

MODELLING LINKAGES VERSUS LEAKAGES NETWORKS: THE CASE OF SPAIN

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Abstract

Network analysis in the input-output field is an ongoing and interesting area of research which has seen a rise in contributions in recent years. In the input-output field, studies based on graph and network theory have been developed only about topological measures used descriptively. Modelling input-output structure by statistical network models is the aim. The proposed network models for the Spanish productive relationships assess the evolution of the productive structure and offers insights into the explanation of the domestically and imported productive structure in the periods 1995 and 2009 in Spain.

Key words: network theory, input-output analysis, imported structure, qualitative input-output analysis.

JEL codes: C67, D57

1. Introduction

Network theory and Graph theory have been applied in the input-output field as a fruitful research. Since Ponsard's (1969), Lantner's (1974), Campbell's (1975) pioneering papers, the extension of these theories has entailed a fresh approach in the study of the complex structures associated with sectoral interactions. From graph and network theoretical concepts a large variety of measures have been proposed to facilitate a scan of the economic structure (Morillas, 1983; Holub, Schnabl and Tappeiner, 1985; Ghosh and Roy, 1998; Lantner, 2001; Aroche-Reyes, 1996; Dietzenbacher and Romero, 2007, García et al., 2008, 2010 and 2011, among others).

In the input-output field, graph and network studies have been developed around measures of centrality, cohesion or intermediation, among others, which put together a synthetic view of the structure. However, these topological characteristics imply a partial description referring to some properties selected a priori by the researcher. Reasonable selection of an indicator is a pre-requisite for effectively using it. And although it is impossible to reproduce the whole complex of the economic network by a limited number of indicators, it is important to identify the measures set, which can preserve the main features of the structure.

The interest of the article goes beyond a descriptive study on the relational structure. The aim is causal modelling of input-output structure from its own positional characteristics. A formal search of the factors that are involved in establishing relations through statistical models is proposed. These models allow us to evaluate objectively possible explicative topological indicators of the network.

Using this methodology we carry out a comparative study of the import and domestic relationships in the Spanish economy in the years 1995 and 2009. The non distinction between imported and domestically produced inputs can produce a strong bias in the measurement of economic effects. The economic multiplier effect of the sectors can be overestimated (Dietzenbacher et al., 2005). Considering that sectors not only use

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imported inputs directly but they also incorporate them indirectly. The production of one sector will also generate effects over the imported input demand of other sectors, it is, the economic leakage (Guo and Planting, 2000). The analysis of imported and domestically inputs allows us to “investigate the impact of international trade on those linkages and how it influences the overall interdependence of an economy (Reis and Rua, 2009). The impact of economic leakages associated to the imports can be estimated by using separate input-output tables: one for domestically produced inputs and the other composed of imports (Guo and Planting, 2000).

The remainder of the paper is organised so that in the next section we present a description of the state of development of network statistical models. Following, the modelling for domestically and imported relationships allows the assessment of the role of both structures in the Spanish economy and reaches some conclusions about its evolution along the studied period. How these sectors function and capacity of explanation of topological measures are revealed.

2. Methodology

Sector relations modelling must reflect the interdependence phenomenon and economic diffusion processes present in an input-output table. This basic requisite implies the changing of the independence-breaking assumption employed in classical statistical regressions.

The network view as a stochastic process, where the global structure schemes arise from local links, has set up an active research line (Wasserman and Faust, 1994, Carrington et. al., 2005). Different classifications of the network models are, but we can made reference to two scopes in the Social Network Theory. Barabási (2002) proposes that complex networks naturally settle into a characteristic scale-free structure. The study of power laws connecting networks is relatively new, but has received widespread attention in many fields. In this work, we follow the scope of statistical network models which allow the inclusion of independent variables. Our choice is compatible with the objective of this paper: structural explanation from topological indicators and their assessment with this aim.

The existing set of statistical network models is varied (Carrington et al., 2005). In this work, the application of the so-called p_1 model is proposed. Although, other more complex models are, the p_1 model has a long tradition, contrasting results in other fields and the independent variables used in the model are well-known in qualitative input-output analysis.

2.1. Model p_1

The p_1 model developed by Holland and Leinhardt (1981) analyses the relationships in a network. This statistical model for social network modelling has become the key stone of statistical analysis of relational data. In the input-output field, this methodology has not been applied yet and supposes a new scope in economic transaction articulation that allows us to evaluate the significance of different structural effects.

Let $\mathbf{X} = \{X_{ij}\}_{n \times n}$ denoting an adjacency matrix associated with the economic network. This matrix represents a set of ordered pairs recording the presence or absence of productive links between sector pairs:

$$X_{ij} = \begin{cases} 1 & \text{if sector } i \text{ is related with sector } j \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

In input-output field, the particular relation gathered in the adjacency matrix can be derived from the technical or distribution coefficients. We assume $\mathbf{X}$ and its elements are random variables. These variables are assumed to be interdependent given the nature of economic sectoral process collected in an input-output table.

The key features of the structure can be represented by a wide variety of topological characteristics. Some structural indicators can be important explanatory variables for the generation of productive links. So, assuming certain sectors have a greater capacity for establishing links, the productive relations can be gathered in the reciprocal relations number (M), the reception and sending of sector demand impulses, in graph terms in-degree (X_{+j}) and out-degree (X_{i+}) and, in the density or total relations number (X_{++}). These basic measures can be formulated as:

$$\begin{aligned} M &= \sum_{i < j} X_{ij} X_{ji} \\ X_{+j} &= \sum_{i=1}^n X_{ij} \\ X_{i+} &= \sum_{j=1}^n X_{ij} \\ X_{++} &= \sum_{i=1}^n \sum_{j=1}^n X_{ij} \end{aligned} \quad (2)$$

The probability of observed values associated with these measures can be derived from a distribution family $\mathbf{X}$ (Holland and Leinhardt, 1981):

$$p_1(\mathbf{x}) = P(\mathbf{X} = \mathbf{x}) = \exp \left\{ \rho m + \phi x_{++} + \sum_{i=1}^n \alpha_i x_{i+} + \sum_{j=1}^n \beta_j x_{+j} \right\} K(\rho, \phi, \{\alpha_i\}, \{\beta_j\}) \quad (3)$$

where $\mathbf{x}$ is random graph, $m, x_{++}, x_{i+}, x_{+j}$ gathering values of reciprocity relations (M), density (X_{++}) and out-degree and in-degree (X_{i+}, X_{+j}), respectively, and $\rho, \phi, \alpha_i, \beta_j$ correspond to the parameters associated with these topological measures so the parameter ϕ gathers the relations density, the coefficients α_i and β_j measure the sender and receiver propensity and ρ represents the reciprocation force. The function K is a normalizing quantity.

The p_i model assumes the density and reciprocity effect are constant, while the in-degree and out-degree affects can vary between sectors. Also some restrictions are required by the model estimation (Fienberg, Meyer and Wasserman, 1985):

$$\sum_{i=1}^n \alpha_i = \sum_{j=1}^n \beta_j = 0 \quad (4)$$

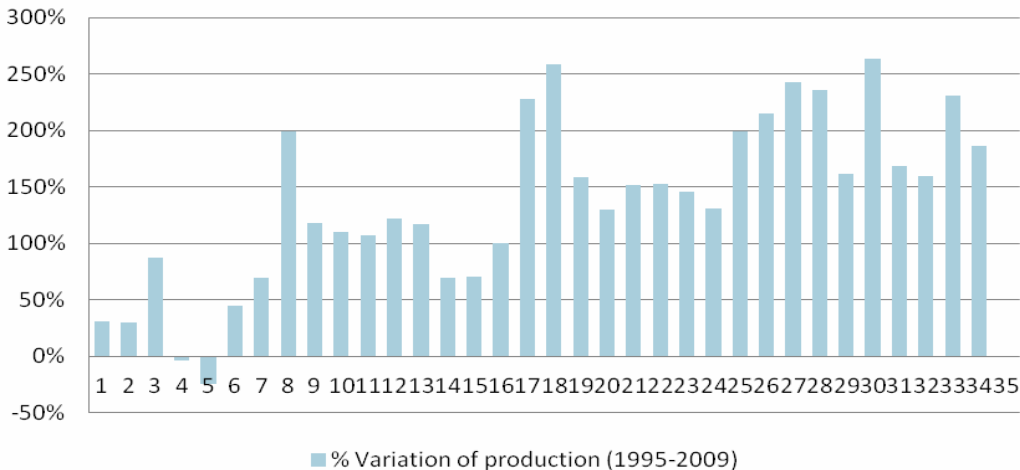
The process of estimation and alternative formulation are gathered in the literature (Fienberg, Meyer and Wasserman, 1985; Holland and Leinhardt, 1981).

3. Spanish economic networks modelling

The empirical analysis is based on the World Input-Output Database (WIOD), which gathers a set of national harmonized supply and use tables, symmetrical input-output tables, world input-output tables and extensive satellite accounts. The information used in this work is supplied by the input-output tables of Spain in 1995 and 2009 with a level of desagregation of 35 sectors. The temporal period corresponds to the first and the last year available on the database. It supposes a long enough period to detect structural change in the economy and furthermore it includes the economic crisis moments suffered worldwide.

In the observed temporal period, the levels of production have changed substantially. The figure nº 1 evidences the percentage of variation of the production for each sector to pass from 1995 to 2009.

Figure nº1. Evolution of the % of variation of sectoral production (1995-2009)



Only the sectors Textile products (4) and Leather (5) have reduced their production in 2009. The sector Private Households with Employed Persons (35) has not suffered any changes. The rest have presented an increase, especially in the case of the electricity, gas and water supply (16), construction (17) and the service sectors (25-34). The increasing importance of the tertiary segment in modern economies has given rise to

a wide range of studies about its contribution to development and technological innovation (Andersen et al., 2000, Antonelli, 2000, among others). The greater role of services can reflect a shift in consumer demand, which is linked to high incomes, elasticity of services, increased business demand as well as some outsourcing of manufacturing to specialised services providers in Spain (García et al., 2008).

The increasing international integration in the production of goods leads to a growing importance of the distinction of domestic and import inputs for sectoral economic planning and policy formulation. In fact, “one of the characteristic factors of Spain’s production structure is its high import content, which exceeds that of the main Euro Area economies (...). This phenomenon appears to be due essentially to the Spanish sectors’ greater propensity to import – particularly in the case of the industrial sectors of high and medium-high technological content – and not so much to differences in productive structure” (Cabrero and Tiana, 2012).

Moreover, the table nº1 presents the evolution of the participation of total intermediate consumptions and imported intermediate consumption over the production. The input’s need of Spain has increased in the studied period. However, the increase of input requirements has led to an increase of imported intermediate consumption and so a decline of domestic intermediate consumptions.

Table nº1. Evolution of the of intermediate consumptions in the production

	1995	2009
<u>Total intermediate consumptions</u> <i>Production</i>	49,57%	50,92%
<u>Imported intermediate consumptions</u> <i>Production</i>	6,80%	7,49%
<u>Imported intermediate consumptions</u> <i>Total intermediate consumptions</i>	13,72%	14,70%

This a tendency observed in many countries (Cadarsó et al., 2008) in which the vertical specialization and fragmentation of production (Hummels et al., 2001, Grossman and Helpman, 2002, among others) play an important role. Some previous works have measured the vertical specialization and/or outsourcing in Spain (Minondo and Rubert, 2001 and 2002; Gómez et al., 2006, Cadarsó et al., 2007, Díaz-Mora et al., 2007, among others) emphasizing their importance.

In the next epigraph, we focus on modelling the domestic and/or import relationships between sectors. Using statistical network models, we assess both structures, the role of each individual sector and the possible explicative structural effects.

3.1. Model estimation

The relational structures are represented by Boolean graphs in p_1 model. When applied in an input-output context, these graph applications convert the transaction matrix into a dichotomy structure. This is done by replacing the value of each coefficient that links one sector i with another sector j by a Boolean coefficient. All values under the filter are set to zero and all values equal or above the filter are set to one. There are an infinite

number of potential values for the filter. So, this conversion is an important matter (Aroche-Reyes, 1996; Morillas, 1983, De Mesnard, 1995). In theory, it is possible to change the value of the filter to explore all feasible sets. In this work, we concentrate on the proposed methodology and we follow one of the usual options in the literature. The partial graph X is associated to the direct input coefficients matrix and the filter is the mean of direct input coefficients. In the case of modelling linkages, the partial graph is associated to the domestic direct input coefficient. The model of import productive relationships is derived from the graph associated to the imports direct input coefficient matrix.

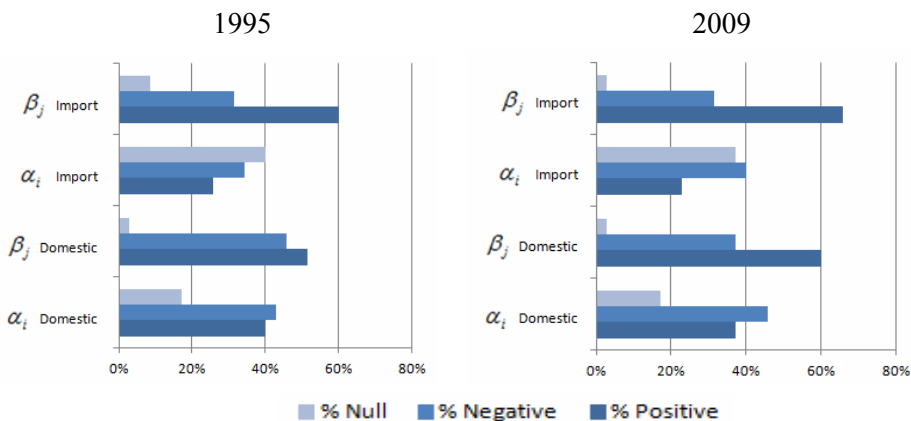
The Spanish p_1 models in 1995 and 2009 are estimated from these Boolean graphs. The results are presented in Table 1 placed in the annex. In the model, the economic structure is represented by the density, reciprocity, out-degrees and in-degrees. The parameters associated with these indicators are $\phi, \rho, \alpha_i, \beta_j$, respectively.

The parameters estimated values allow evaluating the role of these topologic indicators at the establishment of important relations in the Spanish economic network. If the coefficient is positive, there exists a correlation between the topologic variable and the important productive connections (denoted by one in the graph). Coefficients close to zero to zero will mean that changes in the topologic indicators will not have any effect on the dependent variable (generation of relations). Finally, negative coefficients will indicate the nonexistence of correlation between the topologic variable and important relationships generation.

Density, that is, the volume of relations established in the network, does not constitute an explanatory variable of the more important connections. An increase of the number of relations between sectors doesn't suppose an increment of the important connections necessarily. On the other hand, the reciprocity influences positively the generation of important relations. An increase of the reciprocity in the network implies a bigger tendency to generate important relations within the structure, specially imported.

The in-degrees (β_j) have a more important role in the explanation of the productive domestic and imported relations in Spain than the out-degrees (α_i), as we can see in the figure n°2.

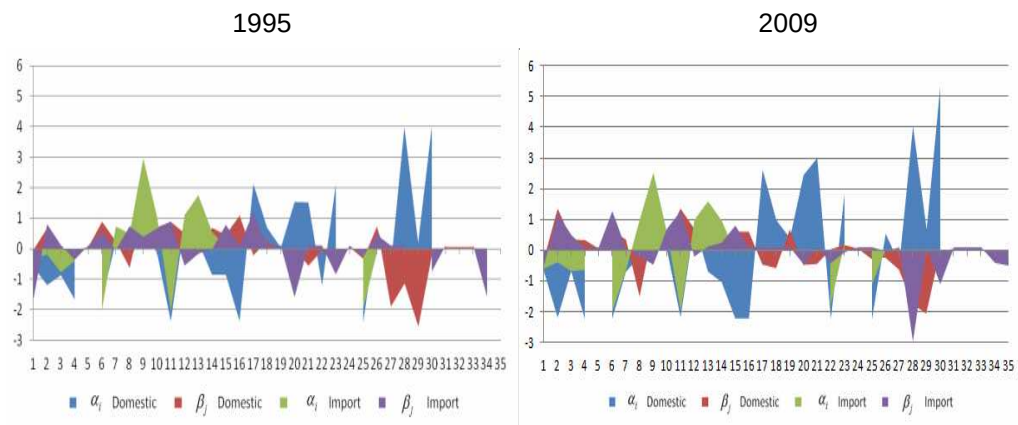
Figure n° 2. Estimated values summary



In fact, a high percentage of sectors, between 50% and 65%, present a high supply relation propensity. However, a lower percentage of sectors have a positive parameter for demand links ($\alpha_i > 0$). A few sectors are able to generate important demand links, most especially in the case of imported relationships. This tendency is emphasized in 2009, above all in the imported structure. The results show an economy orientated to the supplied side in both years and where the weight of external relations ensures itself a key instrument for the economic network explanation. The obtained values of out-degrees and in-degrees for each sector in 1995 and 2009 are represented graphically in the next figures.

In 1995, sectors related with construction, inland transport and some services such as financial intermediation or other business activities present a high propensity to establish important demand relationships in domestic economic structure. The imported purchases tend to generate more in traditional manufacturing industries such as: coke, chemicals, rubber, metal, machinery... So, there seems to be a negative correlation between linkage and leakage from the demand side as other works have emphasized (Reis and Rua, 2009).

Figure nº 3. Model p_1 .



The important supply relations are associated to sales of natural resources including mining, leather, cake, rubber or other non-metallic minerals mainly at non domestic level of transaction. In this case, it does not appear to be a clear correlation between the domestic and imported structure from the supply side of the economy.

These results and the explanatory capacity of the model must be evaluated under a goodness of fit analysis. Given that the model can predict the relations, the comparison between observed data and the calculated model predictions offer a reliability analysis. The network literature (Wasserman and Faust, 1994) usually rounds up the expected values to either 0 (if the model prediction is $<0,5$) or 1 (if the model prediction $\geq 0,5$). Then, the expected values can be compared to the observed data. The estimated models reproduce accurately the domestic and imported relations in both temporal moments. The level of concordance can be observed in the next table. In percentage terms, the concordance degree represents around 86% and 90%, for domestic and imported

networks respectively. The models offer a high level of fit. So, the proposed methodology reproduces the complex of the economic network adequately.

Table n°2. Concordance degree

	1995		2009	
	Domestic	Imported	Domestic	Imported
Percentage	85,96%	90,77%	86,12%	90,53%

4. Conclusions

The statistical models for network data open a new line of research in input-output productive structures modelling. The objective of explaining the structure and topological indicator assessment is obtained. In this work, the p_1 model is proposed to introduce this type of methodology in the input-output field. The reasons for selecting this model and not others are the contrast results in other fields and the use of independent variables well-known in qualitative input-output analysis.

In any case, the p_1 is an initial modelling that can have different extensions (Wasserman and Galaskiewicz, 1984; Wasserman and Iacobucci, 1986; between others). More flexible models (Carrington et al., 2005) that consider more information about dependence structure and supply a more in-depth explanation can be applied also with the same objective.

In the empirical application, the p_1 model reproduces economic structure with a high level of fit in 1995 and 2009. Not all basic topological measures employed in the model have had the same role in the explanation of the networks. The in-degrees have a strong influence on the generation of domestic and imported relations. The demand side of the economy -represented by the out-degrees- results are more relevant in the explanation of the domestic relations. These results are common in general for both temporal moments. Spain shows very similar productive schemes in 1995 and 2009.

Other studies (Jensen et al., 1988; West, 2000; Thakur, 2008) provide empirical evidence of the existence of regularities in economies. Jensen et al. (1988) extend the fundamental production structure concept (Simpson et al. 1965) to the fundamental economic structure term and link it to a possible evolutionary path along which economies can progress. The fundamental economic structure (FES) provides a framework in which economic systems showed some common patterns and regularities. The FES term implies stability and prediction of structural elements. The FES components traditionally are determined by statistical regressions in which the FES activities can be predicted by economic aggregated indicators (population, national product...) used as independent variables in a regression model of productive relations (Jensen et al., 1988). However, "it can be pointed out that a stable or predictable cell in a matrix is not necessarily important; in fact, it is plausible to expect that marginal cells can be quite stable for some industries at least, for which that concept of fundamental structure can also be revised" (Aroche, 2006). The p_1 models suppose an interesting methodological alternative in the FES research that allow prediction of the important and

non-important relations in the network and are concerned with the location of sectors in the economy.

The proposed method also allows not only the indicator selection and prediction of relations but key sectors study. For example, those sectors with a positive value parameter of in-degree and out-degree show a high propensity to establish demand and supply links and can represent key sectors for development. A classic backward and forward linkages analysis based on direct relations can be performed. Advanced statistical network models would allow the study of demand and supply activities separately and the search for explanatory factors for their different behaviour.

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Annex

Complete list of sectors names:

1. Agriculture, Hunting, Forestry and Fishing	19. Motor Vehicles; Retail Sale of Fuel
2. Mining and Quarrying	20. Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycle
3. Food, Beverages and Tobacco	21. Vehicles and Motorcycles; Repair of Household Goods
4. Textiles and Textile Products	22. Hotels and Restaurants
5. Leather, Leather and Footwear	23. Inland Transport
6. Wood and Products of Wood and Cork	24. Water Transport
7. Pulp, Paper, Paper , Printing, Publishing	25. Air Transport
8. Coke, Refined Petroleum, Nuclear Fuel	26. Transport Activities; Activities of Travel Agencies
9. Chemicals and Chemical Products	27. Post and Telecommunications
10. Rubber and Plastics	28. Financial Intermediation
11. Other Non-Metallic Mineral	29. Real Estate Activities
12. Basic Metals and Fabricated Metal	30. Renting of M&Eq and Other Business Activities
13. Machinery, Nec	31. Public Admin and Defence; Compulsory Social Security
14. Electrical and Optical Equipment	32. Education
15. Transport Equipment	33. Health and Social Work
16. Manufacturing, Nec; Recycling	34. Other Community, Social and Personal Services
17. Electricity, Gas and Water Supply	35. Private Households with Employed Persons
18. Construction	

Table A1. Model p_i

	1995				2009			
	Domestic		Import		Domestic		Import	
ϕ	-1,2521		-1,7894		-1,4787		-2,1434	
ρ	0,1047		0,9992		0,0941		1,295	
SECTORS	α_i	β_j	α_i	β_j	α_i	β_j	α_i	β_j
1. Agriculture	-0,591	-0,047	-0,319	-2	-0,7	-0,28	-0,589	-0,516
2. Mining	-1	0,668	-0,188	0,809	-2	1	-0,393	1
3. Food	-0,865	-0,051	-0,773	0,123	-0,687	0,352	-0,673	0,477
4. Textiles	-2	-0,058	-0,392	-0,36	-2	0,329	-0,632	0,039
5. Leather & Footwear	0	0,047	0	0,106	0	0,052	0	0,076
6. Wood & Products	-2	0,878	-2	0,565	-2	0,607	-2	1
7. Paper & Printing	0,218	0,233	0,728	-0,041	-0,687	0,352	-0,632	0,039
8. Coke, Pretroleum	-0,365	-0,631	0,49	0,742	-0,202	-2	1	-0,224
9. Chemicals	0,563	1	3	0,399	0,726	0,697	3	-0,485
10. Plastics	-0,132	0,696	1	0,67	0,032	0,377	0,585	0,682
11. Other Minerals	-2	0,87	-2,049	0,901	-2	1	-2	1
12. Basic Metals	0,839	0,5	1	-0,554	0,876	0,705	1	-0,224
13. Machinery, Nec	0,213	-0,027	2	-0,163	-0,687	0,352	2	0,104
14. Electrical eq.	-0,848	0,675	0,537	-0,017	-1	0,344	0,975	0,229
15. Transport eq.	-0,855	0,446	0,062	0,787	-2	0,607	-0,076	0,783
16. Other Manuf.	-2	1	0	0,106	-2	0,607	0	0,076
17. Electricity	2	-0,224	-2	1	3	-0,475	0	0,076
18. Construction	0,688	0,251	0	0,106	0,99	-0,592	0	0,076
19. Motor Vehicles	0,038	-0,032	0	0,106	0,405	0,681	0	0,076
20. Wholesale Trade	2	0,027	-1	-2	2	-0,487	-1	-0,471
21. Vehicles	2	-0,564	0	0,106	3	-0,452	0	0,076
22. Hotels	-1	-0,055	0	0,106	-2	0,031	-2	-0,425
23. Inland Transport	2	-0,528	-1	-0,841	2	0,167	0,24	-0,082
24. Water Transport	0	0,047	0	0,106	0	0,052	0	0,076
25. Air Transport	-2	-0,336	-2	-0,253	-2	-0,293	-1	0,081
26. Travel Agencies	0,699	0,725	-0,164	0,455	0,545	-0,243	-0,003	-0,043
27. Post and Teleco.	-0,602	-2	0	0,106	-0,43	-0,639	0	0,076
28. Financial	4	-1	0	0,106	4	-2	-2	-3
29. Real Estate	0,193	-3	0	0	0,68	-2	0	0,076
30. Other Business Act.	4	-0,177	5	-0,752	5	-0,071	6	-1
31. Public Admin	0	0,047	0	0,106	0	0,052	0	0,076
32. Education	0	0,047	0	0	0	0,052	0	0,076
33. Health	0	0,047	0	0,106	0	0,052	0	0,076
34. Other Services	-2	-0,334	-1	-2	-1	-0,289	-2	-0,425
35. Domestic Employees	0	0	0	0	0	0	0	-0,516