Modelling economic structures from a Qualitative Input-Output Perspective: Greece in 2005 and 2010

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ABSTRACT

The Input-Output model has made extensive use of graph and network theory, methods and conclusions, in order to carry out structural analysis; such extensions have yielded powerful insights on the relationships existing between industries in an economic system. It is customary in the field to take a deterministic perspective when analysing economic structures, using various measures derived from the Input-Output tables; yet the model can include stochastic experiments. This paper takes that course of action, aiming at modelling the Greek economic structure from a qualitative viewpoint for 2005 and 2010; moreover, sectors are divided by groups of differentiated technology intensity. The methodology is based on a model based on families of distributions that allow predicting and analysing network structures. Results are reached by a probabilistic approach, producing interesting insights about the economic structures under study, while revealing different behaviour of the different groups of industries, classified by technological intensity.

Key words: network theory, qualitative input-output analysis, structural analysis, simulation model

JEL codes: C63, C67, D57, O52

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1. INTRODUCTION

The analysis of the relationships between sectors within economic systems has been a fruitful line of research within the Input-Output (IO) field. Many analytical techniques yield interesting indicators to study economic systems, attending to the technical coefficients tables, such as multiplier analysis (e.g. Chenery and Watanabe, 1958; Rasmusen, 1956; Streit, 1969), matrix triangulation (Simpson et al., 1965; Haltia, 1992; Aroche, 1995), structural decomposition approaches (Dewhurst, 1993), fields of influence (Hewings et al., 1988), extraction methods (Strassert, 1968), to name but a few. In general, these methods produce results on the economic structure as a whole, but they can also be used to analyse the role of individual sectors.

Alternatively, some researchers have also applied concepts and techniques developed for network and graph theories, extending structural analysis within the context of the IO model. Qualitative IO analysis (QIOA) pays attention to the sheer existence of links between industries, regardless of their intensity, represented by the numerical value of the entries in the IO table and further, the set of connections can be depicted in a graph that allows having a picture of the shape of the economic structure in a glimpse (Ponsard, 1969; Lantner, 1974; Morillas, 1983, Schnabl, 1995, Aroche, 1996). Graph theory provides theorems and results which have been used in network problems in various fields of applied mathematics, as well as computational algorithms (Harary, 1969, Cormen *et.al.*, 2009). More recently, QIOA has been paired to social network theory, which has been applied throughout a wide range of social disciplines like anthropology, geography sociology or psychology (García et al., 2008; Semitiel and Noguera, 2012; Lopes, Dias and Amaral, 2012). Network theory, however does not always comply with the assumptions and rationality on which the IO model stands; therefore it is necessary to be aware on the extent to which network analysis is useful in the context of economic analysis.

It is customary that research within the IO model framework takes a deterministic perspective and data arrays are taken as given. A few exceptions can be mentioned though, linking the IO model to stochastic interpretations, for example, Guerrero and Rueda (undated), Simonovits (1975), West (1986), Cabrer, *et.al.* (1998). Those papers share the preoccupation of taking advantage of the statistical properties of databases to explain the characteristics of economic structures; further, data bases can be modelled trough stochastic models. Following such approach, in this paper we aim beyond studying an economic structure within the scope of QIOA, extending a log-linear model first developed by Holland and Leinhardt (1981) in order to study connectivity patterns in a social network. Log-linear models study association patterns between variables or between elements in sets, regardless of any causality hypothesis; they usually take the form of a function whose logarithm is a polynomial function of the parameters of the model.

Our model takes advantage of the probability distributions of connectivity patterns between sectors (e.g., sector *i* can demand inputs from *j* or *j* can demand from *i*, both can simultaneously demand and supply one another or those sectors can be disconnected, see below). We carry out a comparative study of the Greek economy in 2005 and 2010, classifying industries by technological intensity levels. We assume that the various groups of industries show different ability to maintain connections with other parts of the system; therefore, sustaining the connectivity of the economy. Such empirical exercise allows reaching conclusions about the structural features of that economy and the role of technology in the Greek economic network.

2. METHODOLOGY

An economic structure contains a set of industries, interconnected by flows of goods, mutually demanded and supplied; each sector produces one good by means of produced and non-produced inputs, through a specific technology that determines also the proportions in which each good available in the economy is used in each sector as input. The amounts of commodities actually consumed depend on the production level in each branch. As a result, sectors in the economic system are interdependent. It is well known that sectoral interdependence implies that changes in output levels or in the productive technology employed in one industry affects other producers -e.g., input suppliers. Thus changes in one sector may cause changes in the whole structure, when proportions vary. As stated above, it is customary to derive conclusions on the structural features of the economy examining the connections between sectors; further it would be possible to find positional arrangements for each industry, determined by the links of demand and supply that each one maintains with the rest of the productive apparatus

QIOA stresses on the study of the shape of economic structures, from such a perspective, it is customary to transform the technical coefficients matrix into a Boolean array, i.e., positive coefficients are made equal to one, showing the existence of links between demanding and producing sectors. It is said that when a sector *i* demands inputs from another *j*, the former is adjacent to the latter. Further, those relations can be depicted in a directed graph or, properly, a digraph: industries are represented as nodes and demands for inputs as arcs (arrows or directed edges), stemming from the consuming branch to the supplier. The resulting digraph can be understood as an economic network, as nodes and their relationships are of economic nature. As stated before, it has not been difficult to present IO structures as economic networks.

As already mentioned, the methodology used in this paper is based on a log-linear model -called p_1- first presented by Holland and Leinhardt (1981) who developed it in order to study the relationships within social groups; model *p1* begs to structural characteristics of the connectivity between members of the group under study to predict and analyse directed networks. The model uses a minimum amount of statistical information to estimate a minimum amount of parameters that describe the structure of those nets. In the economic context, model p_1 assumes that the existence of exchange relationships between any pair of industries can be explained on the grounds of the probability of occurrence of given patterns of connectivity between pairs of sectors. A sector either receives demand impulses for produced goods from another branch or sends such impulses to the latter (in both cases output always accommodates to demand); connections can also be reciprocal, if those two industries at the same time receive and send demand impulses from one another, or those two sectors can be disconnected, if none demands inputs from the other. Those patterns of established relationships present statistical regularities, which can be disclosed by a probabilistic model and will be useful to build topological indicators that characterise the structure.

Model p_1

In short, Holland and Leinhardt (1981) examine the structural characteristics of a net in order to model the probability that the relational ties among pairs of sectors (dyads) of nodes in the network follow some expected pattern. Later on, Wasserman and Pattison (1996) discuss a generic framework of models (p*), assuming groups of members of the network of any size; nevertheless, estimation problems make it quite difficult to use such generalized versions. Model p_1 expresses each relational tie between two any sectors as a stochastic function of the network's structural properties; i.e., its connectivity features. It includes four structural parameters: The propensity of reciprocity of ties (*M*), i.e., whether a dyad of sectors irradiate and receive an arc at the same time; the propensity that each sector receives or irradiates ties (w_{+j}, w_{i+}) and, finally, tie density (w_{++}) or the total volume of relationships established in the structure portrayed by the adjacency matrix $\mathbf{W} = \{w_{ij}\}$:

$$M = \sum_{i<j} w_{ij} w_{ji}$$

$$w_{+j} = \sum_{i=1}^{n} w_{ij} \qquad (2)$$

$$w_{i+} = \sum_{j=1}^{n} w_{ij}$$

$$w_{++} = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}$$

The probability of observed values associated with these measures can be derived from a distribution family *w* (Holland and Leinhardt, 1981):

$$p_1(w) = P(W = w) = \exp\left\{\rho m + \phi x_{++} + \sum_{i=1}^{n} \alpha_i w_{i+} + \sum_{j=1}^{n} \beta_j w_{+j}\right\} K(\rho, \phi, \{\alpha_i\}, \{\beta_j\}) \qquad (3)$$

where ρ, ϕ, α_i and β_j are parameters, associated to the variables employed in the model and K is a normalising number. Hence, the probability distribution of a network depends on the parameters that measure the tendency shown by each sector to establish either unidirectional relationships of demand (α_i), of supply (β_j), or bidirectional relationships (ρ), as well as the sectoral mean propensity to relate to other branches (ϕ).

The density effect (ϕ) depends on the amount of connections between the sectors in the structure; hence, there is only one value for the network. Model p_1 assumes that every pair of sectors shows an equal reciprocity effect (ρ). The parameters associated to the propensity to establish demand (α_i) or supply (β_j) relationships, however, may differ for each dyad of sectors, but the following restriction prevails (Fienberg, Meyer and Wasserman, 1985):

$$\sum_{i=1}^{n} \alpha_i = \sum_{j=1}^{n} \beta_j = 0$$

Positive values for each parameter provides statistical evidence of how the studied effects favour establishing relationships between sectors. For example, a positive ϕ indicates that if the density of the net increased (i.e., as the amount of connections between sectors grows), any particular sector may establish a greater number of connections with other sectors. On the contrary, when ϕ is negative, the number of connections in the net does not help to explain the density of the connections between a sector and the rest. Likewise, a positive ρ implies that any sector is likely to establish reciprocal connections with other sectors, because the economic system is closely tighten in that fashion; if ρ is negative, the likelihood that a given sector establishes bidirectional connections with other sectors is not related to the characteristics of the economic system. Similar explanations are relevant for positive or negative α_i and β_j.

3. A p_1 MODEL FOR THE GREEK ECONOMY

The previous model has been estimated for the Greek economy, using the most recent IO tables published by EUROSTAT, namely, 2005 and 2010. Those are comparable matrices, disaggregated into sixty-five homogeneous sectors, valued in current basic prices of each year (millions of Euros). Sectoral results are available at request.

In the Greek economy parameter ϕ equals -2.5 in 2005 and -1.9 in 2010; ρ is equal to 0.7 and 0.5 for those years[2]. As established above, a negative ϕ indicates that if two any sectors are interlinked, the existence of that connection is explained independently to the general pattern of the economy; for example, in the Greek system there are many too small intersectoral relationships to influence the integration configuration of the net, so their connectivity is independent from the propensity that any other sector may show to demand inputs from any other industry. That means that a raise in the amount of connections in the system does not explain an existing random connection between two sectors, because there is not a clear scheme of intersectoral relationships in the economy, such as vertical integration from the production of raw materials to related services, or a horizontal order, if the economy specialised in some kind of production. On the contrary, parameter ρ is positive and significant, i.e., when the number of reciprocal relationships increases, the

[2] For the matter, in an unpublished exercise for the European economy in 2000, parameter ϕ equals -2.6 and ρ 0.7 in an IO table aggregated into 25 sectors, published by Eurostat: Greece and Europe show similar integration patterns.

probability that any productive relation between two sectors will be of that kind will be higher.

Concerning parameters α_i and β_j, they are related to the probability that each sector shows either connections of input demand or supply. Those tendencies are related to the nature of each sector and the kind of good it produces. For example, a producer of consumer's goods would mainly demand inputs from the rest of the sectors, whereas a producer of raw materials would preferably show supply connections. Figures 1 and 2 show the distribution values of those parameters in the Greek economy in 2005 and 2010.

Figure 1
Distribution of parameters α_i and β_j
Greece 2005

Figure 2
Distribution of parameters α_i and β_j
Greece 2010

It is apparent that the distribution of parameters α_i and β_j differ in each observed period; nevertheless, differences are not so great comparing each type of measure in the two years, i.e., the economy shows no significant structural changes in this matter. In the two periods under consideration some 20% of sectors show null parameters α_i, but only 5% do so, concerning parameter β_j: the existence or inexistence of demand and supply connections between sectors is independent from the general tendency found in the economy in those proportions. Over 30% of the sectors show positive α_i; that is, demand connections of these sectors are explained by the connectivity pattern shown by the system in general; however over 45% of sectors do not relate their demand connections to that design. In opposition, over 60% of branches exhibit a propensity to establish supply liaisons with other sectors related to the general scheme of the economy (having positive β_j parameter) and over 30% show that kind of links that are not a result of the type of relations existing in the system, by a negative β_j parameter.

Table 1 disaggregates the former results by groups of sectors of different technological level, according to a definition by OCDE (Hatzichronoglou, 1997). First of all, over 60% of all sectors are services, either knowledge intensive (KIS) or otherwise, while the majority of the remaining sectors are either low or high and medium high technology industries. The low and high technology industries show markedly negative α_i coefficients, whereas services (of all sorts) tend to show more mixed results. On the contrary, most non service sectors show positive β_j coefficients, except for the medium-low technology industries.

Table 1

Statistical distribution of parameters α_i and β_j by technological level

Greece 2005 and 2010

		% Positive coefficients				% Negative coefficients				% Null coefficients			
		2005		2010		2005		2010		2005		2010	
	%	α_i	β_j	α_i	β_j	α_i	β_j	α_i	β_j	α_i	β_j	α_i	β_j
KIS*	40	42	62	42	54	54	39	54	46	4	0	4	0
Less KIS*	26	35	71	35	53	24	12	29	29	41	18	35	18
Low technology industries	14	11	44	11	78	89	56	67	22	0	0	22	0
Medium-low technology industries	9	50	33	67	67	50	67	33	33	0	0	0	0
High and medium-high technology industries	11	0	100	0	86	43	0	29	14	57	0	71	0

All industries	100	32	63	34	61	49	32	45	34	19	5	21	5

* Knowledge intensive services

From such results, the various technological segments in the economy show differentiated potential to establish relations with the rest of the economic structure in accordance to the general connectivity pattern of the economy. Indeed the two services blocks show higher ability to establish such relationships with other sectors, as they show higher positive topological measures both for demand and supply; yet, lower KIS show a much less clear tendency to hold demand relationships with other sectors, since a higher amount of sectors have null demand parameters. Services in developed economies contribute significantly to technological innovation and development (e.g. Antonelli, 2000); in Greece in particular, knowledge intensive services are important to bind the set of sectors in a cohesive system (García and Ramos, 2012). Greece has also supported research and development (R&D) in services, particularly health care and information technology (IT) (Kuusisto, 2008).

The manufacturing industries show on the contrary diverse behaviour; for example, the lower technology intensive activities have no nil topological variables, but a large proportion of them have negative demand and supply parameters; thus one can say that such activities also have low propensity to establish relationships with the rest of the productive structure according to the general tendency established by that. The medium low technology branches are oriented in the opposite direction, being prompt to establish relationships in the sense that the whole set of sectors establish; the high and medium high technology sectors present a higher probability to establish supply structural relationships with the rest of the sectors, in the sense discussed in this paragraph, nonetheless, a very high proportion of such industries yield negative α parameter, braking the connection between the connectivity pattern of these industries and that of the whole structure as input consumers. Despite that competitiveness has boosted in many sectors, encouraged by the adoption of new technologies, the chronic problems of technological backwardness in Greek industry and the lack of extensive training in new technologies and skills can have limited the generation of important demand relationships by the high technological intensity sectors (Christodoulakis and Kalyvitis, 1998).

We have said above that the distribution of the parameters α_i and β_j does not change significantly between 2005 and 2010 in the Greek economy; yet, it might be interesting to note the following: Services and high and medium technology industries maintain their ability to establish demand and supply relationships with the rest of the economy, according to the general tendency, whereas the low and medium low technology sectors keep their demand relationships and increase their supply ones. In a word, demand links seem to be more stable in regards to probable structural changes in the economy as a result of the financial turmoil in Greece after 2008.

Results support the idea that intersectoral connections in the Greek economy can be predicted in a high proportion, since they follow the expected schemes with high probability. Nevertheless, they are also subject to contingency (Glücker, 2007). We postulate that sectors with estimated null α_i and β_j parameters are those where contingency may open a gate to the formation of new intersectoral relationships, subject to technological and structural changes, since they show a propensity neither to follow the general, nor to follow independent tendencies. Table 2 shows that the sectors with an estimated in 2005 and 2010 are basically the same.

Table 2

Null Parameters Distribution

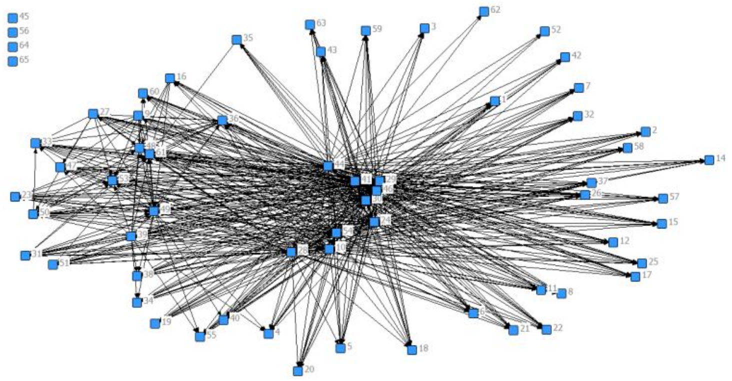
		Services	**Industry**	**Agriculture**
Demand α_i	**2005**	Employment services		
	2005 and 2010	Social work services of which: imputed rents of owner-occupied dwellings Public administration and defence services; compulsory social security services Services furnished by membership organisations Other personal services Services of households as employers; undifferentiated goods and services produced by households for own use Services provided by extraterritorial organisations and bodies	Machinery and equipment n.e.c. Motor vehicles, trailers and semi-trailers Other transport equipment Computer, electronic and optical products	
	2010		Electrical equipment	Products of forestry, logging and related services Fish and other fishing products; aquaculture products; support services to fishing
Supply β_j	**2005**			
	2005 and 2010	Social work services of which: imputed rents of owner-occupied dwellings		

		Services of households as employers; undifferentiated goods and services produced by households for own use Services provided by extraterritorial organisations and bodies		
	2010			

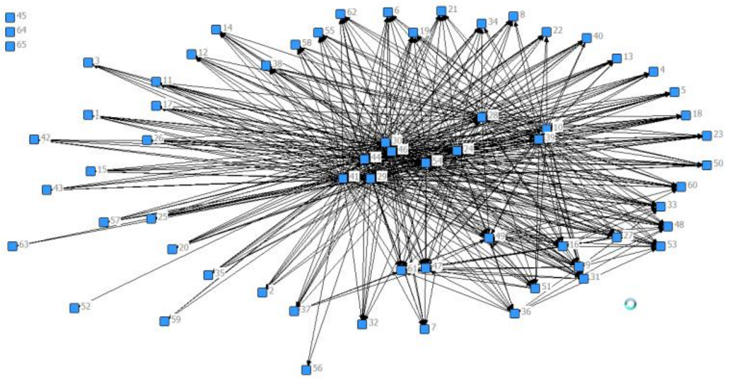
Structural change can also emerge on the demand side, except for a few services with limited significance. Lower intensive knowledge services could also be catalyst of those changes, together with medium and higher technology manufacturing industries related to machinery and equipment. After 2010 primary sectors could also play a role changing the Greek economic structure. "It is a common theoretical view that the primary sector plays a critical role in regional in the developmental progress of Greece. The particular importance attributed to sectors involved in manufacturing of agricultural products and their horizontal connections with other sectors (e.g., tourism, trade) determine the form and rate of economic development to a certain extent" (Polyzos, 2005).

Positive, negative and null parameters allow predicting an adjacency matrix, to which a graph of the economic structure can be attached (see Figure 3). A generalised practice in network literature (e.g. Wasserman and Faust, 1994) is to round the expected values of the entries of the adjacency matrix either to zero if the model predicts a value under 0.5 or to one, otherwise. That prediction can be compared to the Boolean adjacency matrix resulting from the observed technical coefficient table, in order to calculate indicators of goodness of fit analysis. The estimated models reproduce accurately 90% of the relations in matrix 2005 and 89% in 2010. I.e., the model seems to yield relevant results.

Figure 3
Predicted Graphs
The Greek Economic Structure
2005



2010



4. CONCLUSIONS

Structural analysis has made extensive use of graph and network theory yielding powerful insights on the relationships existing between industries in an economic system. Those theories have been particularly useful to identify subgroups of sectors connected in specific patterns and to obtain indicators on various features of the structure.

In this paper we use a statistical model that reproduces the economic structure, besides from exploring the ability that sectors have to link the economic system as a whole, as well as to create new connections and potentially change economic the structure. *p1* model uses a minimum amount of independent variables commonly used in QIOA. Nevertheless, we acknowledge that p_1 model has some limitations, for example, it is assumed that all sectors show a uniform reciprocity parameter; that is not a realistic assumption, particularly in the context of IO and economic models: it is unlikely that all sectors have comparable connectivity patterns. Another weakness is the fact that the model is bounded to the analysis of pairs of sectors and then, each dyad is independent form the rest: e.g., the relationship between sectors *i* and *j* is independent from that between say *i* and *k* or between *k* and *j*.

For arbitrary networks Wasserman and Patison (1996) postulate that successive connections between two any pairs of members of the net need not be of similar type, neither the pattern of connections observed in one dyad affects the probability that the next connection complies with that pattern, or not (e.g. a pair of sectors can be disconnected and the next pair be connected by reciprocal arcs, by one arc only in any direction or, finally, be disconnected again), because those links follow independent distributions. These restrictions have driven to the development of more flexible models that not only address such limitations, but also make it necessary to take into account the need to develop statistical models that demand more information about the dependence structure between sectors.

In this paper, we use p_1 model in order to find a few basic topological indicators which allow us to characterise the Greek economy: density, reciprocity, demand and supply degrees. Results demonstrate that network structure can be predicted with those basic measures. Interesting implications can be also drawn in terms of the generation of important linkages in the structure.

As expected for the Greek economy, the services sectors play an important role to connect the whole structure, regardless of their content of knowledge or technology. Greece has also made an investment effort to develop a high technology services sector. The lower technology manufacturing activities tend not to establish relationships helpful to uphold clear patterns of relationships, among other reasons, because many are small in terms of their share in the total output. Medium low, medium high and high technology sectors have established relationships according to the general tendency of the structure. Nevertheless, the parameters shown by manufacturing industries are consistent with the extended hypothesis that the Greek industry suffers from technological backwardness.

However, it would be reasonable to expect that many services sectors, as well as medium high and high technology sectors would be those with higher possibilities to generate changes in the economic structure. Of course, it is not certain at this point whether those changes would be positive or negative for the ability of the Greek economy to sustain stable growth in the long run. According to out results, if Greece could carry on fast growth in the medium high technological sectors, the general dynamics of the economy could also change rapidly. The strategy to overcome the present turmoil that emerged since 2008, has on the contrary curtail public expenditure, which could probably be essential for such development. Another issue is that of agriculture and other rural activities, which have always been important in the Greek economy. It would be necessary that the sector could be modernised at last.

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