International Regional Science Review

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International Regional Science Review 2011 34: 34

DOI: 10.1177/0160017610387295

International Regional Science Review
34(1) 34-74

DOI: 10.1177/0160017610387295
http://irsr.sagepub.com

The Embeddedness of the Agro-Food System in the Spanish Interindustrial Structure

Pedro Noguera-Méndez[1] and María Semitiel-García[1]

Abstract

The agro-food system (AFS) is an integrating component of the networks behind interindustrial systems. This implies that the structure of AFSs affects and is affected by the characteristics and evolution of the more complex networks in which they are embedded. This article uses national and regional input–output data to analyze the network structure of the Spanish interindustry system for the period 1980–2000. Network theory (NT) and social network analysis (SNA) have been applied to examine the structural position and evolution of the AFS in the whole interindustrial system. Following a systemic view, it is stated that the Spanish interindustry network follows a hierarchical topology, in which a core and a periphery can be identified. The AFS is a cohesive module occupying a peripheral position in the interindustrial structure. Those findings are very relevant from a policy perspective, as it is essential to have a deep knowledge of the structure of a system before acting on it. According to the dynamics of the analyzed national and regional AFSs, actions would imply coordination with policies focused on core sectors, mainly business services, trade and hotels and restaurants, and on sectors belonging to other production systems.

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Keywords
agro-food system, input–output linkages, core–periphery structure, network analysis

Introduction

The agro-food system (AFS) is defined as a production system made up of primary sectors (agriculture, farming, forestry, and fishing), the food industrial sectors that transform primary products (meat industry, milk industry, vegetable preserves, beverages, etc.), and all their market linkages.[1] AFS is a part of the more complex agribusiness system, which includes distribution activities and input suppliers.[2] Agribusiness, in turn, is embedded in a more complex system: the whole national, or regional, interindustrial system, including all the economic sectors and their trade linkages.

From a policy point of view, knowing the structure of AFS and of the whole system in which it is embedded, should be a matter of concern. The design of agro-food policies without knowing the structural characteristics of the sectors to which they are directed, and without understanding how they interrelate with other production systems, leads to efficiency losses. Unwanted and missed policy effects could be partially avoided by applying the rule "knowing before doing." Moreover, the required knowledge should be systemic, given the complexity of economic structures. There are phenomena taking place at system level, in the whole complex of relationships, which are not considered in sectoral analyses. The same applies when sectoral policies are being designed: (1) there are policy effects for the whole complex of relationships that are not taken into consideration in the design of sectoral policies; (2) there are policy effects from the whole complex of relationships, coming from non-AFS sectors, which we could never anticipate by just looking at one particular economic sector.[3]

This article seeks to analyze the technical links defining AFS sectors as interrelated elements in a complex system. The wider complex system in which AFS is embedded is the Spanish interindustrial system. Its structure and evolution is studied over the period 1980–2000, through national and regional input–output (IO) tables, so as to focus on AFS as one of its subsystems. As there is a network behind the interindustrial system, with a specific structure, it is necessary to understand its organizing principles and so obtain an appropriate knowledge of AFS. AFS is, then, analyzed by focusing just on its structure and on its integration in the whole interindustry system. The methodology, network analysis, is also structural, following a systemic view and allowing an appropriate study of relational data. This article will show that the Spanish interindustrial system follows a Modular Scale-free, or Hierarchical, topology, in which a core and a periphery can be identified. AFS is located in the periphery and it integrates into the whole system through direct connections with the core and with other production systems. Service activities appear as key sectors guaranteeing the AFS integration in the whole network, connecting it with other systems and with the core. There are also industrial sectors that belong to other production systems directly connected to AFS and which, therefore, affect its integration.

This article will demonstrate that the consideration of a relational perspective enhances our understanding of regional production systems, so favoring in the design and expected effects of agro-food policies. When a systemic view is followed and network analysis is conducted, one of the main conclusions is that appropriate agro-food policies should not necessarily be directed exclusively or mainly to AFS sectors. Agro-food policies could be directed to sectors outside AFS and policies focused on non-agrarian sectors that have a significant impact on AFS, directly or indirectly, should also be taken into account. This implies a need for economy-wide policy coordination. Although the empirical analysis and the results reported refer to the Spanish economy, the analysis and its main conclusions may be useful in explaining regional production systems in other countries.

The article is organized in the following sections: the context, explaining the main stylized facts of the structural change of agriculture in the world developed economy and in Spain in particular; the theory, where the methodology and the hypotheses analyzed are presented; the data, showing the geographical and temporal dimensions and the data transformations for the empirical analysis; the analysis, conducting the empirical work by applying network theory (NT) and social network analysis (SNA); and the final discussion, focused on empirical and, mainly, political aspects.

The Context: The Structural Evolution of Agriculture

The role of agriculture in the economic system has undergone changes due to its general decline but also because its structural position has changed. The evolution of agriculture in recent decades in developed countries has been characterized, in general terms, by a reduction in the agricultural labor force and in the number of farmers, a decline in the agricultural share in gross domestic product (GDP), rural migrations, a relative decline in agrarian prices, an increase in the use of machinery and of chemical inputs, and productivity growth. In both the agribusiness and the agrarian sector, there have also been important changes at firm level, including an increase in firm's average size coupled with a decrease in the number of firms (Prais 1974; Boehlje, Akridge, and Downey 1995; Eastwood, Lipton, and Newell 2010).

The low, unstable incomes in agriculture have been explained by the farm problem model (Schutlz 1945) on the basis of the inelasticity of supply and demand for agricultural products. This constitutes the main economic perspective in the analysis of the farm problem (Gardner 1992), asserting that it causes a structural adjustment in the agricultural sector, which continues in Organisation for Economic Cooperation and Development (OECD) countries (Blandford and Dewbre 1994). The changes in the structural position of agriculture, as regards its trade links, have been accepted as one of the main factors explaining the sector's evolution. According to Blandford and Dewbre (1994, 1047), "Agricultural productivity growth in most

OECD countries has substantially outstripped productivity growth in the rest of the economy in recent years. Labor continues to leave the sector, as the use of capital and other inputs purchased off the farm continues to rise." Also the World Bank (2008, 37) has stated that "the ratio of food processing to agricultural value added rises with incomes."

In this context, the inter-sectoral relationships are changing and the evolution of agribusiness is distinguished by its growing economic integration: "during the past 150 years the food and fiber segment of our economy has evolved from a status of self-sufficiency to one of intricate interdependency with great segments of our industrial economy. Succinctly stated, it has evolved from an agricultural to an agribusiness status" (Davis and Goldberg 1957, 6). Hirschman (1958) indicates the lack of interdependences and linkages in the agriculture sector and in less developed countries in general. Vogel (1994, 136) has also specified the growing integration of agriculture, pointing out that "a fully articulated development process involves the concomitant transformation of agriculture so that it becomes fully integrated into the industrial economy." Starting from the increasing complexity of AFS, as economic development proceeds, FAO (1997) establishes four stages of agro-industry development: First, there is a large share of agricultural raw products in total intermediate purchases, the majority of consumed agricultural products are minimally processed, all processing is performed within the agricultural sector, processing industries are in their most primitive form, there is a lack of linkages with chemical and mechanical industries and with services; second, agro-industrial activities are more sophisticated, there are stronger links with sectors other than agriculture, particularly with providers of inputs and services, the percentage of raw materials purchased by the food industry is decreasing, the content of nonagricultural products in the final food product is increasing; third, there is a full development of the forward linkage chain, marketing and other services are incorporated in the final product, product innovation prevails over other innovations; fourth, the backward and forward links have been stabilized from the previous stage, linkages develop through the production of specialized machinery and process innovation, there is a growing integration of the producing sectors.

A modern agriculture, when compared to a traditional one, shows more intense relationships and dependences in both directions, as a buyer and as a seller. Figure 1 summarizes this evolution: In traditional agricultures, acquisitions outside the agrarian production unit related to the total inputs used (purchases/inputs) are low and total production, minimally transformed, directed to the market (sales/production) is low. Development processes imply basic changes that favor the complexity of the agribusiness network. Evolution in the relationships of agriculture with its inputs' market (fertilizers, seeds, agrochemicals, fuels, services, machinery, etc.), the transforming industry, and the final market, makes agriculture an increasingly integrated activity in agribusiness and in regional economies.

Changes are found in production systems and also at productive system level because the organizational system in modern agriculture is more complex. Institutional links contribute to that complexity since producers, associations,

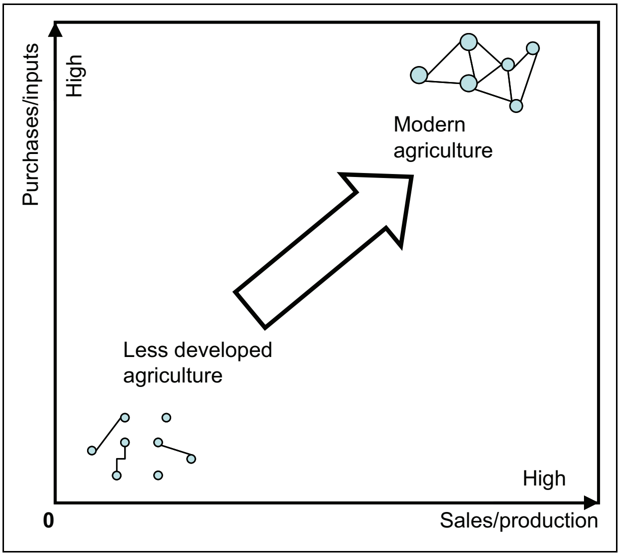

Figure 1. The growing integration of agriculture into the economic system.

cooperatives, professional and interprofessional associations, and so on provide services, information, representation for negotiations with other institutions, which helps achieve an increasing market power, and so on. Development implies a transformation of production relationships (technical links) but also a modification of firms' institutional links (business and nonbusiness and public and private; Garofoli 1992; Skidmore 2000; Trigilia 2001). Focusing on the technical side of systems and on a developed countries context, Table 1 presents some basic data to support the above arguments. The data show the reduction of the weight of agriculture on AFS' intermediate purchases (particularly on agriculture and on the food, beverages, and tobacco industry). This implies an increase in the weight of other intermediate inputs, so highlighting the role of services.

In both sectors, agriculture and foods, beverages, and tobacco, the participation of nonagrarian sectors as intermediate suppliers increases. Services in particular show a significant increasing presence in the composition of the agro-industrial output. Changes in the role of agriculture for Spain, as a seller to itself, are particularly important as its weight moves from one third in the intermediate purchases of agriculture in 1980 to less than a fifth in 2000. The increase in the use of other inputs is, therefore, very significant. The same applies in the purchases of the agrarian transforming industry from agriculture, falling from 62 percent in 1980 to 39 percent in 2000. There is a general tendency that shows the increasing integration of AFS, confirmed particularly for Spain as it is the country with the highest reduction in the weight of "agriculture" on "agriculture" (−43.6 percent) and of "agriculture" on

Table 1. Evolution of the Main AFS Intermediate Purchases (%)

Purchasing Sector		Agriculture		Food, Beverages, and Tobacco	
Inputs From		Agriculture	Services	Agriculture	Services
Spain	1980	33.170	15.773	61.544	13.082
	1995	20.056	18.941	43.361	17.500
	2000	18.716	22.248	39.098	21.909
France	1980	36.006	17.867	55.636	13.541
	2000	30.804	22.200	36.003	29.147
Canada	1981	35.777	25.592	43.883	16.194
	2000	30.950	26.672	33.642	19.484
Japan	1980	26.675	19.376	48.754	18.656
	2000	23.798	36.520	31.754	31.043
USA	1977	41.853	22.854	38.645	19.423
	2000	35.193	33.265	29.492	36.514
Australia	1974	21.342	26.568	44.596	17.641
	1998/99	23.576	37.156	35.121	28.781

Note: AFS = agro-food system. Values correspond to the percentage of agriculture and service inputs on agriculture and on foods, beverages, and tobacco intermediate purchases. Data from Organization for the Economic Cooperation and Development (OECD 1995, 2006) and Spanish National Statistics Bureau (INE 1986, 2009).

"food, beverages, and tobacco" (−36.5 percent). The structural changes indicated merit deep analysis to understand how AFS emerges and evolves as the result of the evolution in its inter-sectoral linkages.

It also merits a deep analysis from a policy point of view. The European strategy EU 2020, put forward by the European Commission in 2010, explicitly recognizes the key roles of agriculture, as one of the strengths of Europe, and of the agrarian policy to achieve the strategy's goals, asserting that they have a potential to contribute, in terms of efficiency and added value. "All common policies, including the common agricultural policies and cohesion policies, will need to support the strategy. A sustainable, productive and competitive agricultural sector will make an important contribution to the new strategy, considering the growth and employment potential of rural areas while ensuring fair competition" (European Council 2010, 5).

The necessity to coordinate policies directed toward agriculture and rural development is stated in the European Agricultural Fund for Rural Development (EAFRD), which highlights the great potential of the AFS for rural development and the need to improve the integration of the agro-food chain in the whole economy, by adopting innovations and by strengthening the links between agriculture and other sectors, particularly business services, tourism, and recreational and social services (European Commission 2008a).

The existence of AFSs and policies in Spain and also at European level, justifies the analysis conducted in the current article as intended: to know the system structurally at national and regional level, before implementing specific policies, and to provide an instrument to propose new policies and to consider the adequacy of policies already designed.[4]

The Theory: Methodology and Hypotheses

This section focuses on the innermost relational mechanisms beyond the changes presented in the above section. These mechanisms, centred on a development process experienced by developed countries, will be translated into hypotheses for the case of Spain, which are testable mainly through NT. The evolution of production systems, which occurs in development processes, implies a quantitative and qualitative evolution of intermediate exchanges. Some inputs and inter-sectoral linkages emerge, or increase their presence, in the economic activity at the same time as other inputs and linkages reduce their importance or even vanish. These transformation processes originate at microeconomic level and show their effects in economic sectors, in productions systems, and in the whole economy.

The evolving patterns of consumption and technological progress lead to the dynamic role of market linkages. Developments occurring in technology and food consumption patterns, particularly in the industrialized countries, affect the direct and indirect relationships between agriculture and final demand. Agricultural products are shaped by technologies of growing complexity at the same time as individual and collective preferences regarding nutrition, health, and the environment are becoming increasingly sophisticated. As a consequence, in general terms, the direct relationship between final demand and agriculture becomes weaker. Primary sectors mantain more intense links with agro-food industry (transformed food products) and the services sector (restaurants, trade, education, health, research, and business services) leading to an intense indirect relationship between agriculture and final demand. One of the main effects of this process is an increasing complexity in the embeddedness of AFS in the interindustrial system, reflected in the growing number of trade links. At firm level, innovation adoptions include outsourcing as a derived strategy which, in turn, increases the number of market linkages. An increase in the number of linkages implies a growing network density according to NT. Density is defined as the ratio between the number of links in a network and the links in a complete network with the same number of nodes. Nodes, in this case, are economic sectors. Density is, therefore, the number of effective trade links related to the total number of possible trade connections and it can be measured as in equation 1, where a_{ij} are elements of the adjacency matrix and take value 1 if sectors i and j are linked and 0 otherwise.[5]

$$\Delta = \frac{\sum_i \sum_{j(i \neq j)} a_{ij}}{n \times (n-1)}. \tag{1}$$

The relationship between density and development has scarcely been considered in economic empirical analyses, although the increasing complexity and density of economies are recognized as proper to development processes (Kubo et al. 1986). Empirical research works have focused on intra-organizational networks and on informal links, revealing a positive relationship of density with performance and with productivity (Reagans and Zuckerman 2001; Reagans and McEvily 2003). In general terms, the positive link between network density and knowledge transfer has been stated theoretically and empirically (Obstfeld 2005; Mariotti 2007; Tang, Mu, and Maclachlan 2008). Knowing whether the density of the interindustrial network increases with development is a basic, necessary step for the knowledge of economic structures and of their evolution.

Hypothesis 1: Economic development, in Spain, is characterized by an increasing density of its interindustrial system.

As density increases, systems become more complex and sectors become more dependent on other sectors. This growing complexity is reflected in the fundamental organizing principles of the interindustrial network. Those principles determine a particular unknown network structure. A possible structure would show a core–periphery topology with a group of sectors making up a core. In social sciences, the core–periphery structure has proved to have a strong capacity to represent different relationships (affective, commercial, or institutional) between several kinds of actors (individuals, organizations, or countries).

Economic research shows an uneven use of formal core–periphery models. In Wallerstein (1976), the world system is divided into core states and peripheral areas and in between there are semiperipheral areas. Krugman (1991, 1999) analyze the processes of economic concentration in particular areas with the formation and persistence of regional core–periphery patterns. Smith and White (1992) and Sangmoon and Eui (2002), among others, also apply core–periphery models to analyze international trade links, at world and EU level. The CEPAL (Economic Commission for Latin America) core–periphery analysis (Prebisch 1950) reports the problems faced by less developed countries, specializing in primary productions and with trade relationships dominated by the Northern countries. Hidalgo et al. (2007) studied the relationship between development and economic specialization using international trade data to analyze networks of related products. The authors identified a hierarchically clustered structure, in the "product space," with a core and a periphery. More recently, Hojman and Szeidl (2008) shows that many economic networks share as a common organizing feature their core–periphery structure.

Core–periphery duality highlights asymmetric interdependency between two, or more, categories in a particular system. In general terms, it describes the conflict between two groups of actors or two geographical spaces, with the core capturing the dominant position and the periphery corresponding to the dependent position.

	1	2	3	4	5
1		1	1	1	1
2	1		1	1	1
3	1	1		0	0
4	1	1	0		0
5	1	1	0	0	

Figure 2. Ideal core–periphery structure.

To date, very few research works (Semitiel 2006) have analyzed the core–periphery structure of IO systems or have tried to identify the structure emerging from IO data.

Hypothesis 2: The core–periphery model has a high capacity to represent the interindustry relationships taking place in the Spanish economy.

Intuitively, and according to Borgatti and Everett (1999), a core–periphery structure can be understood as a two-class partition of nodes. The core is seen as a 1 block, the periphery as a 0 block and ties between the core and the periphery can be either 1 blocks or 0 blocks.[6] In an ideal core–periphery structure, the core is integrated by nodes linked to all the nodes in the system and the periphery is integrated by nodes only linked to the core. Figure 2 represents an idealized core–periphery structure, where the core is made up of two nodes (1 and 2), linked to all the other nodes (e.g., economic sectors), and the periphery is constituted by nodes 3, 4 and 5, which are only linked to the core.

This idealized structure is difficult to find in socioeconomic systems, but it is possible to estimate structures that come close to the theoretical one. In many situations it is possible, and even convenient, to indicate the existence of intermediate groups of nodes, which make up the semiperiphery and are placed between the core and the periphery. SNA offers an appropriate methodology to check for the existence of a core–periphery structure by applying an algorithm that maximizes the correlation between the matrix with the original data and the postulated idealized matrix, as in Equation (2) proposed by Borgatti and Everett (1999).

$$\rho = \sum_{ij} a_{ij}\delta_{ij} \quad \text{with} \quad \delta_{ij} = \begin{cases} 1 & \text{if} \quad c_i = \text{core} \quad \text{or} \quad c_j = \text{core} \\ 0 & \text{otherwise} \end{cases}. \tag{2}$$

The position in the core–periphery structure can be determined by calculating, for each sector, the degree of closeness to the core, or the sector's coreness value, c_i (Borgatti and Everett 1999; Borgatti, Everett, and Freeman 2002). The coreness scores establish a hierarchical order that allows distinguishing different areas in the network, like a core, a strong semiperiphery, a weak semiperiphery and a periphery. The concentration index (Equation 3) increases as the differences between the coreness of core and periphery are higher, indicating the first j nodes comprising the core (Everett and Borgatti 2005, 73). The number of sectors that maximizes the concentration index should be identified as being in the core.

$$\frac{\sum_{i=1}^{j}\left(c_i - \max\left(c_{j+1}, c_{j+2}, \ldots, c_n\right)\right)}{2j} + \frac{\sum_{k=j+1}^{n}\left(\min\left(c_1, c_2, \ldots, c_j\right) - c_k\right)}{2(n-j)}. \tag{3}$$

SNA is not the only methodology that can be followed to test the existence of a core–periphery structure. NT has, in the recent years, offered a set of methods that allow us to understand and characterize the structure of complex networks (Newman, Barabási, and Watts 2006), although they have scarcely been applied to economic data. By applying NT, the degree distribution of sectors should be analyzed to ascertain the organizing principles of the network structure.[7] A degree distribution, $P(k)$, gives the probability that a selected node has exactly k links and allows it to be distinguished among different structures, such as Random and Scale-free networks (Albert and Barabási 2002; Newman, Barabási, and Watts 2006). When the high-degree nodes, called hubs, show a hierarchical order, a hub-and-spoke type of network emerges (Barabási and Oltvai 2004). In an ideal hub-and-spoke network, there is a hub, the largest in relational terms, in contact with a large fraction of all nodes. This corresponds to a core–periphery structure with a core made up of the most central node or the central hub consisting of a fully connected component with maximum density (Krebs and Holley 2002–2006; Bell 2005). This article states that the core–periphery model can be analyzed from NT, in order to identify hub sectors, by studying the degree distribution, the clustering coefficient, and the densities of the modules of interindustrial systems since hierarchical or modular scale-free networks hold the properties of the core–periphery model.

Hypothesis 3: The IO Spanish system follows a hierarchical or modular scale-free network structure.

A modular scale-free network accounts for the coexistence of modularity and scale-free condition. In a scale-free network, the tail of the degree distribution follows a power-law, $P(k) \sim k^{-\gamma}$ (Barabási and Albert 1999). In a scale-free network, there are few highly connected nodes, hubs, holding together numerous low degree nodes. Modularity implies a power-law degree distribution with an inverse relationship between degree and clustering. At the extreme, simulations of perfect hierarchical networks present a clustering coefficient that follows $C(k) \sim k^{-1}$. Sparsely connected nodes are part of clustered areas with the links between the different highly clustered neighborhoods being maintained by few hubs (Ravasz and Barabási 2003). The clustering coefficient quantifies the tendency to cluster, or form cliques, in a network.[8] The clustering coefficient for node i with n_i links connecting the node's neighbors is measured as in Equation 4.[9]

$$C_i = \frac{2n_i}{k_i(k_i - 1)}. \tag{4}$$

The third hypothesis proposes that hubs are present in IO networks as key sectors that connect the whole system. At the same time clusters, or production systems, can be identified as communities, which are also linked to the hubs. One of the modules in the interindustrial network is AFS. Several sectors in AFS (agriculture, farming, forestry, and fishing) have a primary character, indicating that they could be located at the periphery of the interindustrial network. The relational position of primary sectors also affects industrial AFS sectors, since the position of each sector in the core–periphery structure depends on its own degree but also on the degree level of its transacting sectors. This indicates that AFS could be located in the periphery of the interindustry system. Hidalgo et al. (2007) also concludes that agro-food sectors are located at the periphery of the system, using international trade data to measure "proximity" between products and to study the product-space network.[10]

Hypothesis 4: Agriculture and AFS are located at the periphery of the Spanish interindustry system.

The four hypotheses presented in this article will be tested for the case of Spain, using national and regional data and by applying SNA and NT.

The Data

The information used in this article corresponds to the $I_{n \times n}$ IO matrices made by the x_{ij} inter-sectoral domestic trade linkages of Andalusia (Instituto de Estadística de Andalucía 1990, 2006), the Basque Country (Federación de Cajas de Ahorros Vasco-Navarras 1985; EUSTAT 2008), and Spain (INE 1986, 2009) for the years 1980 and 2000.[11]

Although both domestic and total data have been used, the analysis is focused on domestic linkages, as these constitute a fundamental economic dimension.

Table 2. Development Indicators, 1980–2000

		Basque Country	Andalusia	Spain
HDI	1981	0.856	0.784	0.827
	2000	0.931	0.866	0.932
GDP pc ($)	2000	23,010	13,869	18,654
	1980 = 100	154.057	162.381	163.316
Agrarian labor force (%)	1980	6.395	23.416	17.186
	2000	1.436	13.493	6.916

Note: HDI = Human Development Index; GDP pc = gross domestic product per capita in 2000, in Purchasing Power Parity dollars of 1996 and in index number; agrarian labor force is the percentage of total labor force. Data from Herrero, Soler, and Villar (2004) and Spanish National Statistics Bureau (INE).

As Riedel (1976, 320) indicates, total data, including imports, involves technical relationships taking place in a economy but do not allow the production structure of a particular place to be understood: "what is demostrated, however, is that technology is similar across countries, not the structure of production."[12] As total data reflect better the technical aspects of production, it is very useful in analyzing potential relations between sectors and in identifying missing or weak parts in production changes (Feser and Bergman 2000). This article uses IO data for comparative purposes because the objective is to study national and regional production structures, which requires the study of domestic information.

The period analyzed in this article is characterized in Spain by intense economic growth and development. The GDP per capita growth was 63 percent in 1980–2000, the Human Development Index (HDI) in 2000 was 0.90 and the agrarian labor force experienced a strong reduction (Table 2). Two Spanish regions, representative of the lowest and highest level of development in the country, have been selected to consider the significant regional differences. Andalusia, located in the south of Spain, has a per capita income and an HDI below the national average and a high specialization in agriculture and in the agro-food industry. The Basque Country is an industrialized region in the north of Spain, enjoying a per capita income and human development that are among the highest in Spain (Table 2).

Each IO matrix has been transformed to get three different versions of relative domestic interindustry linkages. The intermediate sales matrix (ISM) considers the weight of a trade relation on the intermediate sales of a selling branch (Equation 5). The intermediate purchasing matrix (IPM) considers the importance of a relation in the intermediate purchase of the purchasing branch (Equation 6). The intermediate global matrix (IGM) considers each intermediate link in relation to the total sum of exchanges (Equation 7).[13]

$$\text{ISM} = \frac{x_{ij}}{\sum_j x_{ij}} \tag{5}$$

$$\text{IPM} = \frac{x_{ij}}{\sum_i x_{ij}} \tag{6}$$

$$\text{IGM} = \frac{x_{ij}}{\sum_{ij} x_{ij}}. \tag{7}$$

Only direct links have been considered in the matrices of intermediate coefficients. De Mesnard (2001) offers enough arguments to avoid the use of inverse Leontieff coefficients when conducting a network analysis. The proposed intermediate matrices have been dichotomized by considering all positive entries (1 if intermediate coefficient > 0) and through the application of threshold values, following the usual procedure of SNA and qualitative input output analysis (QIOA) to obtain adjacency matrices (Aroche-Reyes 2002; Schnabl et al. 1999). Even though there is a loss of information, the use of thresholds is convenient because there are transactions with a very low relative value, since the IO structures imply highly tangled networks that are difficult to interpret and because the aim of the research is to study the structure underlying the interindustrial trade.

Thresholds have been selected to make the basic structure of the interindustrial system—its skeleton—emerge. Thresholds for IPM and ISM matrices have been obtained from the network size (1 if intermediate coefficient $> 1/(n-1)$). It is a "structural" threshold applied to the relative sales or purchases of each sectors to eliminate the sector's size effect in the matrix deduced. The two new binary matrices have been named Filter In and Filter Out. These matrices lead to Filter In + Out on applying Boolean sums and, therefore, simultaneously consider transactions that surpass the threshold value from the selling and buying perspective of each branch. The filtered matrices emphasize "pure" relational aspects, focusing on the production system to which each branch belongs and limiting the sectors' size effect (Montresor and Vittucci 2007, 2008). IGM have been dichotomized with the threshold $1/n \times (n-1)$ and then called Filter Global. In this case, the threshold is applied from the whole network perspective, so the selected links are important for the whole economic system, and the "size effect" remains.

The Empirical Analysis

The hypotheses proposed in the theoretical section will be tested by applying the network methodology to the data presented in the above section. NT allows conclusions to be drawn about the structure of interindustry systems and about the relative position of sectors and subsystems, things that cannot be deduced with traditional IO analysis. This section will offer those conclusions, going from the general to the particular, from the most basic structural characteristics of the whole network (its density) to the most concrete positional analysis of AFS.

Table 3. Density Values and Variation Rates

	2000	VR (%)
Spain		
No Filter, Domestic	0.836	19.272
No Filter, Total	0.836	19.375
Filter In + Out, Domestic	0.308	20.603
Filter Global, Domestic	0.177	31.162
Andalusia		
No Filter, Domestic	0.685	9.269
No Filter, Total	0.696	6.341
Filter In + Out, Domestic	0.239	−3.401
Filter Global, Domestic	0.127	−0,856
Basque Country		
No Filter, Domestic	0.664	2.849
No Filter, Total	0.691	4.225
Filter In + Out, Domestic	0.271	13.579
Filter Global, Domestic	0.143	7.223

Note: VR (%) is the variation rate, between 1980 and 2000, of density values.

In the period analyzed, the number of intermediate trade links increases in both cases, when considering all trade links and imposing a threshold (Table 3). Densities increased in the three areas, in domestic and total terms, and the most remarkable change corresponds to Spain, reaching the highest value (0.84), with an increase ranging from 15 percent to 31 percent, depending on the applied threshold. Table 3 comprises total values, domestic plus imports, only for the least restrictive case (1 if intermediate coefficient > 0). Densities have also been obtained for total data in all the cases showing a general density increase. Only in Andalusia is there a density reduction owing to its relative sales. This exception appears when a threshold is imposed, showing an increasing number of small exchanges. Two groups of sectors contribute to this evolution: (1) significant regional sectors reducing their relative weight in total intermediate transactions, such as agriculture and spirits and wine; (2) sectors markedly reducing their number of links—this is particularly the case of clothing and skins. Results allow it to be asserted that IO densities have increased, in a period of growth and development, reaching high levels, as stated in Hypothesis 1.

Once the positive relationship between densities and development has been examined, the analysis focuses on the network structure. Several networks can have identical densities but very different structures, given the distribution of links, and with a very different impact in performance terms. The base structure, or the network skeleton, should be analyzed by studying the distribution of sectors' degrees and of clustering coefficients.

The degree distribution in the IO networks studied shows significant differences in the number of linkages of each sector. Degrees do not follow a normal distribution

Table 4. Power-Law Distributions, Basic Parameters

	1980			2000		
	$\widehat{\gamma}$	$\widehat{X}_{min}$	p Value	$\widehat{\gamma}$	$\widehat{X}_{min}$	p Value
Spain	3.25	24	.594	3.28	27	.182
Andalusia	3.02	16	.147	3.50	30	.471
Basque Country	3.50	22	.382	3.50	30	.529

Note: Data correspond to Filter In + Out matrices.

and networks contain hub sectors with a very high number of links. The threshold that avoids the size bias (Filter In + Out) enables the scale-free structure to come out. According to the results obtained, the probability that a sector can connect to k other sectors decays as a power-law with $3 \leq \gamma \leq 3.5$. Table 4 summarizes the basic statistical parameters obtained after following the Clauset, Shalizi, and Newman (2009) procedure to identify a power-law distribution (Appendix A.1). Our observations are consistent with a model following a power-law distribution when data are filtered, suggesting that the topology of IO networks allow hub sectors to be identified.

The confirmation of a modular scale-free topology also requires the analysis of the modularity of the system. The distribution of the clustering coefficient indicates the existence of modules in IO networks. For the Filter In + Out, the clustering coefficient decreases in 1980, as $k^{-0.4}$ in Spain and Andalusia, and as $k^{-0.3}$ in the Basque Country; in 2000 it decreases as $k^{-0.4}$ in Spain and the Basque Country, and as $k^{-0.3}$ in Andalusia. There is a hierarchy of modules made up by highly connected sectors. One of the modules, or a group of modules, would be a high density group made up of sectors behaving as hubs. Hubs in the modular scale-free IO network make up the core in a core–periphery structure.

The existence of a core–periphery structure has been corroborated by applying the SNA algorithm presented in the section on The Theory: Methodology and Hypotheses (Equation 2). Correlations show, in general, a strong fit with the ideal core–periphery structure represented in Figure 2.[17] Moreover, the representation capacity of the core–periphery structure increases in time, as the registered adjustment improves. These conclusions are in accordance with Hypotheses 2 and 3 and, therefore, with the high capacity of the core–periphery model to represent the intersectoral structure of a particular economy.

Depending on the threshold applied, the number of sectors in the core varies. In Spain, there are sixteen sectors in the core in 2000 for the In + Out and Global filtered matrices, corresponding to 0.5 and 0.6 correlation values (Table 5). In Table 6, all sectors have been ordered according to their coreness score, from the In + Out filtered matrices. Calculations for the Global Filter matrices also show a high coincidence in the ranking of sectors according to their coreness.[18] To consider

Table 5. Main Core–Periphery Indicators

Domestic Data	Number		Correlations	
	1980	2000	1980	2000
Spain				
Filter In + Out	11	16	.468	.497
Filter Global	16	16	.546	.603
No Filter	27	36	.545	.603
Andalusia				
Filter In + Out	9	7	.465	.549
Filter Global	10	8	.508	.573
No Filter	22	24	.524	.569
Basque Country				
Filter In + Out	10	13	.478	.527
Filter Global	16	19	.538	.640
No Filter	29	30	.564	.586

Note: Number indicates the number of sectors making the core. Correlation values are obtained as in Equation 2.

imports, Appendix B proves that results for the core–periphery structure are similar in domestic and total terms. Sectors in the core are the same in both cases. AFS sectors are located in the periphery for both types of data and the position of AFS sectors only shows small variations.

There is also a high regional coincidence for the sectors making up the core and the periphery. Four main deductions can be commented on in this respect. First, the two main hubs (R, R and trade and business services) are the same in the three places. Second, most of the sectors in the core are the same in the three places. Even if the size of cores differs, around 80 percent of core sectors in Andalusia and the Basque Country are also in the Spanish core. Third, in the three areas, AFS sectors are located in the most peripheral positions of their interindustrial systems. Fourth, in the three networks, agriculture and other food industry are the least peripheral sectors of AFS. It should be recalled at this stage that the position of each sector in the core–periphery structure depends on its degree but also on the degree level of its transacting sectors. Therefore, agriculture and other food industry are far from the core positions, even if they have a high number of purchasing and selling links, owing to the importance of their direct links with low degree sectors.

In all the IO networks analyzed, sectors in the core make up a component with a much larger density (Table 7) than the whole network density (Table 3): 0.671 versus 0.308 in Spain, 0.905 versus 0.239 in Andalusia, and 0.750 versus 0.271 in the Basque Country, in 2000. As expected, the periphery component is a very low density group (0.093 in Spain, 0.111 in Andalusia, and 0.097 in the Basque Country in 2000). Similar results are obtained from the Filter Global matrices: in Spain, the core–core density in 2000 is 0.65 and the periphery–periphery density is 0.04. AFS will be

Table 6. Core–Periphery Structure in 2000. Ranking of Sectors and Coreness

	Spain	Coreness	Andalusia	Coreness	Basque Country	Coreness
1	R, R and trade	.172	Business SS	.183	R, R and trade	.202
2	Business SS	.172	R, R and trade	.174	Business SS	.198
3	Chemicals	.164	Transports	.173	Metal products	.184
4	Electricity	.160	Financial Inter.	.166	Construction	.176
5	Metals	.160	Hotels and Rest.	.165	Hotels and Rest.	.168
6	Machinery	.160	Electricity	.163	Coke, P and NG	.167
7	Auxiliary Tr.	.159	Construction	.160	Electricity	.167
8	Financial Inter.	.159	Coke, P and RO	.157	Other land Tr.	.167
9	Public Adm.	.158	Post and Telec.	.156	Gas and water	.165
10	Construction	.157	O Chem.	.154	Office machinery	.163
11	Other land Tran.	.157	Wood	.154	Post and Telecom.	.160
12	Hotels and Rest.	.156	**Agriculture**	.153	Chemicals	.158
13	Post and Telec.	.156	Machinery	.153	Social Ac.	.155
14	Educ. and research	.156	Rubber and plastic	.153	Auxiliary Tr.	.153
15	Petroleum	.155	B Chem.	.152	Metals	.147
16	Rubber and plastic	.155	Metals	.152	Paper	.147
17	Gas and water	.151	Gas and steam	.151	Financial Inter.	.146
18	Glass	.151	Mining	.150	Plastic	.145
19	Tr. Railways	.151	Glass and stone	.150	Other Manuf.	.145
20	Water Tr.	.151	Electrical goods	.150	Health	.145
21	Textiles	.150	Textiles	.150	Textile Ind.	.144
22	Wood and cork	.150	Motor vehicle	.149	NFM and BChe.	.143
23	Paper	.150	Other Tr. Eq.	.149	Tr. Railways	.142
24	Motor vehicle	.150	**Tobacco**	.149	**Other food Ind.**	.141
25	**Agriculture**	.149	Clothing and skin	.149	Glass	.139
26	**Other food Ind.**	.149	Paper	.149	Motor vehicle	.138
27	Office Mach.	.149	**Fishing**	.148	Water and air Tr.	.137
28	Other Tr. Eq.	.149	Water	.148	Insurance	.137
29	Clothing and skin	.148	Ships	.148	Other Tr. Eq.	.136
30	Leathers and Foot.	.148	Other Manuf.	.148	**Agriculture**	.135
31	Ceramics	.148	**Forestry**	.147	**Grain mill**	.135
32	Furniture	.148	Leathers and Foot.	.147	Rubber	.135
33	Air Tr.	.148	P and P	.147	Ceramics	.134

(continued)

Table 6. (continued)

	Spain	Coreness	Andalusia	Coreness	Basque Country	Coreness
34	NMO	.147	**Farming**	.146	Coal and NMO	.132
35	P and P	.147	Ceramics	.146	**Meat Ind.**	.132
36	**Fishing**	.146	**Beer and S.D.**	.146	Wood and cork	.132
37	MO	.146	Insurance	.146	**Fishing**	.131
38	**Forestry**	.145	Cement	.145	**Fish Ind.**	.131
39	**Beverages**	.145	**Meat Ind.**	.145	**Farming**	.130
40	Cement	.145	**Milk Ind.**	.145	MO	.130
41	**Meat Ind.**	.144	**Fish and Veg. Ind.**	.145	Cement	.128
42	**Milk Ind.**	.144	**Spirits and wine**	.144	Ships	.127
43	**Tobacco**	.144	**Oils and fats**	.142	**Milk Ind.**	.126
44					**Beverages**	.126
45					Mach Metallur.	.125
46					**Tobacco**	.122

Note: The AFS sectors have been highlighted in bold. Coreness has been obtained as indicated in Equation 3.

distinguished from the periphery group in order to increase our knowledge about its position and other structural characteristics. Figure 3 represents the core–periphery structure of Spain in 2000 in domestic and total terms (with Filter In + Out). Core sectors have been identified with the lightest color and AFS sectors with the darkest color. The technical details for it representation are in Appendix A.2.

Even if the main selected threshold (Filter In + Out) avoids the size effect, it can be checked from Figure 4 that, in general, sectors with higher relative weights also have higher coreness scores. As a consequence, it could be expected that the peripheral position of AFS sectors is due to their reduced dimension, as the volume of an economic activity is limited or fostered by other sector demands.[20] However, the relationship between relative weights and coreness, for the sectors making up the AFS, moves significantly away from the average. In Spain, there is no sector with a weight equal to or higher than AFS weights and with lower coreness values.[21] On the contrary, there are several sectors with lower weight than AFS sectors and with higher scores. Agriculture, other food industry, and beverages have the highest weight in AFS, with positions 7, 9, and 21, according to their size. When measuring their coreness, they appear in positions 25, 26, and 39 (out of 43 sectors). It should be recalled, at this point, that the Filter In + Out used limits the sector's size effect. In fact, the position of agriculture moves up to position 17 when the Filter Global is used, so revealing too its relative relational disadvantage.

Modules corresponding to several production systems can be identified in the hierarchical Spanish IO network represented in Figure 3. At the bottom of the network there are the production systems around textiles (leathers and footwear, clothing and skins, and textiles) and transports (motor vehicles, Tr. railways, air Tr., and

Table 7. Inter and Intra Groups Densities, 2000

	Core	Periphery	Periphery1	AFS
Spain				
Core	0.671	0.458	0.497	0.367
Periphery	0.306	0.093		
Periphery1	0.385		0.099	0.079
AFS	0.117		0.040	0.232
Andalusia				
Core	0.905	0.623	0.686	0.481
Periphery	0.381	0.111		
Periphery1	0.440		0.155	0.084
AFS	0.247		0.022	0.164
Basque Country				
Core	0.750	0.548	0.582	0.469
Periphery	0.249	0.097		
Periphery1	0.318		0.126	0.065
AFS	0.092		0.022	0.200

Note: The periphery submatrix has been divided in two groups: Periphery1 (includes all peripheral sectors except AFS) and AFS.

other Tr. equipment). At the top of the network there is the production system around wood: forestry, publishing and printing, wood and cork, and paper and furniture. On the left AFS is easily identifiable with the darkest color. The study of inter and intra groups densities allows deductions to be made about the cohesion of AFS and its integration in the interindustrial system (Table 7).[22] Three main results are obtained from the analysis. One, AFS, located in the periphery of the IO system, forms a module with much higher density (0.232) than the density of the periphery submatrix (0.093) to which it belongs. This result indicates the high relative cohesion of AFS. Two, the density AFS core is lower than the density between periphery and core, showing the weaker integration of AFS in the whole system through core sectors. Three, the links between AFS and core are more intense for the AFS purchases than for its sales (0.367 vs. 0.117 in 2000). The purchases that AFS sectors make from the other sectors (core and also peripheral) characterize its integration in the interindustrial system. From a core–periphery analytical perspective, the structural position of AFS in the whole interindustrial system reveals a dependence relation that could reduce its capacity to generate added value.

Those results are in agreement with Semitiel (2006), where the AFS of Andalusia and the Basque Country were analyzed for years 1980 and 1995 using traditional IO analysis and network analysis. The main conclusion was that AFS has a high internal cohesion but not when its embeddedness is considered in the whole system, with medium centrality, located in the periphery and not participating in other modules. A general deduction was that AFS is a weakly embedded subsystem. This is also the case for other regions and even for the

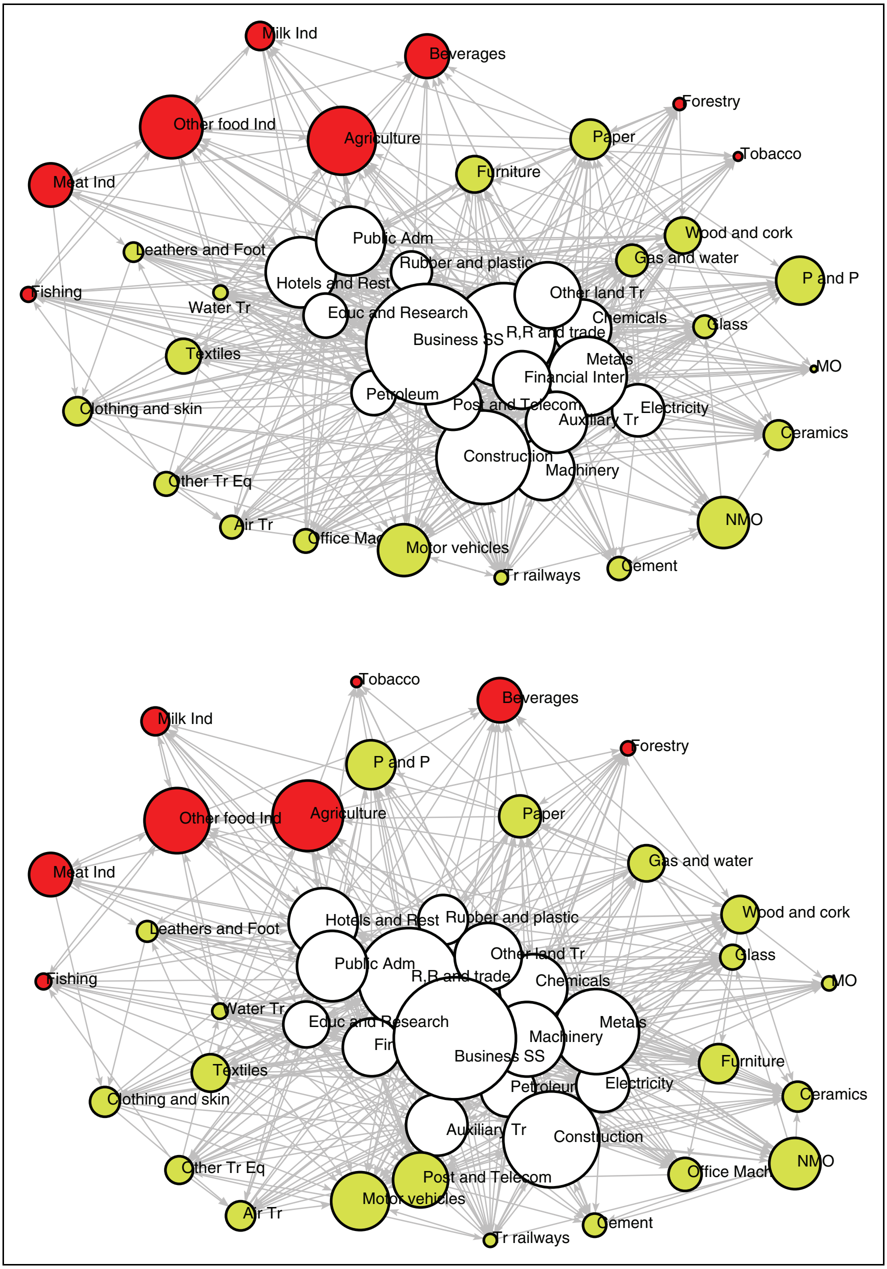

Figure 3. Core–periphery–AFS network, Spain, 2000. Note: First figure in domestic terms and second figure with total data. AFS = agro-food system.

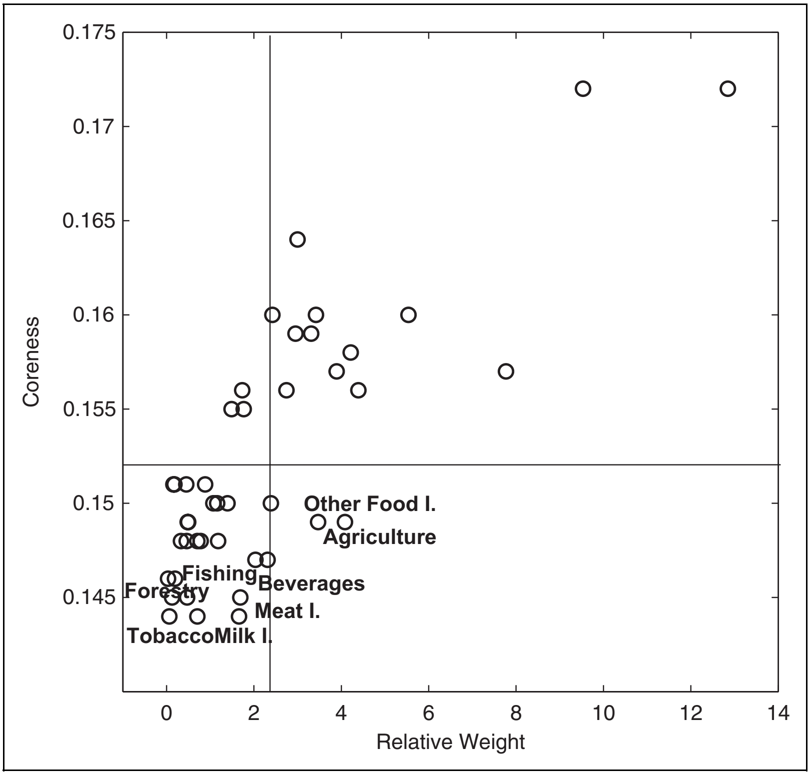

Figure 4. Coreness and sizes, Spain, 2000.

country as a whole. However, those implications are particularly relevant for Andalusia as it is a region with a productive and economic structure that specializes in AFS.[23]

AFS embeds in the interindustrial system through the links that its sectors maintain with the core and also with sectors making up other production systems not located in the core. Figure 5 shows the egonetwork of AFS, when considering only its direct links. A common structural characteristic for the three areas is that the sectors with most direct links with AFS are business services, trade, hotels, and restaurants, and transports, all of which are core sectors. The first two sectors mentioned also increased their trade degree with AFS between 1980 and 2000. Hotels and restaurants maintains the most significant outgoing link among the few that form AFS. In terms of production systems, the direct links of AFS with the paper system and with the textiles system is another common feature.

When comparing both regions, the regional specialization of Basque Country is present through the sector metal products and machinery. The Basque Country shows a historical specialization in the metal-mechanical production system, reflected in its sales to AFS. As domestic data are being used for this analysis, deductions can be interpreted in terms of specialization and regional endogenous growth. Other notable dynamic characteristics are: for Spain the appearance of education and research; for the Basque Country the appearance of "gas and water" and Post and telecommunications and the change in the use of means of transports; for Andalusia the reduction of the integration of AFS in the interindustrial system through the textiles system, the paper system, and the construction system (cement and ceramics disappeared in 2000 and construction reduces its degree).

AFS integrates in the whole network mainly through its purchasing links with core sectors, with primary inputs and through sectors making up other production systems such as textiles, paper, and transports. Those results are relevant from an agro-food policy point of view, supporting the need for intense policy coordination. AFS directly and rapidly suffers from other sectors' problems and benefits from other sectors' improvements. These sectors can be identified, as shown in this article, to design specific coordinated policies. At the same time, regional policies, designed for AFS sectors and directed toward them, should consider their direct and rapid impact on other sectors, as identified from a network perspective. This is the case for public policies, like innovation policies, and also for decision taking at private level.

Discussion and Policy Implications

The agricultural economics perspective has emphasized the sector's evolution, from a self-sufficiency position showing poor links with other sectors, proper to backward agricultures, to positions implying its increasing integration and interdependence with industrial and service activities. The relevance of these relationships was already remarked on when the concept of agribusiness was introduced. However, it is still necessary to offer satisfactory explanations, from alternative perspectives, for the role of certain activities in systems considering the topology and dynamics of economic structures. Those explanations would allow the necessary structural knowledge when designing agro-food policies. NT allows for the structural analysis of complex systems, including the networks made by trade linkages. The application of the network perspective to national and regional IO data in Spain for the period 1980–2000 shows that in a period of economic development, the inter-sectoral density increases. This analysis also reveals the existence of a network skeleton characterized by a hierarchical topology, where a group of hub sectors make up a core, and where a periphery can be identified. The study of the core–periphery model appears as a convenient form to analyze and represent the interindustry relationships taking place in the Spanish economy.

AFS is a production system that can be distinguished in the analyzed networks, contributing to the complexity of economies and to their core–periphery structures. AFS emerges as a module in the periphery of the IO skeleton, with intense dependences as

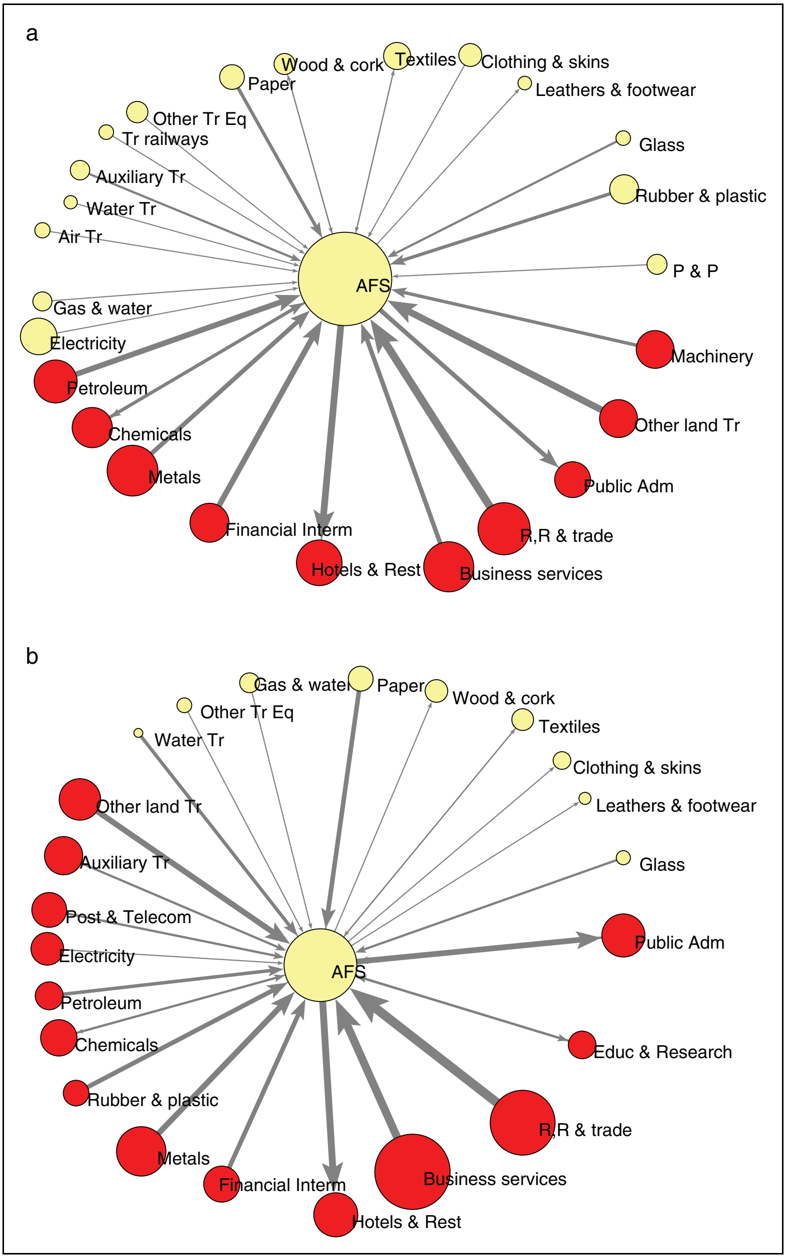

Figure 5. Egonetworks of AFS. Note: The thickness of the arrows indicates the number of links and the darker color shows the core sectors. AFS = agro-food system, a = Spain 1980, b = Spain 2000, c = Basque Country 1980, d = Basque Country 2000, e = Andalusia 1980, f = Andalusia 2000.

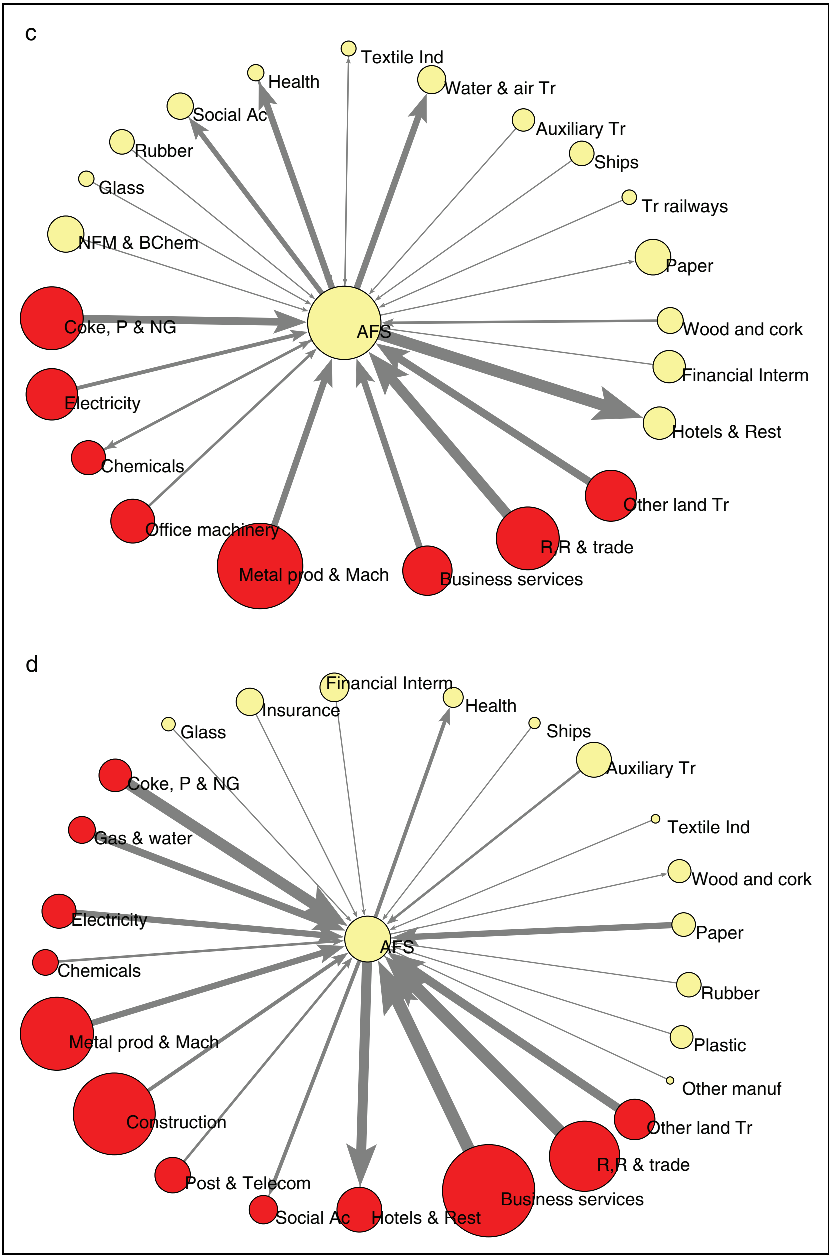

Figure 5. Continued

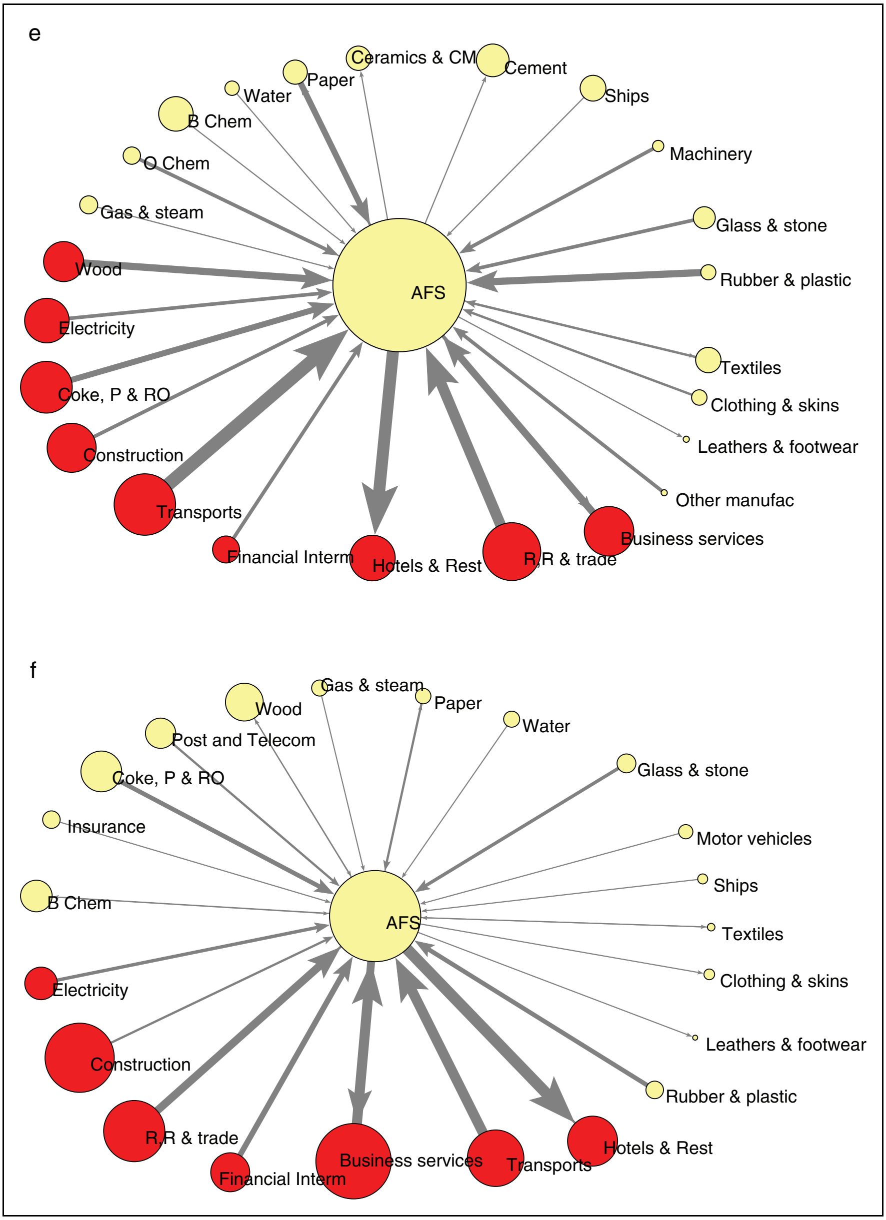

Figure 5. Continued

a buyer. Its integration in the whole network is characterized by the purchasing links it maintains with core sectors (trade, business services, hotels, and restaurants) and by links with other production sectors (textiles and wood). Those distinguishing factors are a reflection of the mechanism taking place at a micro level, where the evolving patterns of consumption and technological progress are taking place.

Those structural deductions are relevant from an economic policy perspective, particularly in places specializing in AFS. The structural study of AFS helps to understand the evolution of agriculture, as it is conditioned by its integration in AFS and in the whole economy, to propose appropriate policies with an impact on regional development and to identify reasons for the failure of already proposed policies. Policy and decision makers should bear in mind the systemic nature of economies and the relevance of trade links, as they allow for material flows but also for the diffusion of information and innovations.

The literature on systems of innovation proposes focusing on systems failures for the identification of problems that require policy interventions (Smith 2000; Metcalfe 2005; Woolthuis, Lankhuizen, and Gilsing 2005; Chaminade et al. 2009). Following Chaminade et al. (2009, 360), this is an appropriate analytical framework as "policy makers often lack tools for identifying competence-building to tackle them" [system failures]. A system failure policy focuses on missing connections and misplaced boundaries to support the knowledge process through interactive learning (Metcalfe 2005). This implies a new rationale for innovation policy, as the policy maker is not particularly interested in promoting individual innovation events but the intention is to set the framework conditions for a better diffusion and adoption process across the structure of economic activities. Knowledge, embedded in individuals, can be incorporated into the innovation process through firms and other knowledge organizations, and innovation policies should facilitate bridging mechanisms to deal with failures of connection and interaction. In order to do so, all the actors of production systems and their connections should be taken into account: actors supplying knowledge and innovation through sales and also users and consumers of their goods as receiving information, and probably adopting innovations. The network study of interindustrial structure is, then, valuable for scholars and policy makers, even knowing that it should be continued to consider other fundamental factors. The limitations of this approach relate to the recognized restrictions of innovation systems: "the theory hitherto seems to be completely oblivious to the specific characteristics of the system, its evolution, the socio-economic context in which it is embedded and the (global) unbalanced distribution of knowledge (Dolfsma, Chaminade, and Vang 2008). In practical terms, what might be a problem in one system might not be a problem at all in another system" (Chaminade et al. 2009, 365).

The above statement justifies the current article using domestic regional data, as general conclusions were not looked for, although some deduced commonalities have been highlighted. Nevertheless, the limitation for not considering the institutional fabric, cultural specificities, and international openness are obviously present in this work. Those aspects will be confronted in a future research that needed this first approach, considering that some linkages within the system are more important than others, as is the case for the relationship between domestic users and producers: "While there is great potential in absorbing knowledge from abroad, building competences on the user side domestically as well as enhancing the quality of non-market interactions (creating the conditions for trust) are crucial elements in a strategy aiming at building mature innovation systems, particularly considering DUI forms of learning" (Chaminade et al. 2009, 370).[24]

The trade interactions taking place inside and outside AFS's in Europe are explicitly taken into account by the European Commission and the Spanish Environmental and Rural and Marine Environment Department. Both institutions consider that agriculture and the agro-food industry are essential for rural economies, as they allow the articulation and integration of several economic activities. The EU 2020 strategy includes both, agricultural and rural policies recognizing that the AFS has multiplying effects on employment of rural areas through input sellers, business services, food processing, and tourism. The European Commission concludes that it is necessary to improve the performance of agro-food chains at regional level to increase the sectors' efficiency and innovation and to promote the transfer, updated and embodiment of innovations to the agrarian sector (Presidencia de la UE 2010). Particularly relevant is, then, the coordination with innovation policies. In fact, the field most targeted by Spanish measures to foster innovation is food, agriculture, and fisheries, followed by biotechnology and transport, the three being above the EU 27 (European Commission 2009, 30). Moreover, biotechnology is directly linked to AFS through the chemical industry that includes chemicals and pharmaceuticals.

Chemicals is a high technology sector with a relevant presence in the economic fabric of Spain, Andalusia, and the Basque Country, as the use of domestic data indicates that it takes part in their chains and systems. It is also located in the core of the three areas analyzed, implying that interventions directed toward it allow faster and more efficient diffusion processes (Huang and Li 2007; Sun and Gao 2007; López-Pintado 2008; Hai-Feng et al. 2009). This can serve as an example of a coordinated policy to be encouraged to foster AFS and innovation by acting on particular selected sectors and their linkages (agriculture, food industry, chemicals, and also innovation institutions).

From the structural study of AFS in Spain, Andalusia, and the Basque Country in the period 1980–2000, it can also be deduced that it is possible to design other common basic agro-food policies, as there is a coincident scheme in the three areas. Then regional particularities should be considered for a complete and effective policy design. Some general systemic ideas are going to be briefly outlined next which imply acting on non-AFS sectors to have an impact on AFS systems. It will be noted that some of them are already considered in the European reports referred to before and can therefore be useful in designing and prioritizing concrete proposals.

1. Hotels and restaurants can be considered a key sector for AFS. It pulls along AFS and it is the only sector that can be remarked as an AFS intermediate buyer.

The link between domestic agro-food firms and the regional hospitality sector could be strengthened in order to have a positive impact in terms of endogenous growth, especially owing to the relevance of tourism for rural areas.

2. Business services and trade are the most influential sectors for AFS in relational terms. They show a high and increasing number of links with AFS and are located in the core and so decisive for the integration of AFS in the interindustrial system and for the adoption of innovations coming from those sectors. Moreover, all AFS sectors are directly and significantly related to trade. Those two service sectors, already stressed in EU recommendations, stand out for AFS and also for the system as a whole.[25]
3. AFS maintains relevant links with sectors having high technology content and with sectors undergoing a continuous innovation process (post and telecommunications, business services, and trade). Policies should promote a fast adaptation of the new services to the necessities of AFS. Moreover, as service activities concentrate on urban areas and agricultural activities may be located far away from them, policies should consider the territory characteristics, transport, and communications conditions.
4. Health, education, research, social activities, and public administration are activities with an increasing presence in AFS, reflecting the evolution of consumption patterns and technological changes already recognized by the European Commission. AFS should advance accordingly and try to prevent its lagging by implementing suitable public and private strategies that facilitate territorial articulation by acting on their linkages.

A network analysis of regional interindustry structures means applying an alternative approach to get richer information to dynamize the AFS. It is also useful to detect problems and opportunities for the adoption of technologies and innovation as knowledge and innovation spread through intermediate trade linkages (Montresor and Vittucci 2008; García, Morillas, and Ramos 2010), considering that organizations acquire knowledge through interactions with other actors making chains or systems (Argote, McEvily, and Reagans 2003; Jensen et al. 2007; McFadyen, Semadeni, and Cannella 2009; Jackson 2010). It is important, in this sense, to improve the coordination of agricultural and rural policies with other European and national policies and initiatives. In this respect, some general ideas deduced from the empirical analysis conducted in this article have been expressed in this last section. The deductions are also useful for private interventions as they inform about investment opportunities to focus scarce resources, to build linkages and to take advantage of future interindustry synergies, as Feser and Bergman (2000) indicates when discussing cluster strategies. As a final general conclusion, it could be stated that the particular structure of the Spanish interindustry system, where a core and a periphery can be distinguished, indicates a very different impact of flows coming from core or peripheral sectors and going to core or peripheral sectors. AFS is located in the periphery of the system and embeds in it, mainly, through a selected number of sectors.

This structural information is basic in the design of policies at sector and at system level and also for private investments to take advantage of.

Appendix A. Technical Explanations

A.1. Procedure to Identify a Power-Law Distribution

Parameters in Table 4 have been obtained after applying the following Clauset, Shalizi, and Newman (2009) procedure:

1. Estimation of the parameters $X_{\min}$ and γ of the power-law model, using the Maximum Likelihood and the Kolmogorov-Smirnov methods. For most empirical phenomena, the power-law applies only for values greater than some minimum $x_{\min}$. Therefore, this parameter, if unknown, should be estimated in order to obtain a proper estimation of the scaling parameter (γ).
2. Calculation of the goodness of fit between the data and the power-law using the Kolmogorov-Smirnov method.
3. Obtaining the p value, which must be greater than .1 to assert that the power-law is a plausible hypothesis for the data analyzed. Clauset, Shalizi, and Newman (2009) recognize that the rule $p \leq .1$ to reject the power-law hypothesis, is a relatively conservative choice, stricter than the usually applied rule $p \leq .05$.

A.2. Procedure to Draw the Core–Periphery Structure

Figure 3 has been elaborated by implementing the Fruchterman-Reingold algorithm in Pajek (Fruchterman and Reingold 1991; Batagelj and Mrvar 2008). This algorithm brings the interconnected sectors nearer, and moves unconnected sectors further away, on the basis of distances. In this form, the most central nodes are located in the core and they move further away as they become more peripheral. The average relative weight of each sector, in intermediate sales and purchases terms, has been considered to decide the nodes' size.

Appendix B

Table B1. Ranking of Sectors from their Coreness, Spain, Total Data

	1980	Variation		2000	Variation
1	R, R and trade	0	1	R, R and trade	0
2	Chemicals	−1	2	Business SS	0
3	Financial Inter	−1	3	Chemicals	0
4	Other land Tr	2	4	Machinery	−1
5	Business SS	0	5	Metals	1
6	Petroleum	0	6	Public Adm	−2
7	Machinery	0	7	Other land Tr	−3
8	Metals	−3	8	Electricity	−5
9	Public Adm	1	9	Petroleum	3
10	Construction	0	10	Auxiliary Tr	3
11	Hotels and Rest	2	11	Hotels and Rest	−1
12	Electricity	0	12	Construction	−2
13	Rubber and plastic	0	13	Financial Inter	−3
14	Educ and Research	−3	14	Educ and Research	3
15	**Other food Ind**	**1**	15	Rubber and plastic	6
16	Glass	1	16	Post and Telecom	1
17	Paper	1	17	Paper	−9
18	**Agriculture**	**−2**	18	Tr railways	−3
19	Post and Telecom	−2	19	Glass	0
20	Wood and cork	1	20	Wood and cork	2
21	Furniture	−1	21	Water Tr	1
22	Office Mach	4	22	Motor vehicles	5
23	Auxiliary Tr	0	**23**	**Agriculture**	**1**
24	NMO	−1	24	Textiles	0
25	P and P	−1	**25**	**Other food Ind**	**0**
26	Textiles	−3	26	Gas and water	−1
27	Motor vehicles	3	27	Other Tr Eq	2
28	Tr railways	−2	28	Furniture	−5
29	Water Tr	−4	29	Air Tr	0
30	Other Tr Eq	−2	30	Clothing and skin	0
31	Gas and water	−1	31	Ceramics	−5
32	Air Tr	−5	32	NMO	1
33	Leathers and Foot	2	33	Office Mach	5
34	Ceramics	0	**34**	**Forestry**	**2**
35	**Beverages**	**−3**	35	Leathers and Foot	−1
36	Clothing and skin	1	36	P and P	−5
37	MO	1	37	Cement	−2
38	**Fishing**	**0**	**38**	**Beverages**	**4**
39	**Forestry**	**2**	**39**	**Fishing**	**1**
40	Cement	0	**40**	**Meat Ind**	**3**

(continued)

Table B1. (continued)

	1980	Variation		2000	Variation
41	**Milk Ind**	**0**	41	MO	−1
42	**Meat Ind**	**0**	**42**	**Milk Ind**	**−1**
43	**Tobacco**	**0**	**43**	**Tobacco**	**3**

Note: Variation is the coreness rank with domestic data minus the coreness rank with total data. AFS sectors are in bold. As an example, Agriculture loses two positions in 1980 and advances one position in 2000 in coreness terms when imports are included.

Appendix C

Table C1. Abbreviation and Whole Sectors' Names, Spain

Agriculture	Agriculture and hunting
Forestry	Forestry
Fishing	Fishing
Petroleum	Extraction of crude petroleum, natural gas, and solid fuels
MO	Mining and processing of metal ores
NMO	Mining and processing of nonmetal ores
Electricity	Electric power
Gas and water	Gas and water
Meat Ind.	Production, processing, and preservation of meat
Milk Ind.	Milk and diary products
Other food Ind.	Other food industry
Beverages	Beverages
Tobacco	Tobacco products
Textiles	Manufacture of textiles
Clothing and skin	Clothing and skin goods
Leathers and Foot.	Leathers and footwear
Wood and cork	Manufacture of wood and cork
Paper	Manufacture of paper and paper products
P and P	Publishing and printing
Chemicals	Manufacture of chemicals and chemical products
Rubber and plastic	Manufacture of rubber and plastic products
Cement	Cement, lime, and plaster
Glass	Manufacture of glass and glass products
Ceramics	Manufacture of ceramic products
Metals	Manufacture of basic metals and fabricated metal products
Machinery	Manufacture of machinery, equipment, and electrical goods
Office Mach.	Manufacture of office machinery and precision instruments
Motor vehicle	Manufacture of motor vehicles, trailers, and semitrailers
Other Tr. Eq.	Manufacture of other transport equipment
Furniture	Manufacture of furniture

(continued)

Table C1. (continued)

R, R and trade	Recycling, repair of motor vehicles, wholesale, and retail trade
Construction	Construction
Hotels and Rest.	Hotels and restaurants
Tr. Railways	Transport via railways
Other land Tr.	Other land transport
Water Tr.	Water transport
Air Tr.	Air transport
Auxiliary Tr.	Supporting and auxiliary transport activities
Post and Telecom.	Post and telecommunications
Financial Inter.	Financial intermediation
Business S S	Business services provided to enterprises
Educ. and Research	Education and research
Public Adm.	Public administration and other service activities

Table C2. Abbreviation and Whole Sectors' Names, Andalusia

Agriculture	Agriculture
Farming	Farming of animals and hunting
Forestry	Forestry
Fishing	Fishing
Mining	Mining and quarrying
Coke, P and RO	Production and processing of coke, refined petroleum and radioactive materials and ores
Electricity	Electric power
Gas and steam	Gas and steam
Water	Water
Ceramics	Ceramic products and building and construction materials
Cement	Cement, lime and plaster
Glass and stone	Manufacture of glass and stone
B Chem.	Manufacture of basic chemicals
O Chem.	Manufacture of other chemical products
Metals	Manufacture of basic metals and fabricated metal products
Wood	Manufacture of wood, cork, metal products, and furniture
Machinery	Manufacture of machinery and equipment
Electrical goods	Electrical goods
Motor vehicle	Manufacture of motor vehicles, trailers, and semitrailers
Ships	Building and repairing of ships and boats
Other Tr. Eq.	Manufacture of other transport equipment
Oils and fats	Oils and fats
Meat Ind.	Production, processing, and preservation of meat
Milk Ind.	Milk and diary products
Fish and Veg. Ind.	Fish and vegetable preserves
Tobacco	Manufacture of other food products and tobacco

(continued)

Table C2. (continued)

Spirits and wine	Spirits, ethyl alcohol, and manufactured wines
Beer and S D	Beer, malt, soft drinks, and mineral waters
Textiles	Manufacture of textiles
Clothing and skin	Clothing and skin goods
Leathers and Foot.	Leathers and footwear
Paper	Manufacture of paper and paper products
P and P	Publishing, printing and reproduction of recorded media
Rubber and plastic	Manufacture of rubber and plastic products
Other Manuf.	Other manufacturing products
Construction	Construction
R, R and trade	Recycling, repair of motor vehicles, wholesale, and retail trade
Hotels and Rest.	Hotels and restaurants
Transports	Transport via railways, other transport, supporting, and auxiliary transport activities
Post and Telec.	Post and telecommunications
Financial Inter.	Financial intermediation except insurance and pension funding
Insurance	Insurance and pension funding
Business S S	Business services provided to enterprises and other service activities

Table C3. Abbreviation and Whole Sectors' Names, Basque Country

Agriculture	Agriculture
Farming	Farming of animals, hunting, and forestry
Fishing	Fishing and aquaculture
Coal and NMO	Mining and processing of coal and nonmetal ores
Coke, P and NG	Mining and processing of coke, crude petroleum, and natural gas
Electricity	Electric power
Gas and water	Gas and water
MO	Mining and processing of metal ores
Metals	Manufacture of basic metals and fabricated metal products
MFM and B Che.	Nonferrous metal ores and basic chemicals
Cement	Cement, lime and plaster
Glass	Manufacture of glass and glass products
Ceramics	Ceramic products and building and construction materials
Chemicals	Chemical products
Metal products	Metal products, domestic appliances, equipment, and furniture
Mach Metallur	Manufacture of machinery for metallurgy
Office machinery	Manufacture of office machinery, machinery, publishing, and printing
Motor vehicle	Manufacture of motor vehicles, trailers, and semitrailers
Ships	Building and repairing of ships and boats

(continued)

Table C3. (continued)

Other Tr. Eq.	Manufacture of other transport equipment
Meat Ind.	Production, processing and preservation of meat
Milk Ind.	Milk and diary products
Fish Ind.	Fish preserves and other seafood
Grain mill	Manufacture of grain mill products
Other food Ind.	Other food industry
Beverages	Beverages
Textile Ind.	Textile, clothes, leathers, skins, and footwear
Wood and cork	Manufacture of wood and cork
Paper	Manufacture of paper and paper products
Rubber	Manufacture of rubber products
Plastic	Manufacture of plastic products
Other Manuf.	Other manufacturing products
Construction	Construction
R, R and Trade	Recycling, repair of motor vehicles, wholesale, and retail trade
Hotels and Rest.	Hotels and restaurants
Other land Tr.	Other land transport
Tr railways	Transport via railways
Water and air Tr.	Water and air transport
Auxiliary Tr.	Supporting and auxiliary transport activities
Post and Telecom	Post and telecommunications
Financial Inter.	Financial intermediation except insurance
Insurance	Insurance
Business S S	Business services provided to enterprises
Health	Health
Social Ac.	Social, personal and community activities and social work

Acknowledgment

The authors thank the helpful comments of three anonymous referees. They also thank Aaron Clauset and Cosma R. Shalizi for allowing them to use their codes for the implementation of the Clauset, Shalizi, and Newman (2009) procedure. Any remaining errors and omissions are of authors'.

Declaration of Conflicting Interests

The author(s) declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The author(s) received no financial support for the research and/or authorship of this article.

Notes

1. AFS is a production system that covers primary sectors, the industry transforming them, and their trade linkages. It is defined as a production system because it only considers

formal market relationships, without explicitly taking into account any kind of informal, social, or interpersonal linkages. The consideration of both, technical and institutional, relationships would lead to the study of productive systems (Semitiel 2006). The sectors included in the AFS are in accordance with the definition applied by the European Commission (2007, 8): "The Agri-Food sector is defined as the combination of the primary sectors (branch A: agriculture, hunting and forestry) and the food industry (branch DA: Manufacture of food products; beverages and tobacco." FAO (1997, 2, 34) also specifies which are the sectors that should be included in the system as they transform primary products: "agroprocessing industry refers to the subset of manufacturing that processes raw materials and intermediate products derived from the agricultural sector. Agroprocessing industry thus means transforming products originating from agriculture, forestry and fisheries," "the term agro-industry ... should not be understood to comprise industries supplying agriculture with industrial machinery, inputs and tools."

2. Davis (1956, 109) indicates that "agribusiness refers to the sum-total of all operations involved in the production and distribution of food and fiber." Davis (1956) and Davis and Goldberg (1957) "were the first to expand the concern of agricultural economists beyond the agricultural production process to include a host of post-farm gate activities including transportation, processing and distribution" (Litzenberg and Schneider 1986, 397). Although the section on The Context: The Structural Evolution of Agriculture includes some necessary references to agribusiness, this article focuses on the AFS production system, primarly, and on agriculture as one of its components.
3. This important question is also considered in FAO (1997, 30): "To a very large extent promoting agro-industrial development and ensuring that agro-industry provides the optimal contribution to economic development depend on appropriate economic and other policies throughout the economy, more than on sector-specific policies and interventions."
4. The agrarian sector manages, directly or indirectly, almost 80 percent of the whole communitarian territory. For the particular case of Spain, rural areas cover 91 percent of the whole Spanish territory and about 20 percent of the population lives in these areas. About 50 percent of the total surface area of Spain is turned over to agricultural land, 75 percent of which is classified as less favoured areas (LFA). The primary sector (agriculture, hunting, and forestry) constitutes the main source for maintaining population and employment in its rural areas (Presidencia de la UE 2010; European Commission 2008b). The European Commission also recalls that the EU is the world's largest producer of food and beverages, which implies opportunities and also threats for many firms (European Commission 2007).
5. The adjacency matrix quantifies the linkages between the actors for the relation in question. If two actors are joined by a link they are adjacent and are called neighbors (Brandes and Erlebach 2005).
6. Another intuitive view "is based on the physical center and periphery of a cloud of points in Euclidean space. Given a map of the space (...) nodes that occur near the center of the picture are those that are proximate not only to each other but to all nodes in the network, while nodes that are on the outskirts are relatively close only to the center" (Borgatti and Everett 1999, 376).

7. Degree is the number of links that a node has to other nodes. In directed networks, like IO, incoming degrees, k_{in}, and outgoing degrees, k_{out}, can be distinguished and interpreted as centrality measures for each node (indegree and outdegree centrality).
8. Wasserman and Faust (1994, 254) defines a clique in a graph as "the maximal complete subgraph of three or more nodes. It consists of a subset of nodes, all of which are adjacent to each other."
9. The clustering coefficient implies the local network property of modularity, indicating the existence of easily identified groups of actors that are highly connected but with few or no links to actors outside their group (Ravasz and Barabási 2003).
10. "Proximity" is obtained from revealed comparative advantages and it is interpreted in the following way: "if two goods are related because they require similar institutions, infrastructure, physical factors, technology, or some combination thereof, they will tend to be produced in tandem, whereas dissimilar goods are less likely to be produced together. We call this measure 'proximity', which formalizes the intuitive idea that the ability of a country to produce a product depends on its ability to produce other products" (Hidalgo et al. 2007, 484).
11. Unfortunately, capital transactions cannot be included, as data are only available for year 1995 and for a very small group of sectors. All sectors have been analyzed and classifications have also been homogenized for each place in the two analyzed years. Intra-sectoral transactions have not been considered (main diagonal). The names of all sectors, or branches, and their corresponding abbreviations are given in the Appendices.
12. "One is not surprised to find that the production of a given commodity requires relatively the same intermediate inputs in the same proportion in one country as it does in another. One would, however, be surprised to learn that the proportions of each input imported or produced domestically is the same across countries" (Riedel 1976, 320).
13. Those coefficients are not calculated in relation to each sector's production and, therefore, differ from the traditional input and output coefficients. The intention is to stress intermediate links, to analyze interindustrial networks through intermediate sales and purchases and, hence, relative intermediate transaction coefficients are used. Feser and Bergman (2000) and Feser, Sweeney, and Renski (2005) apply coefficients similar to the ones we propose and with analogous interpretations.
14. Table 3 comprises total values, domestic plus imports, only for the least restrictive case (1 if intermediate coefficient > 0). Densities have also been obtained for total data in all the cases showing a general density increase.
15. The reduction in the outdegrees of clothing and skins for domestic and total data is a regional question that cannot be related to technical aspects (this outdegree reduction is not present in the Basque Country or in Spain). Twenty sectors disappear from the ego-network of this sector, with a significant impact on the whole net.
16. The most common approach for testing empirical data against a hypothesized power-law distribution is to look for a high fraction of the variance accounted for by the fitted line after a logarithmic transformation has been performed. The power-law distribution, then, follows a straight line on a double logarithmic plot. The scaling parameter is the slope, extracted by performing a least-squared linear regression. Unfortunately, according to

Clauset, Shalizi, and Newman (2009, 4), "this method and other variations of the same theme generate significant systematic errors under relatively common conditions (...) and as a consequence the results they give cannot be trusted."

17. Those correlations can be considered strong even if they are far from the perfect fit corresponding to the ideal model. This assertion is in accordance with Borgatti and Everett (1999) where similar correlation values are obtained.
18. In both filtered matrices, the sixteen core sectors are the same for Spain. In Andalusia, the coincidence is for five out of seven core sectors, and for the Basque Country eleven out of thirteen coincide.
19. Similar results are obtained from the Filter Global matrices: in Spain, the core–core density in 2000 is 0.65 and the periphery–periphery density is 0.04.
20. In this sense, a general positive relationship between sectoral degree and economic dimension could be expected. In fact, one explanation for the increase of services' degree is the new and increasing demand from other sectors.
21. The only exception is cement (weight = 0.473; coreness = 0.145) when compared to fishing (weight = 0.192; coreness = 0.146).
22. Table 7 shows the Filter In + Out case although all results have been checked for both thresholds and also for matrices, without imposing any threshold value.
23. Some of the main deductions, which have important implications for a growth and regional development focus, were only observed from the network analysis result. The traditional IO analysis concluded that AFS sectors are highly interwoven in the system. However, network analysis allows us to know that AFS sectors are strongly linked between themselves but weakly embedded in the interindustrial system.
24. The Doing, Using and Interacting (DUI)-mode of learning, proposed in Jensen et al. (2007) is constituted by learning by doing, learning using and learning by interacting.
25. Jensen et al. (2007) highlights the role of business service firms in the diffusion of innovation, as they deliver disembodied general knowledge to customers and diffuse knowledge widely in the economy through learning by interacting.

References

Albert, R., and A.-L. Barabási. 2002. Statistical mechanics of complex networks. *Review of Modern Physics* 74:47-97.

Argote, L., B. McEvily, and R. Reagans. 2003. Managing knowledge in organizations: An integrative framework and review of emerging themes. *Management Science* 49:571-82.

Aroche-Reyes, F. 2002. Structural transformations and important coefficients in the North American economies. *Economic Systems Research* 14:257-73.

Barabási, A.-L., and R. Albert. 1999. Emergence of scaling in random networks. *Science* 286:509-12.

Barabási, A.-L., and Z. N. Oltvai. 2004. Network biology: Understanding the cell's functional organization. *Nature* 5:101-13.

Batagelj, V., and A. Mrvar. 2008. *Pajek—Program for large network analysis*. Retrieved from http://vlado.fmf.uni-lj.si/pub/networks/pajek/pajek/

Bell, M. I. 2005. Southwest airlines and network-centric operations. *Information Age Warfare Quarterly* 1:24-32.

Blandford, D., and J. Dewbre. 1994. Structural adjustment and learning to live without subsidies in OECD countries. *American Journal of Agricultural Economics* 76: 1047-52.

Boehlje, M., J. Akridge, and D. Downey. 1995. Restructuring agribusiness for the 21st century. *Agribusiness* 11:493-500.

Borgatti, S. P., and M. G. Everett. 1999. Models of core/periphery structures. *Social Networks* 21:375-95.

Borgatti, S. P., M. G. Everett, and L. C. Freeman. 2002. *UCINET for Windows: Software for social network analysis*. Harvard, MA: Analytic Technologies.

Brandes, U., and T. Erlebach. 2005. *Network analysis. Methodological foundations*. Berlin: Springer.

Chaminade, C., B.-Å. Lundvall, J. Vang, and K. J. Joseph. 2009. Designing innovation policies for development: Towards a systemic experimentation-base approach. In *Handbook of innovation systems and developing countries*, ed. B.-Å. Lundvall, K. J. Joseph, C. Chaminade, and J. Vang, 360-79. Cheltenham, UK: Edward Elgar.

Clauset, A., C. R. Shalizi, and M. E. J. Newman. 2009. Power-law distributions in empirical data. *SIAM Review* 51:661-703.

Davis, J. H. 1956. From agriculture to agribusiness. *Harvard Business Review* 1:107-15.

Davis, J. H., and R. A. Goldberg. 1957. *A concept of agribusiness*. Boston: Harvard University Press.

De Mesnard, L. 2001. On boolean topological methods of structural analysis. In *Input-output analysis: Frontiers and extensions*, ed. M. L. Lahr and E. Dietzenbacher, 268-79. New York: Palgrave.

Dolfsma, W., C. Chaminade, and J. Vang. 2008. Knowledge dynamics out of balance: Knowledge biased, skewed and unmatched. *Research Policy* 37:1657-8.

Eastwood, R., M. Lipton, and A. Newell. 2010. Farm size. In *Handbook of agricultural economics, volume 4: Agricultural Development: Farm policies and regional development*, ed. R. E. Evenson and P. Pingali, 3323-97. Amsterdam: North-Holland.

European Commission. 2007. The importance and contribution of the agri-food sector to the sustainable development of rural areas. Directorate-General for agriculture and rural development, Brussels.

———. 2008a. The EU rural development policy: facing the challenges. Brussels. http://ec.europa.eu/agriculture/rurdev/publi/index_en.htm. (Accessed February, 2009).

———. 2008b. Rural development plans in Spain: National rural network (Programa de la Red Rural Nacional 2007-2013). MEMO/08/437, Brussels.

———. 2009. *INNO-Policy TrendChart-Innovation Policy Progress Report. Spain*, Brussels.

European Council. 2010. European Council 25/26 March 2010. Conclusions. DEUCO 7/10, Brussels.

EUSTAT. 2008. Tabla simétrica destino de la Comunidad Autónoma de Euskadi por componentes de valor añadido y ramas. http://www.eustat.es. (Accessed January, 2008).

Everett, M., and S. P. Borgatti. 2005. Extending centrality. In *Models and methods in social network analysis*, ed. P. J. Carrington, J. Scott, and S. Wasserman, 57-76. Cambridge: Cambridge University Press.

FAO. 1997. The agroprocessing industry and economic development. In *The state of food and agriculture*, ed. FAO. Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/w5800e/w5800e12.htm. (Accessed February, 2009).

Federación de Cajas de Ahorros Vasco-Navarras. 1985. Tablas Input-Output de la Comunidad Autœnoma del País Vasco 1980. Vitoria: Servicio de Publicaciones de la Federación.

Feser, E., S. Sweeney, and H. Renski. 2005. A descriptive analysis of discrete U.S. industrial complexes. *Journal of Regional Science* 45:395-419.

Feser, E. J., and E. M. Bergman. 2000. National industry cluster templates: A framework for applied regional cluster analysis. *Regional Studies* 34:1-19.

Fruchterman, T. M. J., and E. M. Reingold. 1991. Graph drawing by force-directed placement. *Software, Practice and Experience* 21:1129-64.

García, A. S., A. Morillas, and C. Ramos. 2010. Spanish and European innovation diffusion: A structural hole approach in the input-output field. *The Annals of Regional Science* 44:147-65.

Gardner, B. L. 1992. Changing economic perspectives on the farm problem. *Journal of Economic Literature* 30:62-101.

Garofoli, G. 1992. *Endogenous development and southern Europe*. Aldershot: Avebury.

Hai-Feng, Z., L. Ke-Zan, F. Xin-Chu, and W. Bing-Hong. 2009. An efficient control strategy of epidemic spreading on scale-free networks. *Chinese Physical Letters* 26: 0689011-14.

Herrero, C., A. Soler, and A. Villar. 2004. *Capital Humano y Desarrollo Humano en España, sus comunidades autonómas y provincias. 1980-2000*. Bilbao: Instituto Valenciano de Investigaciones Económicas, Fundación Bancaja.

Hidalgo, C. A., B. Klinger, A.-L. Barabási, and R. Hausmann. 2007. The product space conditions the development of nations. *Science* 317:482-7.

Hirschman, A. 1958. *The strategy of economic development*. New York: W. W. Norton.

Hojman, D. A., and A. Szeidl. 2008. Core and periphery in networks. *Journal of Economic Theory* 139:295-309.

Huang, W., and C. Li. 2007. Epidemic spreading in scale-free networks with community structure. *Journal of Statistical Mechanics: Theory and Experiment* P01014:1-13.

Instituto de Estadística de Andalucía. 1990. Tablas Input Output de Andalucía. Junta de Andalucía.

———. 2006. Marco Input-Output de Andalucía 2000. Consejería de Economía y Hacienda. Junta de Andalucía. http://www.juntadeandalucia.es. (Accessed January, 2008).

INE. 1986. Contabilidad Nacional de España. http://www.ine.es. (Accessed January, 2008).

———. 2009. Contabilidad Nacional de España. http://www.ine.es. (Accessed January, 2008).

Jackson, M. O. 2010. An overview of social networks and economic applications. In *Handbook of social economics*, ed. J. Benhabib, A. Bisin, and M. O. Jackson. North-Holland: Elsevier.

Jensen, M. B., B. Johnson, E. Lorenz, and B.-Å. Lundvall. 2007. Forms of knowledge and modes of innovation. *Research Policy* 36:680-93.

Krebs, V., and J. Holley. 2002–2006. Building smart communities through network weaving. Technical Report. http://www.orgnet.com. (Accessed January, 2009).

Krugman, P. 1991. Increasing returns and economic geography. *Journal of Political Economy* 99:483-99.

———. 1999. The role of geography in development. *International Regional Science Review* 22:142-61.

Kubo, Y., J. De Melo, S. Robinson, and M. Syrquin. 1986. Interdependence and industrial structure. In *Industrialization and growth. A comparative study*, ed. H. Chenery, S. Robinson, and M. Syrquin, 188-225. New York: Oxford University Press.

Litzenberg, K. K., and V. E. Schneider. 1986. A review of past agribusiness management research. *Agribusiness* 2:397-407.

López-Pintado, D. 2008. Diffusion in complex social networks. *Games and Economic Behavior* 62:573-90.

Mariotti, F. 2007. Learning to share knowledge in the Italian motorsport industry. *Knowledge and Process Management* 14:81-94.

McFadyen, M. A., M. Semadeni, and A. A. Cannella Jr. 2009. Value of strong ties to disconnected others: Examining knowledge creation in biomedicine. *Organization Science* 20:552-64.

Metcalfe, J. S. 2005. Systems failure and the case for innovation policy. In *Innovation policy in a knowledge-based economy. Theory and practice*, ed. P. Llerena and M. Matt, 47-74. Berlin: Springer-Verlag.

Montresor, S., and G. Vittucci. 2007. Constructing inter-sectoral innovation diffusion networks with input-output: How to get relative flows? An illustrative application to six OECD Technological Systems for the middle' 90s. 16th International Input-Output Conference, July 2007, Istanbul.

———. 2008. Innovation clusters in technological systems: A network analysis of 15 OECD countries for the mid-1990s. *Industry and Innovation* 15:321-46.

Newman, M., A.-L. Barabási, and D. J. Watts. 2006. *The structure and dynamics of networks*. Princeton: Princeton University Press.

Obstfeld, D. 2005. Social networks, the Tertius Iungens orientation and involvement in innovation. *Administrative Science Quarterly* 50:100-130.

OECD. 1995. Input-output tables. http://www.oecd.org. (Accessed January, 2008).

———. 2006. Input-output tables. http://www.oecd.org. (Accessed January, 2008).

Prais, S. J. 1974. A new look at the growth of industrial concentration. *Oxford Economic Papers* 26:273-89.

Prebisch, R. 1950. *The economic development of Latin America and its principal problems*. New York: United Nations.

Presidencia de la UE. 2010. La agricultura y la reforma de la PAC en la perspectiva de la estrategia UE 2020. Documento de Trabajo de la Presidencia. Reunión informal de ministros de agricultura de la Unión Europea. http://www.mapa.es/ministerio/pags/jornadas-pac/jornada03. (Accessed April, 2010).

Ravasz, E., and A.-L. Barabási. 2003. Hierarchical organization in complex networks. *Physical Review E* 67:026112.

Reagans, R., and B. McEvily. 2003. Network structure and knowledge transfer: The effects of cohesion and range. *Administrative Science Quarterly* 48:240-67.

Reagans, R., and E. W. Zuckerman. 2001. Networks, diversity, and productivity: The social capital of corporate R&D teams. *Organization Science* 12:502-17.

Riedel, J. 1976. A balanced-growth version of the linkage hypothesis: A comment. *Quarterly Journal of Economics* 90:319-22.

Sangmoon, K., and S. Eui-Hang. 2002. A longitudinal analysis of globalization and regionalization in international trade: A social network approach. *Social Forces* 81:445-68.

Schnabl, H., G. West, J. Foster, and A. Cook. 1999. A new approach to identifying structural development in economic systems: The case of the Queensland economy. *Australian Economic Papers* 38:64-78.

Schultz, T. W. 1945. *Agriculture in an unstable economy*. New York: McGraw Hill.

Semitiel, M. 2006. *Social capital, networks and economic development. An analysis of regional productive systems*. Cheltenham, UK: Edward Elgar.

Skidmore, D. 2000. Civil society, social capital and economic development. Technical Report, Columbia International Affairs Online, CIAO.

Smith, K. 2000. Innovation as a systemic phenomenon: Rethinking the role of policy. *Enterprise and Innovation Management Studies* 1:73-102.

Smith, D., and D. White. 1992. Structure and dynamics of the global economy: Network analysis of international trade 1965-1980. *Social Forces* 70:857-93.

Sun, H. J., and Z. Y. Gao. 2007. Dynamical behaviors of epidemics on scale-free networks with community structure. *Physica A* 381:491-6.

Tang, F., J. Mu, and D. L. Maclachlan. 2008. Implication of network size and structure on organizations' knowledge transfer. *Expert Systems with Applications* 34:1109-14.

Trigilia, C. 2001. Social capital and local development. *European Journal of Social Theory* 4:427-42.

Vogel, S. J. 1994. Structural changes in agriculture production linkages and agricultural demand-led industrialization. *Oxford Economic Papers* 46:136-56.

Wallerstein, I. 1976. *The modern world-system: Capitalist agriculture and the origins of the European world-economy in the sixteenth Century*. New York, Academic Press.

Wasserman, S., and K. Faust. 1994. *Social network analysis*. Cambridge: Cambridge University Press.

Woolthuis, R. K., M. Lankhuizen, and V. Gilsing. 2005. A system failure framework for innovation policy design. *Technovation* 25:653-80.

World Bank. 2008. *World development report: 2008. Agriculture for development*. Washington DC: The World Bank.