .

Newman, M. E. J (2003), “The structure and function of complex networks”. SIAM Review, 45, 167-256.

Newman, M. E. J (2010), “Networks - an introduction”. Oxford University Press, Oxford.

Pardi, F (1998), "Systems (theory)", Treccani Encyclopedia, Encyclopedia of Social Sciences. http://www.treccani.it/enciclopedia/teoria-dei-sistemi_%28Enciclopedia-delle-scienze-sociali%29/ .

Pavard, B, & Dugdale, J (2000), “The contribution of complexity theory to the study of sociotechnical cooperative systems”. Third International Conference on Complex Systems, Nashua, NH, May 21-26. Retrieved October, 2005, from http://www-svcict.fr/cotcos/pjs/.

Pinna, R (2006), ”The Evolution in Organizational Dimension of Supply Chain. From the management of a flow to the management of a network” (book), Franco Angeli editions - ISBN: 9788846474766.

Raikes, P & Friis Jensen, M & Ponte, S (2000), “Global commodity chain analysis and the French filière approach: comparison and critique”, Economy and society, 29(3), 390-417.

Reynolds, C (1987), “Flocks, herds, and schools: a distributed behavioral model”. *Computer Graphics, 21*, 25-34.

Saari, D. G (1995), “ Mathematical Complexity of Simple Economics”. Notices of the American Mathematical Society, *42(2), 222-230.*

Scott, N & Cooper, C & Baggio, R (2008), “Network Analysis and Tourism: From Theory to Practice”. Clevedon, UK: Channel View.

Sebeok, TA & Danesi, M (2000), “The forms of meaning: Modeling systems theory and semiotic analysis” (Vol. 1). Walter de Gruyter, p. 2.

Sieczka P., Holyst J.A. (2009). “Correlations in commodity markets”. Physica A, 388: 1621-1630 Journal homepage: www.elsevier.com/locate/physica .

Sornette, D (2003), “Why Stock Markets Crash”. Princeton: Princeton University Press.

Stacey, R. D (1996), “Complexity and Creativity in Organizations”. San Francisco: Berrett-Koehler.

Surana, A & Kumara, S & Greaves, M & Nandini Raghavan, U (2005), “Supply chain networks: a complex adaptive systems perspective”, International Journal of Production Research 43 (20), pp 4235-4265, DOI: 10.1080/00207540500142274 http//dx.doi.org/10.1080/00207540500142274 .

Tallec, F & Bockl, L (2005) “Commodity Chain Analysis. Constructing the Commodity Chain Functional Analysis and Flow Charts”. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. Online under: www.fao.org/tc/easypol

Thompson J.D (1967), “Organizations in action” (book), New York, McGraw Hill.

Vignes, A & Etienne, J-M (2011). “Price formation on the Marseille fish market: evidence from a network analysis”. Journal of Economic Behavior & Organization, 80: 50-67.

Waldrop, M (1992), “Complexity: The Emerging Science and the Edge of Order and Chaos”. London: Simon and Schuster.

Watts, D. J (2004), “The ‘New’ Science of Networks”. Annual Review of Sociology, 30, 243-270.

Watts, D. J & Strogatz, S. H (1998), “Collective dynamics of 'small world' networks”. Nature, 393, 440-442.

Yu, M & Nagurney, A (2013), “Competitive food supply chain networks with application to fresh produce”, European Journal of Operational Research, vol. 224, no. 2, pp. 273-282.

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Appendix: list of network nodes

Producers	Dairy Supply Chain	Cow Milk, milk for processing
Producers	Dairy Supply Chain	Cow Milk for Grana Padano
Producers	Dairy Supply Chain	Cow Milk for other DOP
Producers	Dairy Supply Chain	Cow Milk, Organic Milk
Producers	Dairy Supply Chain	Buffalo Milk
Producers	Dairy Supply Chain	Sheep Milk
Producers	Dairy Supply Chain	Goat Milk
Producers	Dairy Supply Chain	Losses (Produced Milk - Used Milk)
Producers	Dairy Supply Chain	Cow Milk, Drinking Milk
Producers	Dairy Supply Chain	Cow Milk for Parmigiano Reggiano
Producers	Milk Supply Chain	Animal Feeds, Cow Milk for calves
Producers	Milk Supply Chain	Animal Feeds, Buffalo Milk for young Buffalos
Producers	Milk Supply Chain	Animal Feeds, Sheep Milk for Lambs
Producers	Milk Supply Chain	Animal Feeds, Goat Milk for Kids
Producers	Meat Supply Chain	Male Calves from Meat Supply Chain and Dairy Supply Chain destined for Calves/Beef
Producers	Meat Supply Chain	Cows/Bulls from Meat Supply Chain and Dairy Supply Chain at the end of career
Producers	Meat Supply Chain	Female Calves from Meat Supply Chain and Dairy Supply Chain destined for Heifers, born in Italy
Producers	Meat Supply Chain	Male and Female Calves from Milk Supply Chain destined for Veal Calves
Producers	Meat Supply Chain	Cattle of each category dead or to be suppressed
Producers	Meat Supply Chain	Breeding of Piglets born in Italy
Producers	Meat Supply Chain	Breeding of Gilts + Young Boars born in Italy
Producers	Meat Supply Chain	Pigs (Boars and Sows) for reproduction at the end of career
Producers	Meat Supply Chain	Pigs of each category dead or to be suppressed
Producers	Meat Supply Chain	Fattening phase in Italy, until Beef
Producers	Meat Supply Chain	Fattening phase in Italy, until Veal Calves
Producers	Meat Supply Chain	Fattening phase in Italy, until Heifers
Producers	Meat Supply Chain	Fattening phase in Italy, until Light Pigs

Producers	Meat Supply Chain	Fattening phase in Italy, until Heavy Pigs
Producers	Milk Supply Chain	Import Semifinished Products
Producers	Milk Supply Chain	Import Finished Products - Various
Producers	Milk Supply Chain	Import Powder Milk
Producers	Meat Supply Chain	Import Male and Female Calves
Producers	Meat Supply Chain	Import Beef
Producers	Meat Supply Chain	Import Adult Cattle
Producers	Meat Supply Chain	Import, Gilts + Young Boars, Purity, Company Hybrids
Producers	Meat Supply Chain	Import, Piglets, Commercial Hybrids
Producers	Meat Supply Chain	Import, Light Pigs
Processors	Dairy Supply Chain	Cheese Maturers
Processors	Milk Supply Chain	Conversion into Processed Products: ice cream, dessert, gelled milk, other products
Processors	Milk Supply Chain	Packaging and Selling through Conventional Channels
Processors	Milk Supply Chain	Losses and Waste
Processors	Meat Supply Chain	Meat Supply Chain Losses and Waste
Processors	Meat Supply Chain	Maturers of Meat Products
Processors	Milk Supply Chain	Animal Feeds, Powder Milk for Animal Feeding
Processors	Milk Supply Chain	Animal Feeds, Whey for Animal Feeding
Processors	Milk Supply Chain	Cheese Factory, Whey
Processors	Dairy Supply Chain	Cheese Factory, Ricotta
Processors	Dairy Supply Chain	Cheese Factory, Packaging and Direct Selling Ricotta
Processors	Milk Supply Chain	Pasteurized Whole Milk
Processors	Milk Supply Chain	Semi-skimmed Pasteurized Milk UHT
Processors	Milk Supply Chain	Packaging and Direct Selling Pasteurized Whole Milk
Processors	Milk Supply Chain	Semi-skimmed Pasteurized Milk
Processors	Milk Supply Chain	Skimmed Pasteurized Milk
Processors	Milk Supply Chain	Raw Milk
Processors	Milk Supply Chain	Packaging and Direct Selling Raw Milk
Processors	Milk Supply Chain	Goat Milk
Processors	Milk Supply Chain	Buffalo MIlk
Processors	Milk Supply Chain	Sheep Milk

Processors Dairy Supply Chain	Cheese Factory, NOT DOP Caciocavallo cheese
Processors Dairy Supply Chain	Cheese Factory, Italico cheese
Processors Dairy Supply Chain	Cheese Factory, Crescenza and Stracchino cheese
Processors Dairy Supply Chain	Packaging and Direct Selling NOT DOP Caciocavallo cheese
Processors Dairy Supply Chain	Packaging and Direct Selling Italico cheese
Processors Dairy Supply Chain	Packaging and Direct Selling Crescenza and Stracchino cheese
Processors Dairy Supply Chain	Cheese Factory, Other Soft Cheeses of all kinds
Processors Dairy Supply Chain	Cheese Factory, other Fresh Cheeses, with spun and unspun dough (Scamorza,Robiola,Mascarpone)
Processors Dairy Supply Chain	Cheese Factory, Melted Cheese
Processors Dairy Supply Chain	Packaging and Direct Selling other Soft Cheeses of all kinds
Processors Dairy Supply Chain	Packaging and Direct Selling Melted Cheese
Processors Dairy Supply Chain	Packaging and Direct Selling other Fresh Cheeses, withspun and unspun dough
Processors NOT-cheese dairy	Fermented Milk, Yogurt, Other
Processors NOT-cheese dairy	Butter
Processors NOT-cheese dairy	Packaging and Direct SellingYogurt
Processors NOT-cheese dairy	Packaging and Direct Selling Butter
Processors NOT-cheese dairy	Cream or Heavy Cream to be consumed
Processors NOT-cheese dairy	Drinks made from Milk
Processors NOT-cheese dairy	Buttermilk
Processors Milk Supply Chain	Organic Yogurt
Processors Milk Supply Chain	Organic Butter
Processors MIlk Supply Chain	Other Organic products and Organic Chesees
Processors Milk Supply Chain	Organic Milk
Processors Milk Supply Chain	Packaging and Direct Selling Organic MIlk
Processors Milk Supply Chain	Packaging and Direct Selling Organic Yogurt
Processors Milk Supply Chain	Packaging and Direct Selling Organic Butter

Processors Milk Supply Chain Packaging and Direct Selling other Organic Products and Organic Cheeses

Processors Meat Supply Chain Import of Meat cuts slaughtered abroad, Pig Sector

Processors Meat Supply Chain Cuts of Beef meat slaughtered abroad

Processors Meat Supply Chain Cuts of Veal Calves meat slaughtered abroad

Processors Meat Supply Chain Cuts of Adult Cattle meat slaughtered abroad

Processors Meat Supply Chain Cuts of Heifers meat slaughtered abroad

Processors Meat Supply Chain Slaughterhouse of Bovine Meat in Italy, Cuts of Veal Calves meat

Processors Meat Supply Chain Slaughterhouse of Bovine meat in Italy, Cuts of Beef meat

Processors Meat Supply Chain Slaughterhouse of Bovine meat in Italy Cuts of Heifers meat

Processors Meat Supply Chain Slaughterhouse of Bovine meat in Italy, Cuts of Adult Bovine

Processors Meat Supply Chain Slaughterhouse of Pig meat in Italy, Heavy Pig Thigh

Processors Meat Supply Chain Slaughterhouse of Pig meat in Italy, Light Pigs, for consumption of Fresh Cuts

Processors Meat Supply Chain Slaughterhouse of Pig meat in Italy, Cuts "not thigh" from Heavy Pigs

Processors Meat Supply Chain Slaughterhouse of Pig meat in Italy, Direct Selling to the Consumers

Processors Meat Supply Chain Packaging and Selling through Conventional Channels for meat of all the types

Processors Meat Supply Chain Packaging and Direct Selling of Beaf and Veal and of all types of Processed/Matured Products

Processors Meat Supply Chain Processing in Salami and other Meat DOP or IGP Processed and/or Matured Products

Processors Meat Supply Chain Processing into Salami and other Meat NOT DOP and NOT IGP Processed and/orMatured Products

Processors Meat Supply Chain Processing in DOP Cured Ham

Processors Meat Supply Chain Processing into Bresaola of ValtellinaIGP

Processors Dairy Supply Chain Cheese Factory, DOP, Provolone Valpadana DOP

Processors Dairy Supply Chain Chese Factory, DOP, Mozzarella cheese from Bufala Campana DOP

Processors Dairy Supply Chain Cheese Factory, DOP, Gorgonzola DOP

Processors	Dairy Supply Chain	Cheese Factory, DOP, Grana Padano
Processors	Dairy Supply Chain	Cheese Factory, DOP, ParmigianoReggiano
Processors	Maturing in dairy	Packaging and Direct Selling Parmigiano Reggiano
Processors	Maturing in dairy	Packaging and Direct Selling Grana Padano
Processors	Maturing in dairy	Packaging and Direct Selling Provolone Valpadana DOP
Processors	Maturing in dairy	Packaging and Direct Selling Gorgonzola DOP
Processors	Dairy Supply Chain	Packaging and Direct Selling in dairyMozzarella cheese from Bufala Campana DOP
Processors	Dairy Supply Chain	Cheese Factory, DOP, other DOP cheeses: Asiago, Taleggio, Montasio, Quartirolo l., Fontina
Processors	Dairy Supply Chain	Cheese Factory, DOP, Pecorino Romano DOP
Processors	Maturing in dairy	Packaging and Direct Selling other DOP cheeses
Processors	Maturing in dairy	Packaging and Direct Selling Pecorino Romano DOP
Consumers	Milk Supply Chain	Losses / Waste
Consumers	Milk Supply Chain	Semi-Skimmed UHT Milk
Consumers	Milk Supply Chain	Pasteurized Whole Milk
Consumers	Milk Supply Chain	Powder Milk
Consumers	Milk Supply Chain	Semi-Skimmed Pasteurized Milk
Consumers	Milk Supply Chain	Skimmed Pasteurized Milk
Consumers	Milk Supply Chain	Raw Milk
Consumers	Milk Supply Chain	Goat Milk
Consumers	Milk Supply Chain	Organic Milk
Consumers	Milk Supply Chain	Organic Yogurt
Consumers	Milk Supply Chain	Organic Butter
Consumers	Milk Supply Chain	Organic Cheeses
Consumers	Milk Supply Chain	NOT DOP Caciocavallo cheese
Consumers	Milk Supply Chain	Italico cheese
Consumers	Milk Supply Chain	Crescenza e Stracchino cheeses
Consumers	Milk Supply Chain	Ricotta
Consumers	Milk Supply Chain	Soft cheeses of all types

Consumers	Milk Supply Chain	Fresh Cheeses with spun and unspun dough (Scamorza,Robiola, Mascarpone)
Consumers	Milk Supply Chain	Melted Cheeses
Consumers	Milk Supply Chain	Parmigiano Reggiano
Consumers	Milk Supply Chain	Grana Padano
Consumers	Milk Supply Chain	Provolone Valpadana DOP
Consumers	Milk Supply Chain	Mozzarella di Bufala Campana DOP
Consumers	Milk Supply Chain	Gorgonzola DOP
Consumers	Milk Supply Chain	Other DOP Cheeses: Asiago, Taleggio, Montasio, Quartirolo l., Fontina
Consumers	Milk Supply Chain	Pecorino Romano DOP
Consumers	Meat Supply Chain	DOP Cured Ham
Consumers	Meat Supply Chain	Bresaola of Valtellina IGP
Consumers	Meat Supply Chain	Salami and other meat DOP and/or IGPprocessed or matured products
Consumers	Meat Supply Chain	Salami and other meat Non DOP - Non IGP processed or matured products
Consumers	Meat Supply Chain	Losses / Waste
Consumers	Meat Supply Chain	Cuts "not thigh" from Heavy Pig
Consumers	Meat Supply Chain	Cuts of Light Pig for consumption of fresh meat
Consumers	Meat Supply Chain	Cuts of Veal Calves meat
Consumers	Meat Supply Chain	Cuts of Beef
Consumers	Meat Supply Chain	Cuts of Heifers meat
Consumers	Meat Supply Chain	Cuts of Adult Bovine meat
Consumers	Milk Supply Chain	Fermented Milk, Yogurt, other
Consumers	Milk Supply Chain	Butter
Consumers	Milk Supply Chain	Other Processed Products
Consumers	Milk Supply Chain	Cream and Heavy Cream for consumption
Consumers	Milk Supply Chain	Milk based Drinks
Traders		Intermediariaries / Agents / Representatives
Traders		Large-scale Retail Channel (Supermarket Chains)
Traders		Retail Sales
Traders		HO.RE.CA.
Traders		Recovery of unsold for Humanitarian purposes
Traders		Losses and Unsold

Traders Milk Supply Chain Importers of Finished Products in the Milk Supply Chain

Traders Milk Supply Chain Importers of Semi-Finished Products in the Milk Supply Chain

Traders Meat Supply Chain Importers of Live Animals in the Meat Supply Chain

Traders Meat Supply Chain Importers of Cuts of Meat slaughtered abroad in the Meat Supply Chain

Traders Milk Supply Chain Exporters of other DOP products

Traders Milk Supply Chain Exporters of other products

Traders Milk Supply Chain Exporters of Parmigiano Reggiano

Traders Milk Supply Chain Exporters of Grana Padano

Traders Meat Supply Chain Exporters of Salami and other Processed and/or Matured products NOT DOP - NOT IGP

Traders Meat Supply Chain Exporters of Salami and other Processed and/or Matured products DOP and IGP

Traders Meat Supply Chain Exporters of Bresaola of Valtellina IGP

Traders Meat Supply Chain Exporters of Bovine Meat, Fresh Cuts

Traders Meat Supply Chain Exporters of DOP Cured Ham

Traders Meat Supply Chain Exporters of Pig Meat, Fresh Cuts

Processors Meat Supply Chain Slaughterhouse Waste destined for Food Industry for Pets

Processors Meat Supply Chain Slaughterhouse Waste destined for Rendering

Processors Meat Supply Chain Energy from Rendering

Processors Meat Supply Chain Other Products from Rendering