Available online at www.centmapress.org

Proceedings in
System Dynamics and Innovation in Food Networks 2016

INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Modelling the Pig Supply Chain: a Network Analysis Applied to the Italian Case

Flavia Clemente[1], Piero Nasuelli[1], Rodolfo Baggio[2]

[1]*DISTAL - School of Agriculture and Veterinary Medicine, University of Bologna, Italy*

[2]*Dondena Centre for Research on Social Dynamics, Bocconi University, Milan, Italy*

flavia.clemente@unibo.it, piero.nasuelli@unibo.it, rodolfo.baggio@unibocconi.it

ABSTRACT

Various economic theories and many approaches in the study of food chains have produced, over the years, a variety of models. They are used as tools for analysis and forecasting, and often offer a basis for the development in software of various kinds.

In an earlier stage of our field research we developed a model mapping the dense network of links connecting the actors of the supply chains of products of animal origin of the Italian territory. An initial version of the model has shown the basic characteristics of the system and already provided a number of interesting insights (Clemente et al., 2015a, 2015b). The Eva.CAN model (Evaluation of Complex Agro-food Networks) is a complex network model representing together the chains of milk (cow, goat, sheep and buffalo), and beef and pig meat along with all their products, fresh and matured, in which the links represent the economic exchanges between the different actors.

In this next phase of analysis our aim is to show, in particular, a study of the structure of the Italian pig meat sector (fresh and cured products), the dynamics of import of raw materials and export of processed products, and also those of consumption on the Italian territory. A special attention is given to our PDO products, considered among the best in the World as for quality and quantity. The pig production in Italy reached 1.6 million tons. The meat of more than 70% of the bred animals is destined to the production of PDO products (In Italy the PDO products are 21 out of a total of 36 European). The industry imports nearly 1.2 million tons of meat that is intended in part to fresh consumption and in part to the transformation. In the analysis we use a higher amount of actual data pertaining to a greater number of years compared to the previous works.

We apply network analytic methods to assess the topology (structural characteristics) of the network which is known to affect the overall functionality and dynamics (Newman, 2010). For the analysis of the sector it is important to understand what is the mix of processed products destined to domestic consumption and exports that allow the company to get the best economic performance. On this basis a series of simulations can provide different development scenarios. The evidence resulting from these allows examining possible strategic suggestions for what concerns business management and policies to be adopted in the whole sector.

Keywords: *food supply chain, network analysis, Italian pig meat chain, fresh and seasoned products*

1 Introduction

In earlier stages in our research we already presented the model we developed explaining the idea of the merger of Supply Chain Analysis (SCA) and Network Analysis (NA) into the Netchain Analysis. We showed various layout possibilities for our network obtained with the software yEd Graph Editor allowing to appreciate its various features, and we collected the results of qualitative analysis about the Centrality Measures regarding network nodes (Nasuelli, Clemente, Baggio, Berruto, Busato, “Supply Chains of Products of Animal Origin: a Complex Network Model for Strategic Management”, International Journal on Food System Dynamics Vol 6, No 4, 2015).

DOI 2016: pfsd.2016.1651

Subsequently we used the Python programming language and the library NetworkX for the analysis of the adjacency matrix of our complex network. For the graphical representation we used a software specialized in representation and study of complex networks called Pajek. Our aim was to make quantitative analysis on the structure of the network, conditioning the functionality of the system, by measuring specific characteristics. Another purpose of this second part was the search for associative forms among network nodes (clusters) which showed that, like other cases of analysis of networks of the real world, there is a mechanism of self-organization that does not depend on the designers' choices about graphical representation of the model (Clemente, Nasuelli, Baggio, "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, 2015). This mechanism is characteristic of the networks of the real world which depends on local decisions made by the individual nodes based on information that is biased toward the more visible, more connected nodes, irrespective of the nature and origin of this visibility (Barabasi, Albert, "Emergence of Scaling in Random Networks", Science vol 286, 15 October 1999).

2 Presentation of Eva.CAN model

The model that we realized is a new concept model we called Eva.CAN model which stands for Evaluation of Complex Agro-food 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. Eva.CAN is open to the addition of other supply chains of other products too. 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). "While Global Commodity Chain (GCC) analysts attempt to work under a unified theoretical framework, no such effort is made in French Filière analysis, which includes several different schools of thought or research traditions, each adhering to its own theoretical underpinnings and posing its own research questions. 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 neo-classical welfare analysis (Kydd, Pearce and Stockbridge 1996: 23). 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 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 French Filiere-inspired. The network consisting of nodes (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 agro-food productions as complex networks given by several

DOI 2016: pfsd.2016.1651

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. Furthermore, the application of the Network theory takes place thanks to this model for the first time in the field of agri-food confirming also in this context the principle of self-organization of complex networks of the real world. The Modularity analysis showed the subdivision into groups of nodes (clusters) most closely connected within the group than with the rest of the network. We found 19 clusters of unexpected composition, different from that one of the groups that we initially set up for needs of representation. These clusters in a network of economic actors can be interpreted as a kind of collaborative form. We also measured the efficiency of the system by measuring the diameter of the network (small = very efficient, large = less efficient), the degree distribution that provides information about what proportion of network nodes has control of the rest of the network. Finally, through measurements on individual nodes, we identified which of them occupy the most strategic position in the system.

Such information obtained by a network analytical approach can be useful in formulating agricultural policies, or, at the level of single company, in the choice of business policies or even in the design of traceability systems.

In the following figures some representations of the model made with yEd Graph Editor (Fig. 1 – 2 – 3) and with Pajek (Fig. 4 – 5- 6).

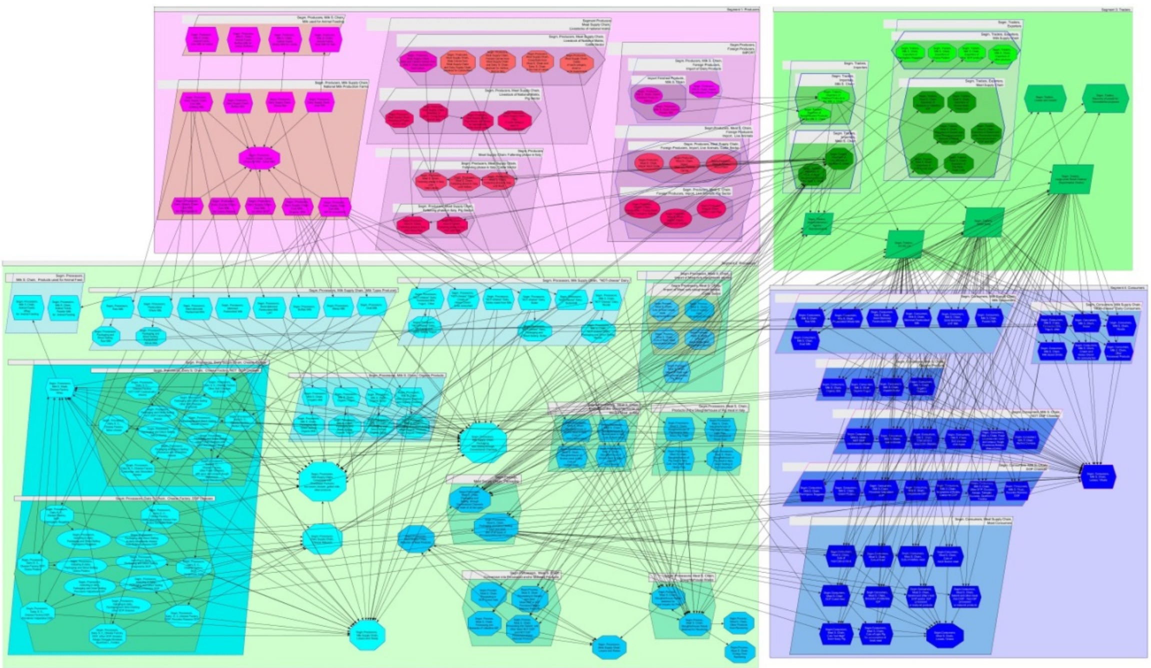


Figure 1: Eva.CAN model with yEd Graph editor

DOI 2016: pfsd.2016.1651

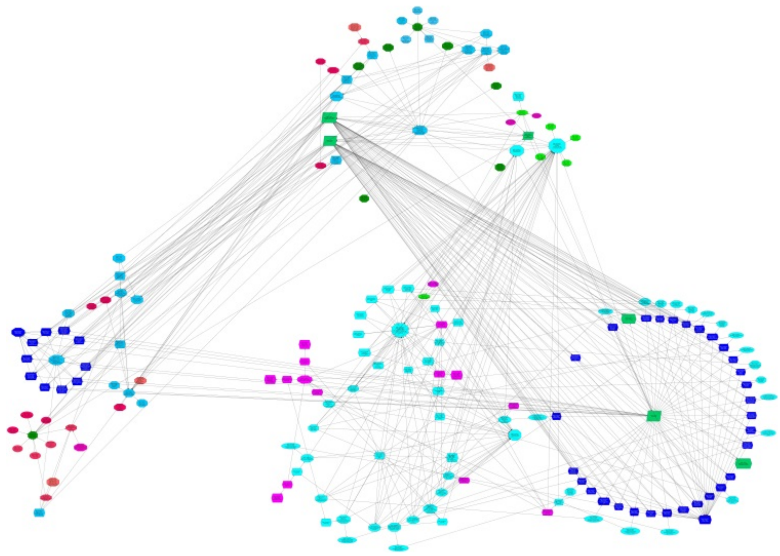


Figure 2: Eva.CAN model in another layout with custom groups configuring subnetworks (yEd Graph Editor)

Figure 3: Eva.CAN in hierarchical structure layout (yEd Graph Editor)

DOI 2016: pfsd.2016.1651

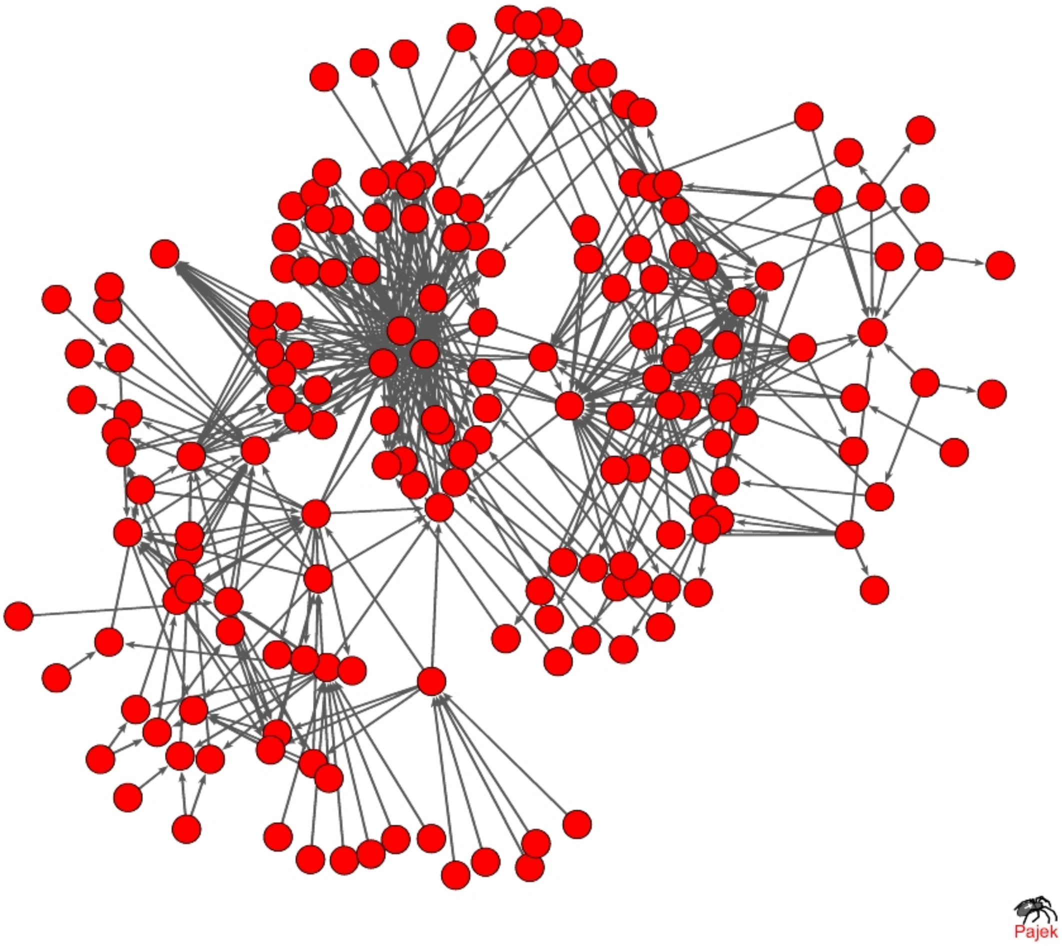
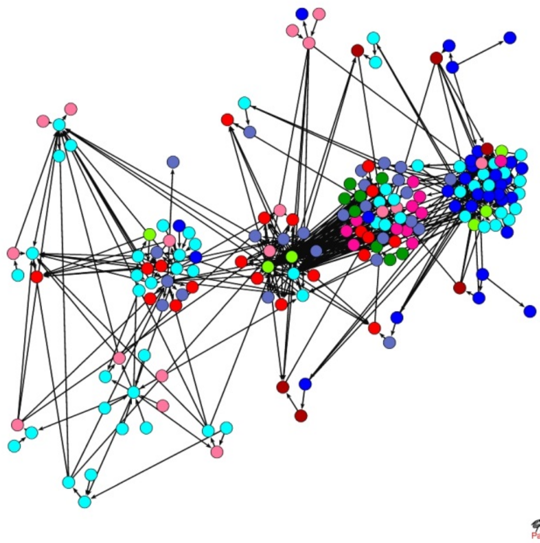


Figure 4: Eva.CAN model displayed by Pajek



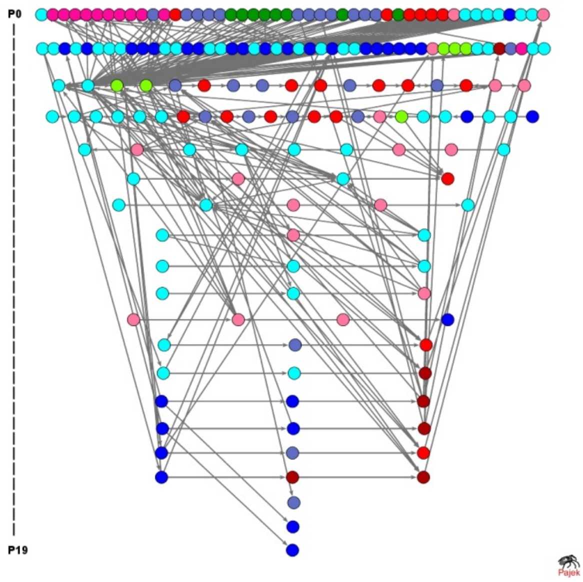


Figure 5: Modularity analysis (number and composition of clusters); Figure 6: the same Modularity in another layout (made by Pajek).

3 The supply chain of pig meat in Italy: new case study

DOI 2016: pfsd.2016.1651

In this next phase of analysis our aim is to show, in particular, a study of the structure of the Italian pig meat sector (fresh and cured products), the dynamics of import of raw materials and export of processed products, and also those of consumption on the Italian territory. A special attention is given to our PDO products, considered among the best in the World as for quality and quantity.

According to the last Census made by ISTAT (Italian National Institute of Statistics) published in September 2015 and covering the years 2010 to 2013, in 2013 the number of farms decreased of 9.2% compared with that recorded by the Census of Agriculture in 2010. Also the total area of farms decreases, although to a lesser degree compared to their number. The average company size increased, however, from 7.9 to 8.4 hectares. The livestock sector is in decline for pigs: compared to 2010, it has 7.8% less for the number of animals. The decrease in livestock numbers has been recorded especially in the regions traditionally engaged in the production of pigs (-13.0% in Emilia-Romagna, -9.4% in Lombardy). Nevertheless, the Northwest is confirmed the territorial division which has the highest number of pigs (64.1% of the national total). Of all the breeding companies of farm animals those breeding pigs correspond to 14% (http://www.istat.it/it/archivio/167401).

The heavy pigs delivered to the circuit PDO now account for 70% of the national pig production: of the approximately 12.281 millions pigs produced in Italy in 2012 the heavy pigs certified for processing into PDO products were about 8,308. 000.

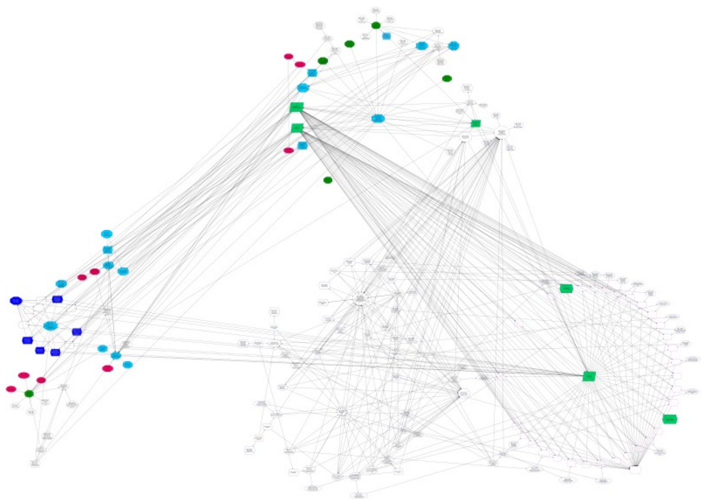
In Italy the breeding of pigs is mainly directed to get heavy animals destined to the production of PDO ham or other cured meat products. It is different in the rest of Europe where breeding produces mainly light animals for consumption of fresh unprocessed meat. The heavy pig is bred up to a high weight of over 160 kg and not slaughtered before reaching the age of 9 months (3 months more than the EU pig). These pigs are bred and selected according to criteria that make them particularly suitable for processing in hams and sausages. In the rest of Europe and the world instead farming selects and breeds pigs for the production of fresh meat slaughtered at lower weights (100-110 kg). (http://www.mangimiealimenti.it/articoli/609-suinicoltura-in-italia-il-punto-della-situazione)

The decrease in production has worsened the self-sufficiency of pig meat (estimated by ANAS to 61%) and led to an increase in imports of live pigs and of pig meat from abroad. In 2014 live pigs imported increased by around 29% and imported fresh pig meat of 8.4%. With regard to fresh and frozen pig thighs, ANAS (National Association of Swine Breeders) estimated that last year more than 62 million were imported (compared to about 57 million in 2013) mainly from Germany, Holland, Denmark, Spain and France (http://mangimiealimenti.it/articoli/1482-per-colpa-della-crisi-sono-aumentate-le-importazioni-di-suini-vivi-e-carni-suine-fresche).

4 The model for Pig meat supply chain

The supply chain pig meat and its products (fresh and cured) is a part of the network model Eva.CAN, as shown by the images shown below in figure 7 and 8.

DOI 2016: pfsd.2016.1651



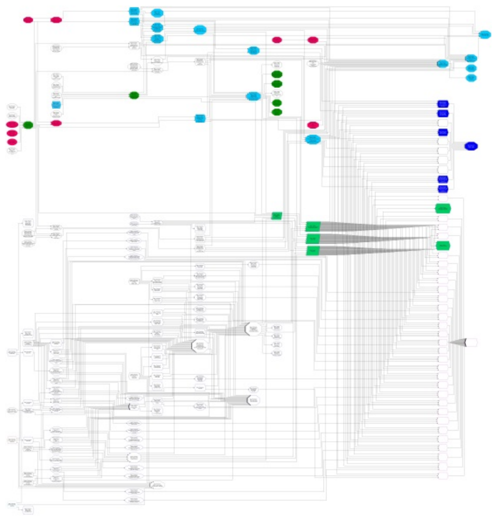


Figure 7: Circular layout (the colored nodes represent the chain of pig meat); Figure 8: hierarchical layout (yEd Graph editor).

We can extract from the general network the only supply chain of pig meat, but remain embedded nodes that are shared with other supply chains represented in the model Eva.CAN or even with the beef food chain (colored in green, are part of the segment Trade) as shown in figure 9.

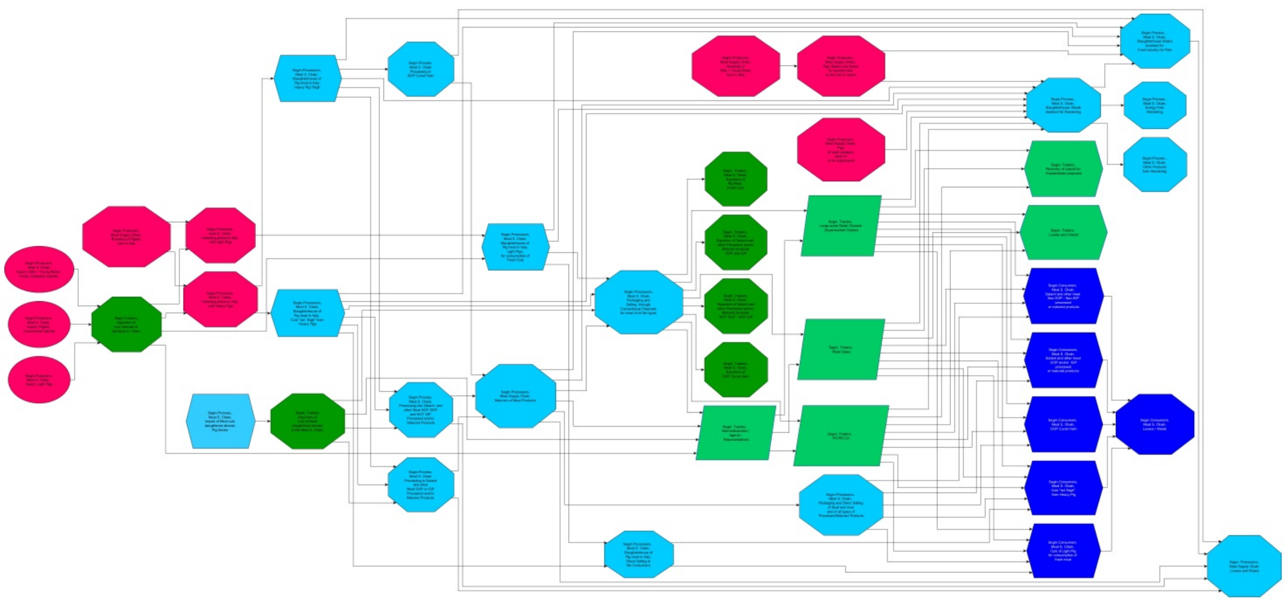


Figure 9: the Pig meat supply chain made with yEd Graph Editor

5 Analysis of Pig meat network

To analyze the adjacency matrix and the links between the nodes of the network that is the supply chain of pig meat we used the same methods and materials used for the analysis of the overall complex network already analyzed. We therefore used Python programming language and NetworkX library.

For the representation of the results of analysis performed with Python we used Pajek, a software specialized in the representation and analysis of complex networks.

DOI 2016: pfsd.2016.1651

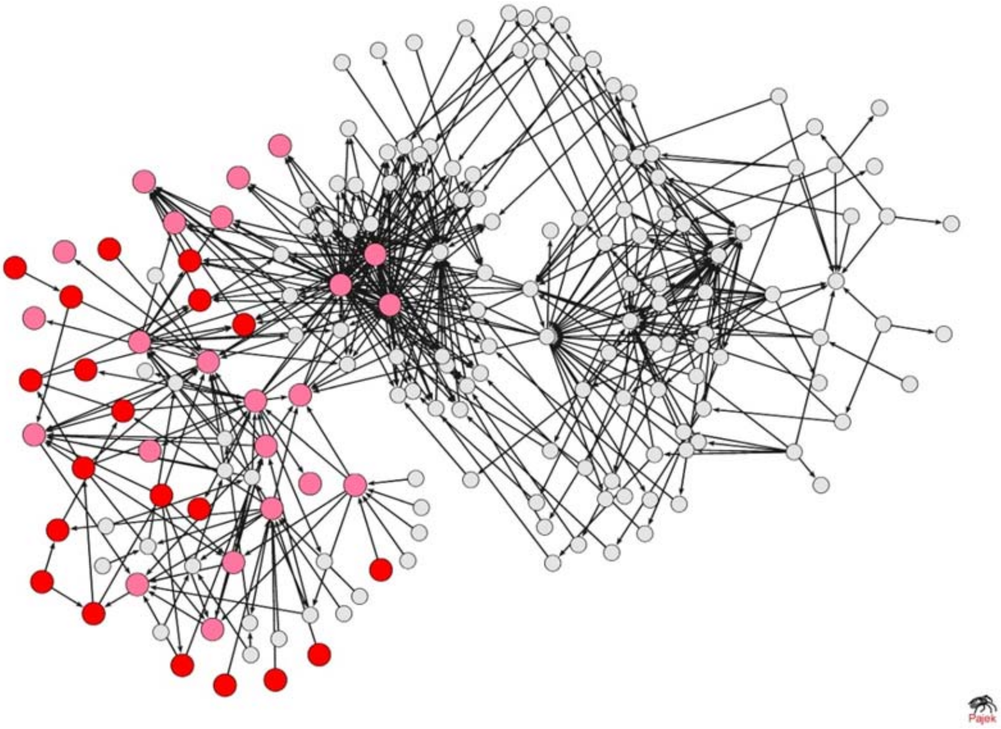


Figure 10: Pig meat supply chain colored in red; nodes in common with other supply chains colored in pink; nodes of other supply chains of Eva.CAN model uncolored. This image was obtained with Pajek.

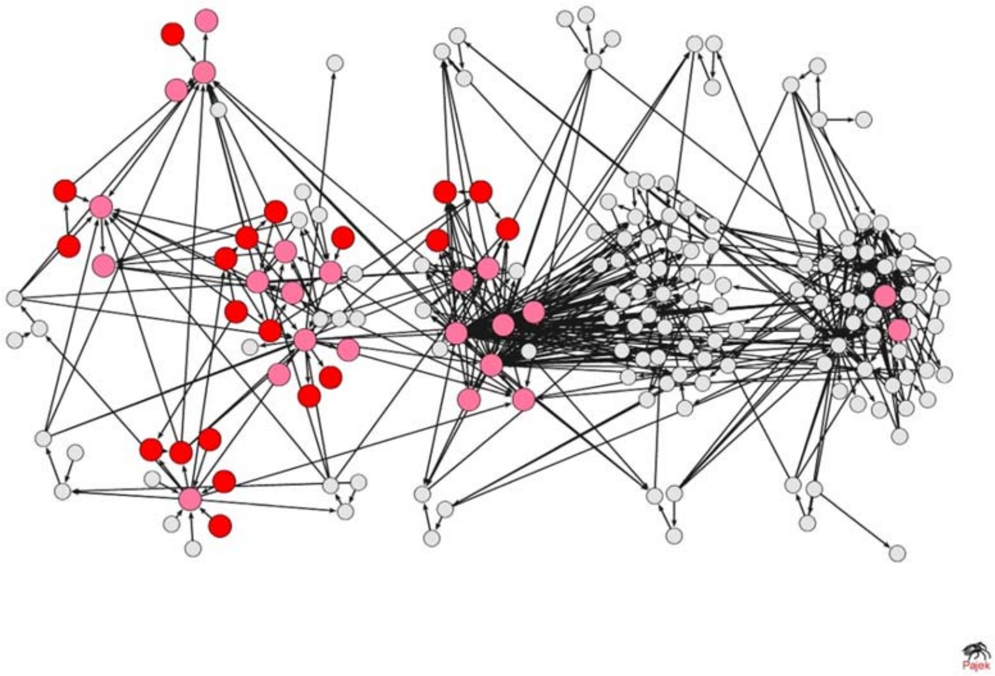


Figure 11: Overall complex network: as you can see the nodes of pig meat supply chain are placed only in some of the clusters that are spontaneously formed in the network and represent collaborative forms

6 Degree Distribution

DOI 2016: pfsd.2016.1651

The Degree Distribution follows a power law (Fig. 12). This behavior is typical of many phenomena in the world of nature, sociology and economics, represented by networks "scale free" (Barabasi 1999). Important consequence of this is that the removal of nodes at higher connection may lead 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. This corresponds to the general characteristics of the Scale Free Complex Network, the ones of the real world: they are resistant to failures intended as malfunctions or detachments of "random" nodes which will very likely be nodes with few links because most of the nodes in these networks has few connections. At the same time Scale Free Complex Networks are susceptible to "attacks" intended as the malfunction or detachments targeted to the nodes with high connectivity that are far fewer but determine the breaking of the network.

In figure 13 we compare the Degree Distribution curve of the overall network of our model representing the 6 supply chains together and we can observe how the two curves are essentially similar. The comparison, as customary, is done by using the unweighted version of the network which better provides a representation of the general topology of the system.

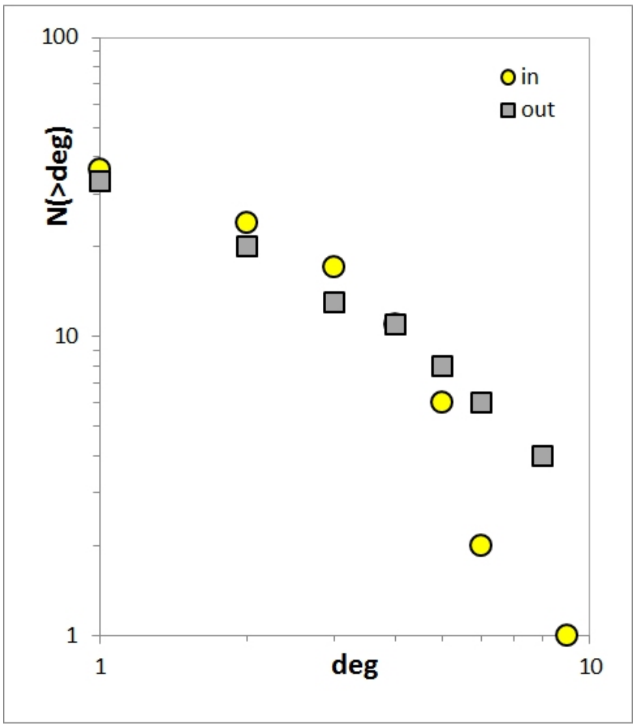


Figure 12: Degree Distribution curve on the unweighted pig meat network: power law

DOI 2016: pfsd.2016.1651

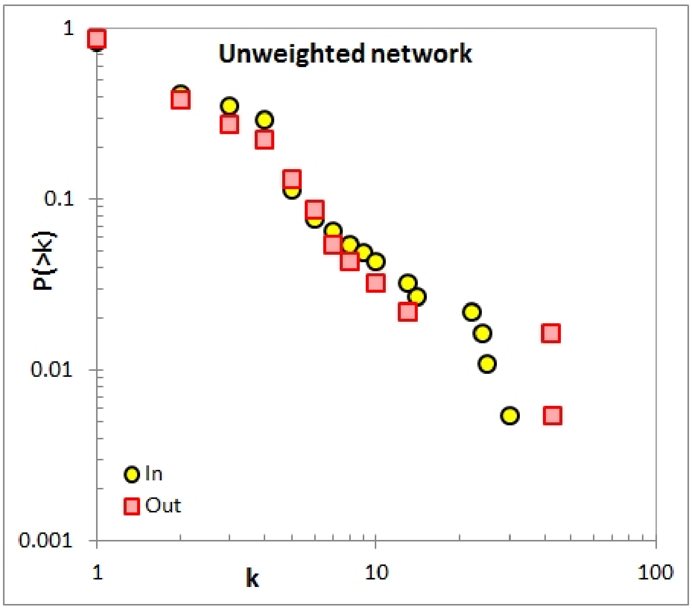


Figure 13: Degree distribution of the overall network representing 6 supply chains together

7 Modularity analysis

We extracted from the overall network the pig meat supply chain also in the images with the software Pajek, and we performed an analysis of Modularity, the tendency to form clusters in the network. We found 5 clusters (figure 14) marked by 5 different colors. The most numerous cluster consists of 15 nodes, the 2nd contains 14, the 3rd is 6 nodes, the 4th and 5th clusters contain 4 nodes for each cluster.

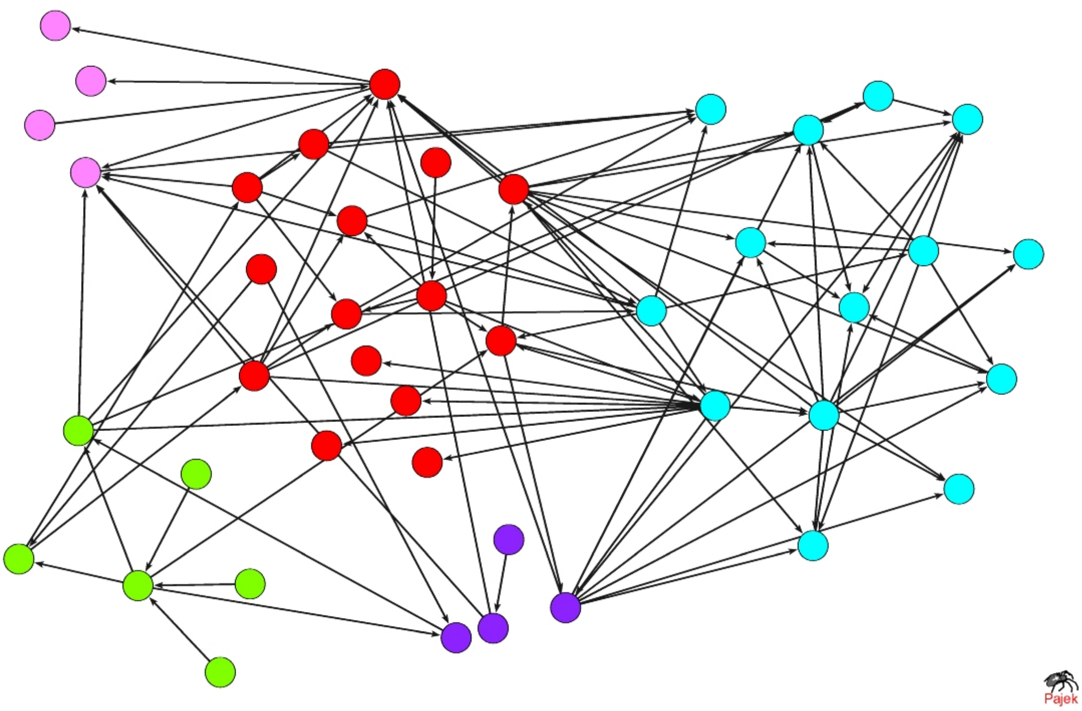


Figure 14: clusters in the pig supply chain

DOI 2016: pfsd.2016.1651

We could identify each node in each cluster through the alphanumeric identification code assigned to each node in our database.

Therefore we know the composition of each cluster which is as described below:

1st cluster: 7 nodes of Processing sector, 7 nodes of Trade sector, 1 node of Production sector; tot: 15.

2nd cluster: 6 nodes of Consumption sector, 5 nodes of Processing sector, 3 nodes of Trade sector; tot: 14.

3rd cluster: 4 nodes of Production, 1 node of Processing sector, 1 node of Trade sector; tot: 6.

4th cluster: 3 nodes of Processing sector, 1 node of Production sector; tot: 4.

5th cluster: 3 nodes of Production sector, 1 node of Trade sector; tot: 4.

8 Conclusions

Network analysis of the network representing the supply chain of pig meat with its fresh and seasoned products reveals substantially the same characteristics of the overall network of the entire model Eva.CAN. It is a network of the real world and as such its degree distribution follows a power law curve.

The modularity analysis performed on the pig meat network confirms what we already observed in the overall network: the clusters that spontaneously emerge do not correspond to groups expected by the the design phase of the model. The network nodes show a self-organization capability resulting in a configuration that highlights some degree of "affinity", collaborative forms, which probably need common policies

In particular, observing the precise identity of the individual nodes (and not only the segment of the origin) we can say that, even if the number of nodes concerned in the case of the analysis of modularity of the pig meat network is much lower compared to the overall network, the composition of the clusters does not respect, even in this case, criteria for type of product or type of distribution or provenance from a specific segment in the chain. For example we can find in the same cluster PDO products but also non-PDO, or packaging and direct selling but also packaging and selling trough conventional channels.

As the pig meat network has nodes in common with the others of the model Eva.CAN, it would be interesting to assess the role of common nodes in the overall network and compare it to the role played by the same nodes in each supply chain. This study, that we plan to conduct in the near future, would highlight the difference between the analysis of a single supply chain and the analysis of the whole complex system of products of animal origins.

References

Barabasi, Albert, "Emergence of Scaling in Random Networks", Science vol 286, 15 October 1999

Clemente, Nasuelli, Baggio, "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, 2015.

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

Nasuelli, Clemente, Baggio, Berruto, Busato, "Supply Chains of Products of Animal Origin: a Complex Network Model for Strategic Management", International Journal on Food System Dynamics Vol 6, No 4, 2015.

DOI 2016: pfsd.2016.1651

ISTAT, The farm structure, 2015 (http://www.istat.it/it/archivio/167401).

Miraglia, "Because of the crisis imports of live pigs and fresh pig meat have increased", 2015, Mangimi&Alimenti (http://mangimiealimenti.it/articoli/1482-per-colpa-della-crisi-sono-aumentate-le-importazioni-di-suini-vivi-e-carni-suine-fresche).

Newman, MEJ 2010, Networks - an introduction, Oxford University Press, Oxford.

Raikes, Friis Jensen, Ponte, 2000, 'Global commodity chain analysis and the French filière approach: comparison and critique', Economy and society, 29(3).

Soligon, "Pig farming in Italy, the situation" , 2013, Mangimi & Alimenti (http://www.mangimiealimenti.it/articoli/609-suinicoltura-in-italia-il-punto-della-situazione).

DOI 2016: pfsd.2016.1651