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Integrating Supply Chain and Production Chain: a Genesis in the Ethanol Industry

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ABSTRACT: Although frequently used interchangeably, the concepts of supply chain and production chain are considered in this study as two distinct and complementary theoretical frameworks for the conception of a data-mapping model titled SCMap – Supply Chain Map. The model's objective is to identify and assess real chains of companies and products. An application in the agribusiness sector, starting with a specific sugarcane processing plant and the biofuel ethanol is performed. The SCMap establishes a structured and integrated manner of linking products and companies, considering three different categories of relationships: (1) between companies – supply chain approach; (2) between products – production chain approach, and; (3) between companies and products – regarding commercial practices in the corporate environment. Grounded on Graph Theory and Social Network Analysis – SNA, the software UCINET and NetDraw application are used to draw the maps and quantitatively assess the centrality of each company and product relative to the whole chain.

Keywords: Supply chain maps, product maps, production chain, chain visibility, agribusiness.

1. INTRODUCTION

Though often applied with similar meaning, supply chain (SC) and production chain (PC) are two terms that define distinct approaches widely used by academics and professionals for analysis of inter-business activities and relationships. The SC approach, linking companies, is associated to business management from the 1980s in order to address the integration of the internal company functions of purchasing, production, sales and distribution (Oliver & Webber, 1992); but as the concept applications evolve, the analysis begins to incorporate the external integration among companies with their suppliers and their customers at all levels, from producers of raw materials to final consumers (Lambert, Cooper, & Pagh, 1998). As a result of the expansion of the method's range, the concept of the network, instead of a chain, starts to reflect more accurately the complex relationships of the business environment in the scenario of global production and trade (Braziotis, Baurlakis, Rogers, & Tannock, 2013; Carter, Rogers, & Choi, 2015). However, for the purposes of this analysis, the term supply chain – SC is used both in the restricted sense of a string and in the expanded sense of a network.

On the other hand, the PC approach, linking products, is developed as an instrument of systemic vision (Castro, Lima, & Cristo, 2002), related to the concepts of filière, commodity chains and systems of provision, which attempt to describe the complex relationships between production and consumption (Bair, 2009) and contributes to the understanding and performance of comprehensive production systems with special application in agribusiness (Batalha, 1995). The term is widely used in Brazil to refer to a specific industry or sector for instance: the meat chain or the orange chain.

Individually, both SC and PC conceptual frameworks posit consistent contributions when dealing with the issues they respectively address. However, when considered in the real business environment, where it is usual for a particular company to produce and/or sell a varied and large number of products, often belonging to different chains (Braziotis et al., 2013; Mentzer et al., 2001), either the SC or PC approach, singly, demonstrate limitations to dealing with the relationships linking companies and their products.

The purpose of this paper is to provide an instrument which is able to identify and dispose companies and products as well as their relationships relative to the chains and networks. The specific objectives of the study are: (1) to create a scalable and structured way of showing companies, products and their relationships in real corporate environments, based on the application of the complementary approaches of supply chain and production chain; and (2) to assess the positioning of products and companies in relation to real chains and networks in which they are embedded, using the quantitative indicators that measure the centrality: degree, closeness and betweenness, from Social Network Analysis (Borgatti, Mehra, Brass, & Labianca, 2009).

Three types of relationships are considered and represented in an integrated and complementary manner: (1) relationships of companies, among customers and suppliers from the SC approach; (2) relationships of products, among components and derivatives, from the PC approach, and (3) relationships of companies and products, among firms and the products which they produce and/or sell in the market, typical of a corporate trading environment.

A real application of the SCMap was implemented, based on a focal firm related to a focal product in the agribusiness sector: a sugarcane processing plant located in the region of Ribeirão Preto, in the state of São Paulo, here designated as EP01 (ethanol plant number one); and the biofuel ethanol. The choice of ethanol, or ethyl alcohol, is due to the prominent role that biofuel occupies in the global scenario since it is considered an alternative source of renewable energy in the face of exhaustion of fossil fuel sources, especially oil and natural gas (Pimentel et al., 2008); also due to the role of Brazil as the second largest producer, which along with the United States, accounts for approximately 90% of all ethanol produced in the world (Renewable Fuels Association [RFA], 2013).

Considering the focal company (EP01) and the focal product (ethanol), the SCMap's model implementation is initiated by three basic procedures: (1) products' association, through a product tree structure following the PC approach; (2) companies' association, through a customer supplier structure following the SC approach; and (3) association of the products to the companies which supply them, through a relational structure following the SC and PC approaches together. The use of the NetDraw app (Borgatti, 2002) version 4.14, together with the UCINET ® software for Windows, allows the representation and assessment of companies, products and their respective relationships.

2. LITERATURE REVIEW

The idea of ties and links forming chains, and later networks, has been the subject of numerous analyses and results in different conceptual frameworks under no less varied terminology, in order to contribute to the understanding of the ways in which people, processes, goods and places are connected to each other, and the consequent influence that such configurations impacts in production systems at local, regional and global levels.

This literature review addresses two distinct chains and networks approaches applied in the study: Supply Chain – SC and Productive Chain – PC. It also presents a review of the concepts of Social Network Analysis – SNA as the foundation of the conceptual framework of the SCMap model.

2.1 Supply Chain

The term Supply Chain Management – SCM was introduced in 1982 by Keith Oliver, vice president of the London office of international consultancy, Booz Allen Hamilton (Bair, 2009; Frankel, Bolumole, Eltantawy, Paulraj, & Gundlach, 2008; Houlihan, 1984; Oliver & Webber, 1992; Stock, 2009).

Mentzer et al. (2001) define the term supply chain as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer". Similar concepts are mentioned in the literature, such as "set of firms" passing material forward (Londe & Masters, 1994), "alignment of firms" that bring products or services to the market (Lambert, Stock, & Ellram, 1998), and "network of organizations" linked in both directions, upstream or downstream, providing several processes and value-adding activities to the final consumer (Christopher, 1992).

Albeit with slight variations, it is evident that the focus of this approach is organizational entities and not products. It emphasizes, therefore, the firms' relationships common among customers and suppliers; and not products' relationships between components and derivatives, inherent to the transformation processes of manufacturing.

According to Mentzer et al. (2001) three levels of SC are identified considering its complexity: 1) the "direct supply chain", comprising a company and its immediate suppliers and customers, 2) the "extended supply chain", comprising a company, its immediate suppliers and customers, the suppliers of the immediate suppliers and customers of the immediate customers and so on, and 3) the "ultimate supply chain" involving a company, its immediate suppliers and customers, all suppliers and also all involved in the upstream and/or downstream flows of products, services, finances and/or information.

From the mechanical concept of a chain consisting of elements that are connected to each of its two immediate neighbors and which together form a strong flexible connection, the term supply chain conveys the idea of linearity when in reality it is observed that real SCs are more like expandable networks (Lazzarini, Chaddad, & Cook, 2001) that integrate multiple business and relationships (Lambert, Cooper et al., 1998), or supply networks composed of sets of SCs (Lamming, Johnsen, Zheng, & Harland, 2000). As a result of the expansion of the borders of this approach, the concept of network instead of chain starts to reflect more broadly the complex relationships of the business environment in the setting of production and global trade (Braziotis et al., 2013; Carter et al., 2015).

Even recognizing that the term supply network is better suiting than the term supply chain – SC, the latter will be used in the present work just for the purpose of maintaining the original terminology; but it is accepted that the resulting SCMap is most similar to a network instead a chain configuration with linear connections, or in other words, it is more similar to a "supply chain network structure", as coined by Lambert, Cooper et al. (1998).

In order to build theory and develop normative tools and methods for a successful SC management, Lambert, Cooper and co-author (1998) present a conceptual framework covering the combination of three strongly interrelated elements: 1) the structure of SCs, 2) the SC business processes, and 3) the management of SC components.

Placing the focus of this analysis just on the chain structure, which is understood as the network chain members and their connections and relationships, the present study considers just the two primary aspects of the network structure proposed by the authors: a) identification of members of SC, and b) structural network size. Assuming that a well-developed system of metrics (that is, it is able to evaluate the performance of SCs as a whole) can increase the chances of success of the entire chain with regard to aligning processes across multiple companies focusing on market sectors more profitably and achieving competitive advantage, Lambert and Pohlen (2001) present a new conceptual framework for the development of metrics to CSs analysis which consists of seven steps.

They are: 1) map the SC, 2) analyze every relationship, 3) develop statements of profit and loss, 4) realign processes in SC, 5) align non-financial measures with P & L, 6) make comparisons between companies and, 7) replicate.

Without losing sight of the integrated role that each one of those elements and steps play in their respective conceptual frameworks (Lambert, Cooper et al., 1998; Lambert & Pohlen, 2001), the SCMap model specifically focuses on the structure of the SC by identifying the members who comprise it and mapping them as a chain or network. Unlike other mapping approaches and methods found in academic works whose intent to incorporate various intra company levels of processes in a single consolidated instrument of analysis (Miyake, Torres, & Favaro, 2010), the SCMap model seeks just to contribute to the development of a structured and scalable model, able to identify and situate companies and their relationships in the real business environment with the aim of highlighting development opportunities in dyadic relationships of firms and in inter-organizational networks (Harland, Lamming, & Cousins, 1999).

2.2 Production Chain

According to Jennifer Bair (2009), the concept of production chain – PC is originally based on the filière approach, introduced in the 1960s by French researchers at the Institut National de La Recherche Agronomique and the Centre de Cooperatión Internationale en Recherche Agronomique pour le Développement. Frequently used interchangeably with the terms "commodity systems analysis" (Friedland, 1984) and "systems of provision" (Fine & Leopold, 1993), the researchers seek to describe "the sequence of processes by which goods and services are conceived, produced and brought to market".

In Brazil, the term filière, used as a synonym for production chain and special application in the agricultural sector, also describes a system that is the "chain of technical operations (downstream and upstream) reflecting the sequence of processing raw materials into finished products" (Batalha, 1995). Based on Jean Parent's study (1979), which defines the term as the sum of production and business processes needed to pass one or more "raw materials" to a "final product" until the product reaches the final consumer; Castro et al. (2002) summarize the concept as a "system, in which the various actors are interconnected by material flows of capital and information, in order to supply a consumer end market with system products".

It should be emphasized that, although based on the same chain design that connects actors, activities and products, it is clear that the focus of the PC approach encompases the products, whether raw materials, intermediate products or even products ready for consumption. In this approach, the firm's position within the system can be identified by observing the manufacturing process for which it is responsible in preparing the final product (Batalha & Silva, 2008).

Interestingly, instead of companies as depicted in the SC illustrations, the PC illustrations describe the transformation processes performed by these companies; this fact actually makes more sense, taking into account that the focus of analysis in this case are products.

The systemic character of the approach is another aspect worth mentioning in this study. While the concept of SC evolves from a linear supply chain to a network chain comprising interconnected organizations, the concept of PC also growsthrives from the idea of a chain to a systemic approach, able to contribute to the analysis of complex production systems.

The systemic vision of agriculture, coined as agribusiness, by John Davis and Ray Goldberg (1957) from Harvard University, was introduced in Brazil by Décio Zylbersztajn (1994) from the São Paulo University under the term "agroindustrial complex" and later "agribusiness system". The broader aspect of the approach enables the identification of other subsystems that compose it. Castro et al. (2002) argues that the agribusiness system consists of several production chains, or subsystems of the agricultural business.

Batalha and Silva (2008) term an agro-industrial system – SAI as a set of activities carried out in agricultural production from the production of inputs until the arrival of the final product to the consumer, but is not associated with any raw material or specific product. However, when the focus of analysis is a specific raw material, the authors use the term "agro-industrial complex"; on the other hand, when the starting point of analysis focus on a specific finished product, the term used is "agro-industrial production chain".

While acknowledging the application of the approach as originating from the agricultural sector, by virtue of its systemic character, Castro et al. (2002) argue that the model of PCs can "be applied to productive activities other than agriculture, such as the production of industrial products". The term is also used as one of its institutional action tools in Brazil, by the Ministry of Development, Industry and Foreign Trade, responsible for implementing the economic and administrative policy related to industry and commerce. The PC approach emphasizes the systemic view, since it allows comparison of a chain made up of links, each link in the chain in turn is equated with a particular sector of the production, which occurs in different industries responsible for independent operations and technologically separated (Ministério do Desenvolvimento, Indústria e Comércio Exterior [MDIC], 2015).

Particularly, in the food sector, where the issue of health is key, the focus on products justifies the PC approach, as it can contribute to traceability from components to the final product (Dekker, Verkeerk, & Jonjen, 2000; Miraglia et al., 2004). The above examples underscore the relevance of the SCMap model for the analysis of connected and sequential operations in different industries.

The analytical meso feature of the PC approach should also be highlighted. The approach is situated between the two great bodies of economic theory: microeconomic analysis, which considers the basic elements of the economic system; and macroeconomic analysis, which considers the major economic aggregates (Batalha, 1995).

2.3 Integrating Supply Chain (SC) and Production Chain (PC) Theory

As mentioned earlier in this literature review, two facts become evident when SC and PC theory are considered in an integrated way: 1) the micro analytical feature of the SC approach, focusing on the microeconomic environment composed of a company, its customers and suppliers and their respective relationships; and 2) the meso analytical feature of the PC approach, where the products are viewed in an aggregate way and not as individual atomic products; when referring to, for example, the beef chain or even the automobile chain, the idea is to explain a wide variety of meats or even different kinds of automobiles and their components, which in turn are produced by a set of aggregate companies in the meat industry or automotive industry, according to the case.

If, as stated by Batalha and Silva (2008), on the one hand the PC approach is shown useful as a tool for the development of public and private sector policies as a result of its meso analytical feature; on the other hand it is less efficient as a tool in the management of individual companies and their positions in their respective chains.

In order to move towards enabling the micro analytical feature of the SC approach to communicate with the meso analytical approach of the PC, it is necessary that the subsystem, called the productive chain, be also decomposed into another micro analytical subsystem at the product level, allowing specific products to be linked with specific companies. For this purpose, the SCMap model employs two different and complementary concepts widely used to standardize the description of materials and production processes: 1) the Harmonized Commodity Description and Coding – HS, which in Brazil led to the Mercosul Common Nomenclature – NCM/HS; and 2) the "product structure tree" or bill of materials – BOM.

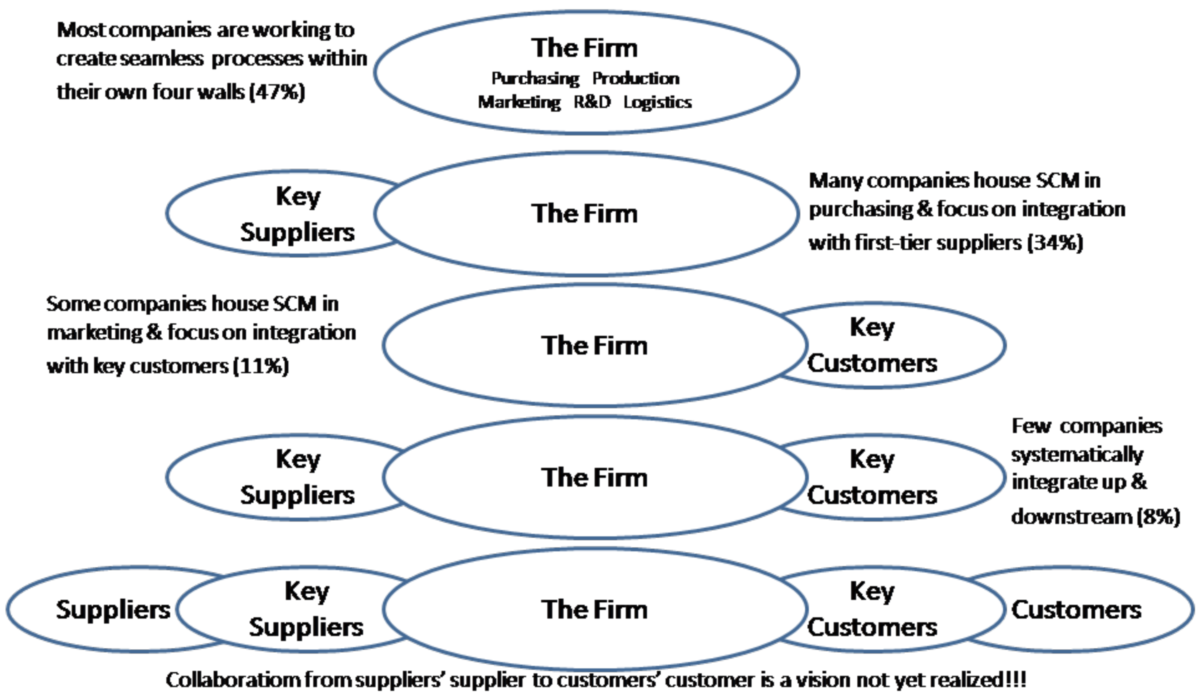
Able to establish a common language, to refer to products between two or more agents, the Harmonized Commodity Description and Coding System, also known as the Harmonized System HS, consists of a standard set of names and numbers for classifying traded products, developed and maintained by the World Customs Organization – WCO and accepted by more than 200 countries and economies. "It comprises about 5,000 commodity groups; each identified by a six digit code, arranged in a legal and logical structure and is supported by well-defined rules to achieve uniform classification" (World Customs Organization [WCO], 2015). In the South Common Market – MERCOSUL, comprised of Brazil, Argentina, Paraguay, Uruguay and Venezuela, the HS is used with the addition of two digits for the purpose of a more detailed characterization of the products, resulting in the Mercosul Common Nomenclature – NCM/SH. But for scope delineation, this study only considers the classification of products with the first four digits of the HS, two for the chapter and two related to the position the product occupies in relation to everything else.

The BOM is a formally structured list for an object, semi-finished or finished product, which lists all the component parts of the object with the name, reference number, quantity, and unit of measure of each component, which captures the end products, its assemblies, their quantities and relationships. The academic contribution and both the opportunities and challenges related to these lists is significant (Choi, Dooley, & Rungtusanatham, 2001; Giménez, Vegetti, Leone, & Henning, 2008; Li, Yang, Sun, Ji, & Feng, 2010; Pathak, Dilts, & Mahadevan, 2009; Vegetti, Leone, & Henning, 2011; Vidal & Goetschalckx, 1997; Yan, Yu, & Cheng, 2003). Despite the discussion about the use of the BOM in inter companies relationships, in the SCMap model the list is considered only as a means of determining relationships between two classifications of products: 1) the products which companies provide to the market, or "top products" (Hegge & Wortmann, 1991) and, 2) the products which these companies acquire from the market in order to produce the former, or "primary products" (Hegge & Wortmann, 1991). Processes and production methods as well as intermediate products resulting from different stages of the inside company manufacturing process, also called "subassemblies" (Hegge & Wortmann, 1991) are not part of the scope.

Among the difficulties in the application of the SC theoretical concepts in the corporate environment, there is the fact that a company belongs to different chains. Although Lamming et al. (2000) attempt to classify supply networks according to the type and characteristics of the product that is being considered, their respective representations fail to show real situations where a company can produce more than one product and therefore belong to more than one SC.

The difficulties encountered in implementing the concepts and definitions of conceptual frameworks of SCs in real environments are mentioned in Fawcett and Magnan's (2002) study, where "few companies have adopted and disseminated the formal definition of SCM. And they've even less meticulously mapped their supply chains, so that they can know who the suppliers of their suppliers and customers of their customers are" (Fawcett & Magnan, 2002, p. 340). The authors conclude that integration to the extent proposed by academic concepts was perceived as very rare – constituting more a theoretical ideal than a practical reality, as shown in Figure 1.

Figure 1. Different views of supply chain integration



Source: Fawcett and Magnan (2002).

The same view is shared in the work of Kim, Choi, Yan and Dooley (2011) where the authors point out the low quantity of actual supply networks studies, given the difficulty of obtaining data and also the lack of effective tools for mapping and treating such data. According to Lamming et al. (2000), a review of the supply networks literature, reveal that none of the existing approaches correctly addresses the practicalities of day-to-day life lived by the professionals working in the area.

However, this situation gets new contours in the first decade of the 21st century with the development of modern methods and collection technologies, processing and analysis of large amounts of data via computer systems and the internet (Barabási, 2012). Based on the study and analysis of social networks – SNA (Social Network Analysis) in the social sciences, a stream of SC researchers recognize the acceptance of the fundamentals and instruments of the SNA approach as particularly adjusted to the study of the inter-relationships in a SC (Borgatti & Li, 2009; Carter et al., 2015; Kim et al., 2011; Mueller, Buergelt, & Seidel-Lass, 2008; Talamini & Ferreira, 2010).

2.4 Social Network Analysis

Social Network Analysis – SNA, belongs to a field of sociology that studies sets of individuals and the links between them, based on graph theory, algebra and statistics. Starting from sociometric studies prepared by psychiatrists Jacob Moreno and Helen Jennings, who in 1932 tried to understand the drop-out students in a school in New York, it was possible to associate the theme Physics and Sociology and conclude that such behavior was more related to the position of students in the network that they were part of, than to their individual characteristics (Borgatti & Li, 2009).

In the following years, the expansion of the use of the SNA approach to other fields occurred explosively, the analysis was used to study the behavior of genes and other cell components, counter-terrorism, prediction and analysis of epidemics, mapping neural networks, and the administration of intra and inter-organizational structures, among others (Barabási, 2012).

Early studies of graph theory, a subarea of mathematics, that studies the combinatorial relationships between objects of a given set, focused on network analysis, dating from 1735 (Barabási, 2012). Significant contributions were the work of Erdős and Rényi (1959), who introduced the study of random networks in graph theory and Granovetter (1973), who addressed the influence of the social network in which individuals are involved. But only at the end of the 1990s, with the development of instruments for collecting and processing data and the advent of information and internet technology, were the practical applications of these concepts made possible, as then it became feasible to visualize, study and describe the behavior of systems compounded of hundreds to billions of interacting components, such as the list of friends, friends of friends and so on; detailed list of interactions and reactions of genes, proteins and metabolites in a cell; or even the behavior of hundreds of billions of interconnected neurons in the brain (Easley & Kleinberg, 2010).

Despite the obvious differences between the individual characteristics of each network found in nature or in society as well as between the diversity of processes that shape the relationship of its agents, the fundamental fact is that the architecture and evolution of these networks are very similar to each other, allowing the use of a set of mathematical tools in common to exploit these systems and understand the behavior of each of its components as well as the network as a whole (Barabási, 2012).

In the academic literature, networks consist of a number (N) of actors, commonly called nodes or vertices and a relationship (L) between them, usually called links or edges. The real networks are composed of a widely varied number of nodes (N) and links (L) that can be analyzed from a vast amount of mathematical assessment tools. This requires that a complete list of nodes and links is represented by an adjacent matrix composed of a square matrix with the same number of rows and columns as the number of network agents, and Aij elements of this matrix to represent the links between agents (Mueller et al., 2008).

The standardized representation of agents (nodes) and their relationships (links) through charts also facilitates visualization and understanding as it allows recognition and can suggest new perspectives and inferences about a set of data, based on the assumption that it is possible to get more information by sight than by all other senses combined (Ware, 2004).

Thus, the fundamental functionality of the SNA is the application of mathematical models based on the properties of graph theory for the study and evaluation of a network formed by a number of agents and links that represent the relationships between them, according to the position occupied and the frame that compose the network. The metrics used in SNA are designed in two levels – at the level of individual agents (nodes) and at the network level.

From the point of view of an agent, the concept widely used is the centrality, which measure as a single agent is associated with all the remainder agents that comprise the network and thus reflects the relative importance of this agent in the network (Freeman, 1979). Three metrics are most commonly used to evaluate the centrality index: degree, closeness and betweenness. The centrality degree indicates the amount of other agents with which a particular agent is connected (indegree – outdegree), thereby measuring the visibility of an agent on a network. The centrality of closeness indicates how close an agent is to the other agents in the network, besides those to which it is directly connected; this makes it possible to measure how easily the agent can be connected to any other agent of the network. The centrality indicator, which measures the betweenness, indicates the importance of an agent in relation to other agents, through which it could be connected to the rest of the network, so it is able to measure the agent's ability to allow interaction between other agents in the network (Freeman, 1979).

At the network structure level as a whole, three metrics are noteworthy: density, centralization and complexity. The density refers to the actual number of links of the network, compared to the total of all the possible links assuming that all agents were connected to each other, when the network density would be equal to 1 (Scott, 2000). The network centralization indicator seeks to assess the degree of the central agents in a network. A central agent is one through which pass most of the network connections; in this case a network with a greater degree of centralization is the one that shows the structure of a star where a single agent is connected to all others that, in turn, are not connected to each other; on the other hand, the lowest degree of centralization network occurs when all agents have the same number of connections to each other (Freeman, 1979). Thus, it can be said that the level of centralization of a network is related to the distribution of power or control over all network agents, whereas the density reflects the cohesion between its agents. The degree of complexity, in turn, is defined as the number of dependency relations in a network and considers both the number of agents as well as the degree to which they are connected to each other. This fact indicates that more complex networks require more operational responsibility and coordination (Kim et al., 2011).

It is not uncommon in the literature the existence of studies where SNA and SC are used concomitantly. In these studies, companies are linked to other companies as notes linked to other nodes assuming the configuration of networks (Borgatti & Li, 2009; Kim et al., 2011; Mueller et al., 2008; Pahri, 2005). The SC-Map model makes advances in this regard, including in the analysis a structured way to connect products and their relationships to both its components and to companies that provide them; or even to connect companies and their relationships to both their customers and suppliers, as well as to the products they manufacture and/or sell.

3. METHODOLOGY

Given that in an extended sense all products, and agents that produce and make them available on the real market, are in some way related, being part of a single, interconnected global network, this paper defines a limited scope to a company and a product, and thus seeks to establish a starting point for analysis chains and more complex networks.

Each one of the four steps of the methodology, detailed in the following subsections, is supported by real data provided by the studied Ethanol Plant. Excel spreadsheets listing all the products (components) acquired for the Ethanol production, as well as its suppliers, were made available by the Company under a non-disclosure agreement.

Although the quantitative methods of the SNA analysis can be carried out concerning the flow of materials, tangible and intangible goods, for example: products, money and information, as pointed by Talamini and Ferreira (2010), the present analysis considers products and firms as nodes linked by ties following the method of use SNA in a SC context proposed by Borgatti and Li (2009). The paper is also intended to follow the methodology proposed by Kim et al. (2011), where the authors applied the SNA approach to analyze in terms of both the flow of material and the contractual relationships of three different automotive supply networks.

To this end, the following procedures are followed in this study: (1) definition of a focal company and consequently a specific focal product manufactured and

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supplied by it, connecting them through a company/ product link or relationship; (2) identification of the acquired components used for the focal product manufacturing, and consequently linking each component to the focal product by a product/product connection; (3) identification of components' suppliers and the product's buyers and consequently association of the focal company with both, on the one hand, its suppliers and on the other hand, its customers, through company/company connections; and finally, (4) association of each component to the companies which provide them via company/ product links.

3.1 To Define a Firm and Associate It to a Product

The concept of a focal company – FC is considered as the starting point for the definition of a supply or network chain as shown by Lambert, Cooper, and Pagh (1998) and by Fawcett and Magnan (2002). But once a company can produce a varied and wide range of products, the purpose of this work is to associate it with a specific focal product – FP.

In this paper the choice of ethanol as FP takes into account the importance of agribusiness in the global and domestic scenario in Brazil, previous work of the authors, and the relevance of renewable fuel within this context in Brazil and worldwide. The FC (ethanol plant), here designated EP01, properly identified in the Brazilian national register of legal entities CNPJ, Ministry of Finance of Brazil, under a specific record, located in the state of São Paulo, and therefore entitled to produce and supply the FP (ethanol) to other companies or consumers through commercial activity (Rosenbloom, 2008), is one of the units belonging to one of the largest sugar and ethanol groups in Brazil with milling capacity of over 20 million tons of sugarcane per year.

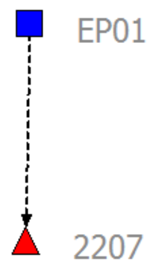
The concept of FP is connected to the chapter and position 2207 of the international code of the Harmonized System – HS, identified as Ethyl Alcohol. In this case the FC produces two distinct products under the same 2207 HS Code:

1. Anhydrous alcohol (undenatured ethyl alcohol with water content =<1% vol), NCM 22071010, and

2. Hydrated alcohol (other ethyl alcohol undenatured with alcohol content => 80 vol%), NCM 22071090.

For illustration purposes, FC represented by a square named EP01, and FP (ethanol) represented by a triangle identified by the code 2207 are connected via a company/product link represented by the dashed arrow (Figure 2).

Figure 2. Focal company – EP01, associated to the focal product (Ethanol) – 2207



3.2 To Identify the Components Acquired by the Focal Company and Associate Them to the Focal Product

The identification of ethanol components is performed based on information provided by EP01, which consists of the description and NCM code of each product that it acquires for the production of ethanol.

For scope delimiting effect, 19 products are considered, representing more than 90% of the inputs used for the production of the FP. The inputs are classified as eight agricultural inputs (AI) used in the production of cane sugar (codes 1207, 2521 , 2710, 2833, 2921, 3103, 3105 and 3808); ten chemical inputs (CI) used in the production of ethanol (codes 2102, 2801, 2807, 2815, 2828, 2902, 2941, 3821, 3822 and 3907), and the sugar-cane (SC) (code 1212).

While EP01 provides commercial names and the eight digits of the NCM of each input, the SCMap model allows visualization of only the first four digits of the harmonized system corresponding to the chapter and the product. The complete coding NCM is only maintained for indexing purposes, allowing consistency for future comparisons. For the purposes of graphic representation, each input has been identified by the first four digits of the HS.

Based on the product tree structure or bill of material, each of the agricultural raw materials are associated with sugarcane; consequently, in the same way sugarcane and the other chemical inputs have all been associated to the focal product, ethanol, through the solid arrows, as shown in Figure 3, which represent the product/product links.

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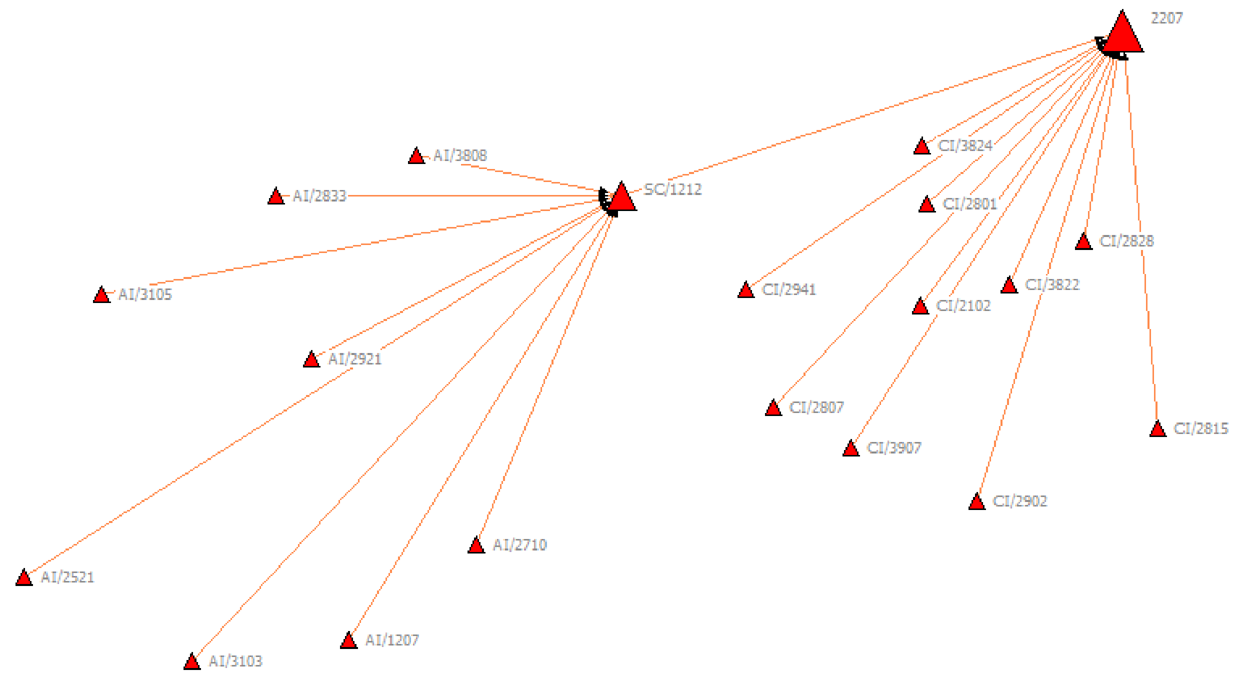
Figure 3. Relationships among the focal product ethanol (2207) and its components



Data about quantities and prices as well as the manufacturing and transformation processes exercised internally in the company are not part of the study scope.

3.3 To identify the Direct Customers and Suppliers Associated to the Focal Product and Link them to the Focal Company

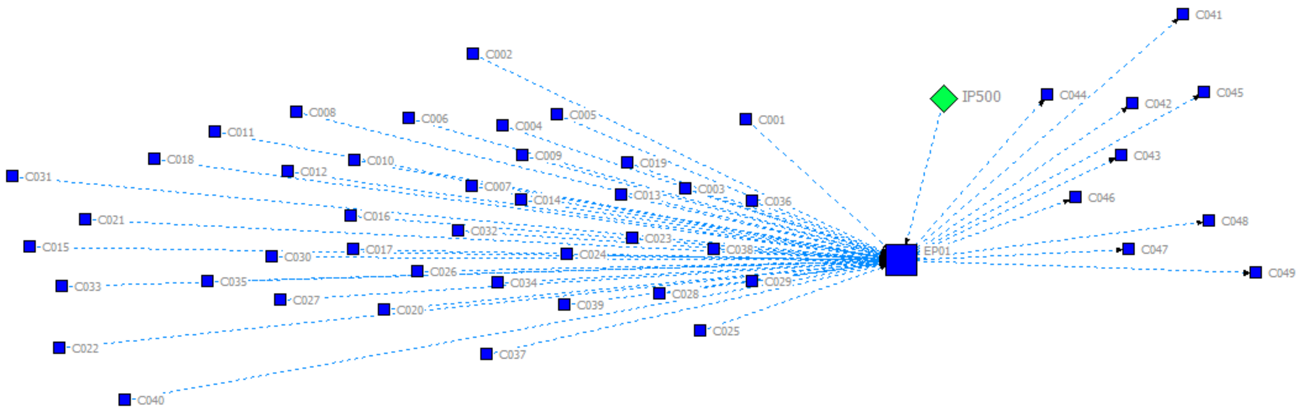
Along with the identification of the components, EP01 provided the commercial name and the CNPJ number of each of the 40 active suppliers of chemical inputs (CI) and agricultural inputs (AI) acquired for the ethanol manufacturing; the focal company also provided the commercial name and CNPJ code of its nine customers responsible for the acquisition of more than 80% of its biofuel production.

According to the company, the sugarcane is produced by their own farms, and complementarily is also acquired from a set of 729 external producers: 500 of them independent producers that negotiate based on market conditions, and 229 partners under contractual relations (Neves, Waak, & Marino, 1998).

Each of the 40 suppliers are represented by circles identified as C001 (company one) to C040 (company forty), and the nine customers are represented by the circles from C041 to C049. The 500 independent producers, suppliers of sugarcane, are represented by a single diamond identified as IP500.

Producer "partners" are not represented in this work, as the output of their production is considered as part of the EP01 production itself. All input suppliers, independent producers that supply sugarcane and customers which acquire ethanol, are associated with EP01 via company/company links represented in Figure 4 by the dotted arrows.

Figure 4. Part of the focal company direct supply chain associated to the ethanol



Only the active suppliers and customers with whom EP01 maintains or has maintained trade relations (Choi & Krause, 2006), involving the purchase and sale relating to ethanol operations within the last 12 months are considered. Strategic information, such as price, quantities, production processes and any other kind of commercial relationships, are not part of the scope. Data such as corporate name and CNPJ code of each company are not disclosed, but will have the important function of acting as indexers able to allow future comparison and visibility between companies that allow mutual information-sharing. Sugarcane suppliers are not identified individually, and may not be indexed, so will not allow further comparisons with data from other companies.

As defined by Mentzer et al. (2001), the representation of a company, its suppliers and direct customers are called the "direct supply chain". Thus, if EP01 produces just one product, or ethanol, it could be said that Figure 4 represents its direct supply chain. But in reality, besides ethanol, EP01 also produces sugar, and even taking into account that, in this particular case, almost all of the inputs used to produce ethanol are the same as those used in the production of sugar (Tokgoz & Elobeid, 2006), the customers are different when taking into consideration the ethanol and sugar separately. So the complete direct supply chain representation of EP01 should also consider all customers who acquire the sugar from the company, which is out of the scope of the present work.

Taking these factors into account, it is prudent to note that Figure 4 represents only a part of the direct supply chain of EP01; in other words, the part of its direct supply chain referent to the product ethanol.

3.4 To Associate Each Component to the Company which Supplies It

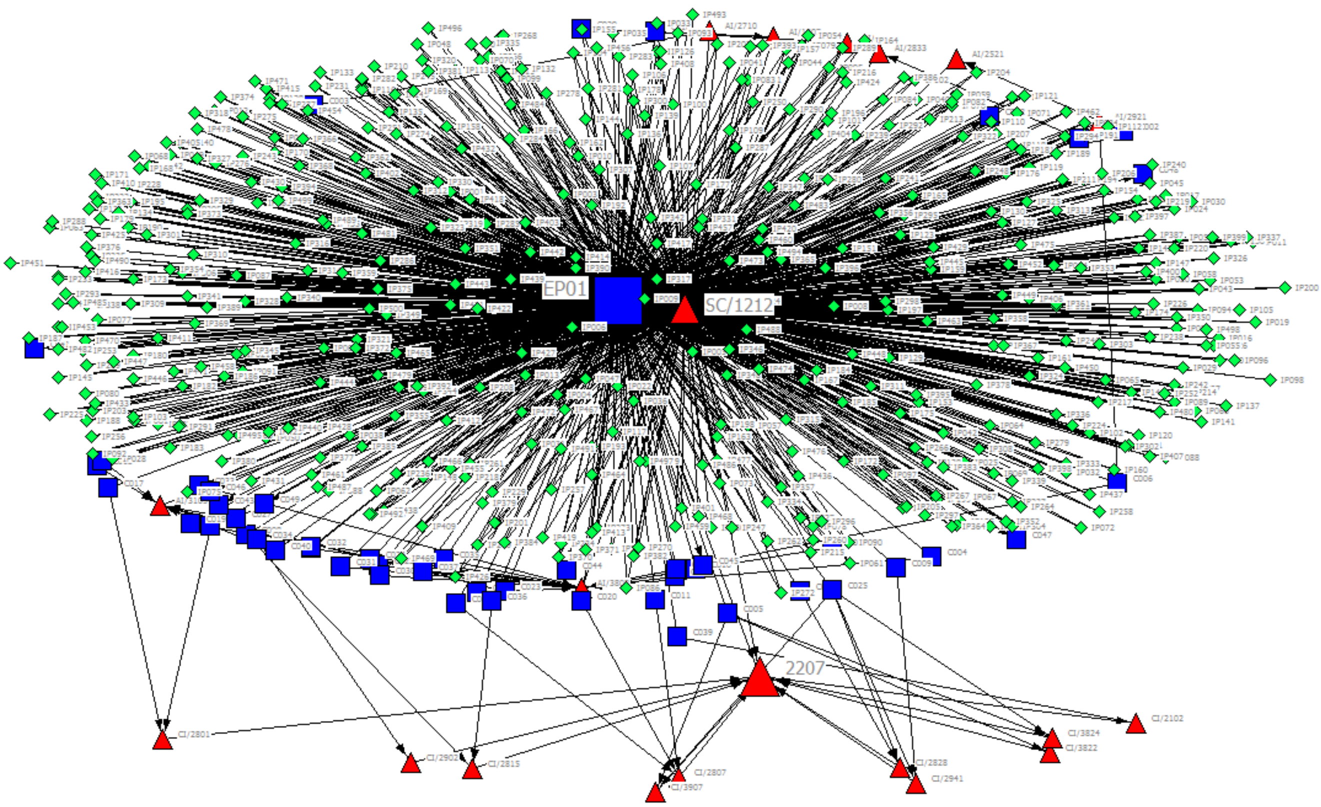
After have each component identified and associated to the ethanol, according to the PC approach (Figure 3); as well as each supplier and customer associated to EP01, according to the SC approach (Figure 4); all considered companies are then associated to the product or products that they produce and/or provide to the market integrating the approaches of PC and SC in a complementary way. These company/product links are represented by dashed arrows.

3.5 Social Network Analysis Methodological Tools

Considering companies and products as agents or nodes, and the relationships or associations among such agents as connections that connect the nodes which configure the network, it is possible to calculate indicators that measure the centrality degree, closeness and betweenness, or in other words, the importance of an agent, company or product, in relation to the others being considered (Carter et al., 2015, Freeman, 1979). Quantitative analysis of the importance of each product and company, based on their respective positions in relation to all the others, is reached using the UCINET® software, grounded on graph theory and social network analysis – SNA (Borgatti et al., 2009).

While the study's scope covers a total of delimited agents in 50 companies, 500 producers of sugar-cane and 20 products, the constant concern is with the search for instruments capable of supporting analyses that consider the exponential increase of agents which act in the real environments of chains and networks of companies and products. Thus, by using NetDraw software, part of UCINET, it is possible to portray the products and companies related to EP01 and ethanol as shown in Figure 5.

Figure 5. A NetDraw view of the products and companies related to EP01 and ethanol (2207)



4. RESULTS

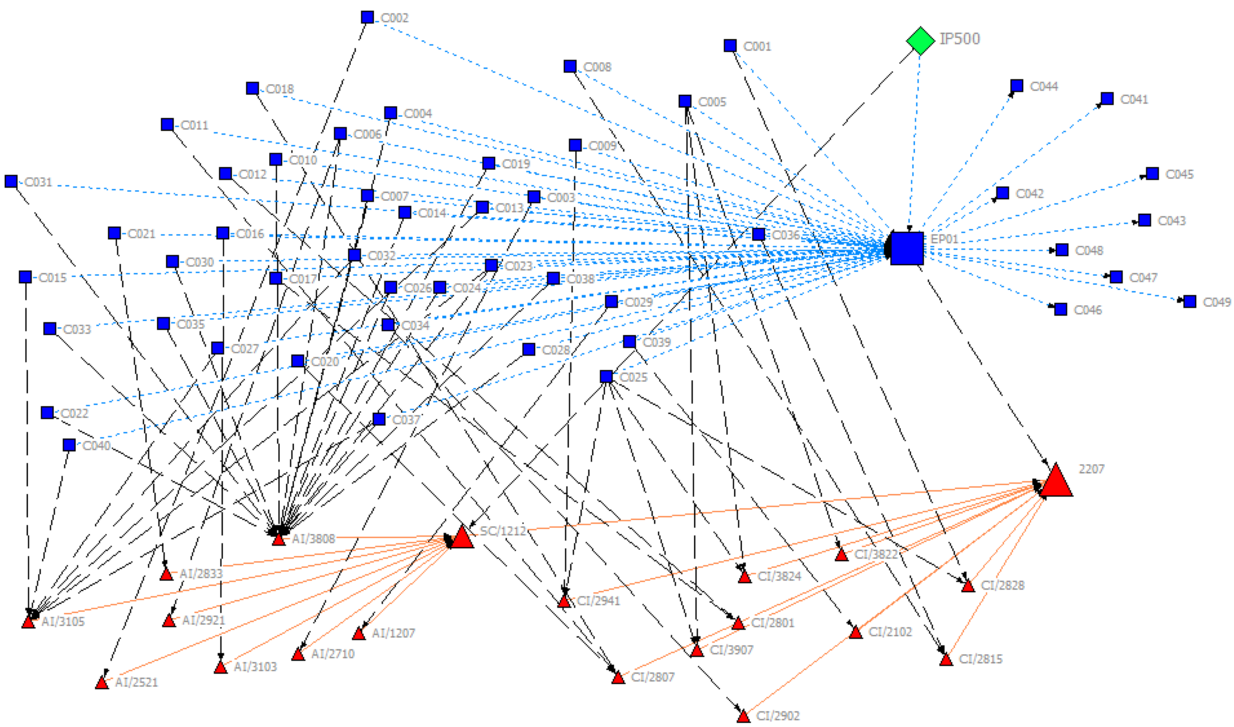
Although the resulting network diagram (Figure 5) cannot be considered absolutely illuminating, visually speaking, through the software UCINET, and its NetDraw application, following the SCMap model, it is possible to create a more user-friendly graphical image of real companies, products and their relationships based on both SC and PC approaches. See Figure 6.

It is also possible to quantitatively evaluate the position of each company and each product related to the whole network, calculating the centrality degree indicators as described in Table 1.

4.1 Graphic Design

The map resulting from this study allows the visualization of the EP01's chain of companies and products associated with respect to ethanol. Three different kinds of relationships are introduced, as shown in Figure 6.

Figure 6. SCMap of EP01 relative to ethanol (2207)



At the bottom side, the products are represented by triangles. According to the PC approach (Castro et al., 2002), the FP (ethanol) is associated with sugarcane as well as with agricultural and chemical inputs which EP01 uses to manufacture it. Product/product links are represented by solid arrows.

Displaying products and their components, the map contributes to some relevant issues such as transparency analysis, traceability, sustainability, life cycle, environmental footprint and reverse logistics, as well as other metrics concerning the origin of the products used and consumed in global markets as well as the destination of their wastes and discharges, a growing concern among large business groups and organizations representing society (Hoffman, 2013).

In the upper portion of the SCMap, the direct supply chain (Mentzer et al., 2001) of EP01 related to ethanol (2207) is shown. Companies are represented by squares and the sugarcane producers represented by a single diamond; EP01 is associated on one side with its suppliers and on the other side with its customers by company/company linkages according to the SC approach (Braziotis et al., 2013; Fawcett & Magnan, 2002; Lambert et al., 1998; Mentzer et al., 2001). Such links indicate trade relations between customers and suppliers (Choi & Krause, 2006) and are represented by dotted lines.

The upper portion (SC) and the lower portion (PC) are then associated, allowing the visualization of the company/product links represented by dashed arrows according to the SCMap model, in order to allow each company to be associated to the product or products which it provides. It becomes an important tool, able to identify companies and the products they supply in the commercial market environment.

Figure 6 is thus the graph results of this work, in compliance with the proposed scope and objective of the study. Even illustrating just part of the direct supply chain, it can be considered the starting point of an unlimited network map.

The differential, and therefore the contribution of the SCMap structured model, is to allow the expansion of the representation of companies and products indefinitely by the replication of the model.

By changing the focus of analysis, considering any other product and company associated with each other, as focal product and company, the model allows replication of the procedures described in the methodology, thus expanding the representation exponentially, but in a structured way, once products and companies are indexed through their respective standard codes.

Besides the above-mentioned contributions to the supply chain management area, the SCMap model additionally offers the possibility to identify and display individual classes of products associated to the companies which produce and/or trade them, allowing the identification of products, components as well as the companies that produce and/or supply them to the market.

4.2 Quantitative Analysis of the Chain Companies and Products

Using the UCINET software, it is possible to calculate the centrality degree indicators: in/outdegree, closeness and betweenness for each one of 550 companies (Table 1) and 20 products (Table 2) comprised in this analysis. Considering the limited scope of this starting analysis, the density, centralization and complexity's measures of the network as a whole are not considered.

As shown in Table 1, with respect to EP01's suppliers (from C001 to C040), the highest outdegree value (5.000) for the supplier C025 shows that it enjoys greater importance as it is connected to a higher number of nodes than any other supplier (four products and one company); this fact means it is the company which provides the largest number of products on the network. By the same criterion, the supplier C005 with a value 4,000 of outdegree, and suppliers C006, C023 and C037 with outdegree of 3,000 each, are next in order of importance. Taking into account just the quantity of products provided to the network, all other suppliers have the same relative importance (outdegree = 2,000).

While this result does not indicate a significant importance, due to the small size of the sample considered, as more companies begin using the model, this indicator becomes more relevant, since it is able to measure among others the relationship of a company and a product with other companies and products, and thereby contribute effectively to the identification of bottlenecks, concentration of products and suppliers, and dependence risks of suppliers and materials.

Table 1. Centrality indicators of each company COMPANIES

	DEGREE		CLOSENESS		BETWEENNESS
CODE	**OUT**	**IN**	**IN**	**OUT**	
EP01	10.000	540.000	3.333	0.179	5.142.950
IP500	2.000	0.000	0.175	0.179	0.000
C001	2.000	0.000	0.175	0.179	0.000
C002	2.000	0.000	0.175	0.180	0.000
C003	2.000	0.000	0.175	0.180	0.000
C004	2.000	0.000	0.175	0.180	0.000
C005	4.000	0.000	0.175	0.180	0.000
C006	3.000	0.000	0.175	0.180	0.000
C007	2.000	0.000	0.175	0.180	0.000
C008	2.000	0.000	0.175	0.179	0.000
C009	2.000	0.000	0.175	0.179	0.000
C010	2.000	0.000	0.175	0.180	0.000
C011	2.000	0.000	0.175	0.179	0.000
C012	2.000	0.000	0.175	0.179	0.000
C013	2.000	0.000	0.175	0.180	0.000

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C014	2.000	0.000		0.175	0.180		0.000
C015	2.000	0.000		0.175	0.180		0.000
C016	2.000	0.000		0.175	0.180		0.000
C017	2.000	0.000		0.175	0.179		0.000
C018	2.000	0.000		0.175	0.179		0.000
C019	2.000	0.000		0.175	0.180		0.000
C020	2.000	0.000		0.175	0.179		0.000
C021	2.000	0.000		0.175	0.180		0.000
C022	2.000	0.000		0.175	0.180		0.000
C023	3.000	0.000		0.175	0.180		0.000
C024	2.000	0.000		0.175	0.180		0.000
C025	5.000	0.000		0.175	0.180		0.000
C026	2.000	0.000		0.175	0.180		0.000
C027	2.000	0.000		0.175	0.180		0.000
C028	2.000	0.000		0.175	0.180		0.000
C029	2.000	0.000		0.175	0.180		0.000
C030	2.000	0.000		0.175	0.180		0.000
C031	2.000	0.000		0.175	0.180		0.000
C032	2.000	0.000		0.175	0.180		0.000
C033	2.000	0.000		0.175	0.180		0.000
C034	2.000	0.000		0.175	0.179		0.000
C035	2.000	0.000		0.175	0.180		0.000
C036	2.000	0.000		0.175	0.179		0.000
C037	3.000	0.000		0.175	0.180		0.000
C038	2.000	0.000		0.175	0.180		0.000
C039	2.000	0.000		0.175	0.179		0.000
C040	2.000	0.000		0.175	0.180		0.000
C041	0.000	1.000		3.339	0.175		0.000
C042	0.000	1.000		3.339	0.175		0.000
C043	0.000	1.000		3.339	0.175		0.000
C044	0.000	1.000		3.339	0.175		0.000
C045	0.000	1.000		3.339	0.175		0.000
C046	0.000	1.000		3.339	0.175		0.000
C047	0.000	1.000		3.339	0.175		0.000
C048	0.000	1.000		3.339	0.175		0.000
C049	0.000	1.000		3.339	0.175		0.000

Regarding the products (Table 2), the indegree indicator shows that the agricultural input AI 3808 is the one with the highest value (17,000), indicating that it is less important from the point of view that there are more companies able to provide it; on the other hand, the agricultural and chemical inputs whose indegree has the lowest value (1.000) should receive greater care from the point of view of supply, since they are supplied by only one company, indicating a high commercial dependence level.

Also deserving some note are the products' betweenness indicators. As can be seen, the agricultural input AI3808 with the highest value (15,500) indicates it is the product most common to the entire chain or network in terms of access to all other products and companies, which may indicate that its availability is more vulnerable to external impacts of other chains. On the other hand, the chemical input CI3822 with

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the lowest value (0.250) is the most isolated product in terms of connection with other network agents and therefore less sensitive to external impacts.

Table 2. Centrality indicators of each product

PRODUCTS					
	DEGREE		CLOSENESS		BETWEENNESS
CODE	**OUT**	**IN**	**IN**	**OUT**	
2207	0.000	12.000	9.122	0.175	0.000
SC/1212	1.000	508.000	2.853	0.176	258.000
AI/1207	1.000	1.000	0.176	0.176	1.000
AI/2521	1.000	1.000	0.176	0.176	1.000
AI/2710	1.000	1.000	0.176	0.176	1.000
AI/2833	1.000	1.000	0.176	0.176	1.000
AI/2921	1.000	1.000	0.176	0.176	0.500
AI/3103	1.000	1.000	0.176	0.176	1.000
AI/3105	1.000	7.000	0.178	0.176	6.000
AI/3808	1.000	17.000	0.181	0.176	15.500
CI/2102	1.000	1.000	0.176	0.176	0.500
CI/2801	1.000	2.000	0.176	0.176	1.000
CI/2807	1.000	3.000	0.176	0.176	1.500
CI/2815	1.000	2.000	0.176	0.176	1.000
CI/2828	1.000	2.000	0.176	0.176	0.700
CI/2902	1.000	1.000	0.176	0.176	0.500
CI/2941	1.000	2.000	0.176	0.176	0.700
CI/3822	1.000	1.000	0.176	0.176	0.250
CI/3824	1.000	2.000	0.176	0.176	0.450
CI/3907	1.000	2.000	0.176	0.176	0.450

The in/out closeness indicators, as well as all indicators related to the purchasing companies (from C041 to C049) and EP01, are not relevant, given the size and scope of the sample. The sugarcane (1212) and ethanol (2207) indicators will also make more sense when it is possible to expand the network by considering new products and businesses.

Among the limitations of the work, there is the restriction of the scope for a focal company and a focal product, as well as the limitation of analysis that considers only three central indicators among many others possibly arising from the SNA. This fact speaks to the wide possibilities of expansion of the analysis under this model, which is presented only as an initial approach; we cannot see the full consequences of this model presently.

5. CONCLUSION

Using the SCMap model it is possible to visualize products, companies and their relationships, as well as to identify and analyze the positioning of products and companies that make up the real chains and networks of the corporate environment, thus contributing to the issue of visibility and application of supply chain management concepts in real environments of companies and the products which they trade.

It is also possible to provide a quantitative analysis of their respective positions in relation to the other, obtaining the centrality indicators derived from the network analysis, specifically Social Network Analysis. These indicators have proved able to measure and assess the importance, criticality and substitutability of companies and products when compared with each other on the same chain or network.

While recognizing the limitation of this study, considering the modest number of companies and products in face of real situations, the proposed structure should be viewed just as a starting point for linking products and companies properly indexed in a standardized manner, allowing unlimited expansion through replication of the methodology.

The SCMap model enables the development of future work where real chains may be identified and represented in expanded form, taking into account suppliers, customers, components and derivatives of each single product and/or company represented in this initial work, thus contributing to perform the theoretical ideal of the production chain and supply chain approaches.

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