**MODELLING ECONOMIC STRUCTURES FROM A QUALITATIVE INPUT-OUTPUT PERSPECTIVE: GREECE IN 2005 AND 2010**

**Fidel Aroche Reyes[[1]](#footnote-1)**

**Ana Salomé García Muñiz[[2]](#footnote-2)**

#### ABSTRACT

Sectors in economic systems are interdependent because they trade goods that the consuming sectors use as inputs in their productive processes; sectors need also to sell their produce to carry on production. Those supply/demand links are the bases of economic structures. Sectors play different roles in the structure according to the number of connections they maintain with other industries; they are also different if they supply inputs in preference to demand from other producers. Hence structures will also be different if more industries are of the supplying or the consuming type or *vice versa*. The connectivity patterns between industries are a tool of structural analysis. For that purpose we extend a stochastic structural model, originally developed in the social networks field into the structural economic context. The model is based on the statistical distribution of the qualitative connectivity patterns between members in a net. Further we apply this model to the recent Greek Input-Output data; the economy has shown structural weaknesses for decades, despite high grow. Results help to find some of those failures. We conclude that those must be solved if Greece is to resume growth after the 2011 economic crisis.

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

**JEL codes:** C63, C67, D57, O52

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# INTRODUCTION

 The analysis of the relationships between sectors within economic systems has been a fruitful line of research within the Input-Output (IO) domain. Many analytical techniques yield indicators widely used to study economic systems, as they are relatively simple, such as multiplier analysis and sectoral linkages that determine key sectors (e.g. Chenery and Watanabe, 1958; Rasmusen, 1956; Streit, 1969); matrix triangulation aims at finding a sectoral hierarchy by the relative size of the connections that each industry holds in the system (Simpson et. al., 1965; Haltia, 1992; Aroche, 1995); structural decomposition approaches, which decomposes structural change by components (Dewhurst, 1993), fields of influence, that measures the effects of technical change on the coefficients. For that reason the technique models the IO table as a a logistic process (Hewings et al., 1988) and a very long and exciting etcetera. Most of those methods produce numerical indicators 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 mere existence of links between industries, regardless of the values of the non-zero input coefficients. Further, the set of connections can be depicted in a directed graph (properly speaking, a digraph) that pictures the economic structure (Ponsard, 1969; Lantner, 1974; Campbell, 1975; Morillas, 1983, Schnabl, 1995, Aroche, 1996).

More recently, QIOA has been paired to the theory of economic networks[[3]](#footnote-3), since economic agents relate one another when they exchange produced goods (e.g. Semitiel and Noguera, 2012; Lopes, Dias and Amaral, 2012; García, 2013). Topological analysis of economic networks is also achieving new results in applied economics, for example in the field of econo-physics (e.g. Hidalgo et al., 2007; Gao, 2013). These papers apply network theory into economics, which has been used as a methodological framework throughout a wide range of social disciplines like anthropology, geography sociology, ecology and psychology. Network theory also translates phenomena under study into graphs, representing the set of incumbent agents and their relationships, which are central to the analysis and *ipso facto* bestow further advantages to those agents, in relation to their initial endowments.

General equilibrium, IO and other multisectoral models understand the economy as a system of interconnected individual agents by means of the exchange of commodities. For example, an industry (*i*) demands produced goods to be used as inputs in its production process; in turn, *i* will also offer its output to other activities, which also use it as an input. Individual production processes are thus interdependent. Leontief (1937) described the IO model as primarily concerned with sectoral interdependence. QIOA analysis and economic network theories are mainly interested in analysing whether sectors are connected one another (in preference to the intensity of those links) and then, whether different connectivity patterns have any consequence on the system’s dynamics. For example, a widely spread hypothesis is that when sectors hold fewer connections between them the economic structure is relatively simpler and demand shocks received by one sector will not propagate fast and widely. QIOA offers methods to find the specific channels that interconnect given sectors.

Research within the IO model framework often adopts a deterministic perspective, assuming data arrays 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). In short, if technical coefficients are assumed independent, random and symmetrically distributed. Then the question is whether the indicators derived from such a coefficients matrix **A** are probabilistically sound. Nevertheless, those methods are mostly quantitative, dealing with the numerical technical coefficients. We suggest using a stochastic method in a qualitative model.

Likewise, social networks are often informal and relationships between members are seldom quantifiable; they can often be reduced to “yes” or “no” answers, e.g., an agent complies or not with that feature. If social networks can be modelled, the question is whether it is possible to systemise those relationships. Moreno (1953) suggests applying digraph theory for the task, together with other scientific tools in this context; thus establishing the so-called sociometric studies. The key element of those is the existence of patterns of relationships between social agents involved in an each social network (in network Y, there are *x* members that are related in way ; there are also *z* members related in way therefore, the probability that members *g* and *h*, taken at random are related in way  is *p*). Holland and Leinhardt (1981) note however, that sociological methods based on statistical techniques to analyse nets are scarce; in order to contribute to fill that gap they develop a log-linear model that can be used to analyse data derived from digraphs.

QIOA methods can be also charged with disregarding statistical perspectives, while it can be fruitful to include them in methodical enquiries of the way sectors link one another to weave the economic system. So we extend Holland and Leinhadt (1981) model to examine economic structures. We assume that the interdependent sectors show given connectivity patterns and that it is possible to assign probability distributions to those patterns. In turn probability distributions can be systemised in order to construct statistical log-linear models.

Greece is an interesting case of study from the empirical viewpoint. It is well known that the economy has undergone a deep crisis in the 2010s, triggered by the financial turmoil the World economy underwent in 2008. Greece has suffered various economic calamities in a unique profundity in the European Union -even if all the Member States were immersed in the same environment. Therefore it is relevant to question whether the structural features of the Greek economy explain that.

For that purpose we use the latest Greek IO comparable tables published by EUROSTAT for 2005 and 2010, disaggregated into sixty five homogeneous sectors and valued in current basic prices of each year in millions of Euros. EUROSTAT has classified sectors by their technological intensity; we use a database built on those bases in order to compare the behaviour of those groups of sectors in the economy.

Indeed, EUROSTAT (2005) sorts out sectors by their technological intensity, defined by their ability to create and employ new technology. The latter is associated to the sectoral expenditure in research and development activities in relation to the sectoral value added, sectoral output and the embodied technology in intermediate and capital goods employed in each branch. We assume *a priori* that the different groups of industries play different roles upholding the connectivity of the system.

# METHODOLOGY

An economic structure contains a set of industries interconnected by flows of goods mutually supplied and demanded to be used as inputs by the demanding sectors; each industry 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 is used in each sector as an input. The amounts of each goods that each sector consumes or supplies to every other sector is determined by the technology used by the producers, as well as by their production levels. As a result, sectors in the economic system are interdependent and interconnected. Sectoral interdependence implies that changes in the levels of output or in the productive technology employed in any industry affects other producers -e.g., input suppliers. Thus, changes in one sector may cause changes in the whole structure, when proportions vary. Further it would be possible to find the structural position of each industry, determined by the links of demand and supply that each one maintains with the rest of the productive apparatus.

QIOA stresses the study of the shape of economic structures; from such perspective, it is customary to transform the technical coefficients matrix **A** into a Boolean array **W** = {*wij*}, *w*ij = [ 10 known as the adjacency matrix, i.e., positive coefficients are made equal to one to show that one sector demands goods from another, zero otherwise. When sector *i* demands inputs from another *j* it is said that the former is adjacent to the latter and they are directly connected. Further, those relations can be depicted in a directed graph or, properly, a digraph **G**:(**V, E**), **V** stands for the set of nodes or vertices representing the industries and the demands for inputs are represented as arcs, arrows or directed edges (**E**), stemming from the consuming branch to the supplier. The assumption behind is that the IO model is demand-driven and when a sector receives a demand order, it adjusts its output correspondingly. The resulting digraph can be understood as an economic network, as nodes and their relationships are of economic nature.

It has already been mentioned that the methodology used in this paper extends the QIOA perspective, by means of a log-linear application based on the so-called *p1* model, first presented by Holland and Leinhardt (1981), in order to systemise the relationships within social groups; model *p1* begs to the structural characteristics of the connectivity between members of the group under study -taken as nodes in a digraph. The model uses a minimum amount of statistical information to estimate a minimum amount of parameters to describe the structure of those nets.

In the economic context, model *p1* will 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 in the adjacency matrix **W**. A sector either receives demand impulses for produced goods from another branch -when its output is demanded by another sector- or sends such impulses to the latter, when the former demands goods from the other one (in both cases output is always elastic to demand); connections can be reciprocal as well, if those two industries at the same time receive and send demand impulses from one another, or finally two sectors can be disconnected, if neither demands inputs from the other. Those patterns of established relationships present statistical regularities in each economic structure, which can be disclosed by a probabilistic model and help to find topological parameters that characterise the structure.

2.1 Model p1

Indeed, Holland and Leinhardt (1981) model the probability that the arcs connecting pairs (dyads) of nodes follow some expected pattern, arising from the characteristics of that digraph. Model *p1* expresses each arc between any two sectors as a stochastic function of the network’s connectivity features. The function includes four structural parameters: (i) The first two refer to the propensity that any pair of sectors are connected through a single arc in one direction or another (*w+j*, *wi+*); i.e., one sector has an influential role and the other reacts to it (and *vice versa*); (ii) the propensity that any dyad of sectors are connected by reciprocal directed edges (*M*), i.e., whether any pair of sectors irradiate and receive an arc at the same time and, finally, (iii) tie density (w++) or the total volume of relationships established in the structure, portrayed by the adjacency matrix **W** = {*w*ij}. Needless to say, *w*+j, *wi+*, *M* and *w++* derive from the observed complexity of the net associated to adjacency matrix **W**. The former measures will be represented as follows:

|  |  |
| --- | --- |
|  | (1) |

The probability that the observed connectivity of any two sectors in the empirical structure complies with those measures (*w+j*, *wi+*, *M* and *w++*) derives from a distribution family *w* (Holland and Leinhardt, 1981):

$$p1\left(w\right)= P \left(W = w\right)=exp\left\{ρm+ φw\_{++}+\sum\_{i=1}^{n}α\_{i}w\_{i+}+ \sum\_{i=1}^{n}β\_{i}w\_{+i}\right\} K(ρ, φ, \left\{α\_{i}\right\}, \left\{β\_{i}\right\}$$

(2)

where *M*, *w+j, wi+,* and *w++* are values computed from **W**; whereas *****i* and*j* are statistical parameters, and *K* is a function that guarantees that *p*(*w*) sums to one over all *wij* in **W**. Hence, the probability distribution of the connectivity patterns between pairs of sectors in a network depends on the parameters that measure the tendency shown by each node to establish either unidirectional relationships of demand (**i), of supply (**j), or bidirectional relationships (**), as well as the sectoral mean propensity to relate to other branches (**

The density effect (** depends on the amount of connections between all the sectors in the structure; therefore, there is only one value for the whole network. Moreover, model *p1* assumes that every pair of sectors in one system shows equal probability to be linked by reciprocal ties (**. The parameters associated to the propensity to establish demand (*i*) or supply (**j) relationships, however, may differ for each dyad of sectors, but the following identifying constraint prevails (Fienberg, Meyer and Wasserman, 1985):

|  |  |
| --- | --- |
|  | (3) |

If the former parameters take positive values, it can be said that the connectivity between sectors is explained by the patterns observed in the network as a whole. For instance, if the network is “dense”, the likelihood that any sector *i* is directly connected to another *j* is “high” and it is likely that any particular sector connected with any other sectors; ** will be positive. On the contrary, if ** is negative, the number of connections in the network is “low” and the parameter does not help to explain the existing connections between a given sector and the rest. Likewise, a positive  implies that any sector is inclined to establish reciprocal connections with other sectors, because the economic system is closely knitted in that fashion; if ** 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 *i* and **j.

Because the determination of *K*and its parameters are not exempt from problems, an alternative formulation is applied. The *n* sector network is decomposed into an equivalent set of  dyads. Each dyad (*wij*, *wji*) represents a direct relation between sectors *i* and *j* in a network of n sectors; as it has been said above, that relationship is a random variable with four possible cases: mutual relation, null or two cases of asymmetric relations, The probability function for the type of connection in each dyad is modelled as a non-linear combination of the previously mentioned parameters. The *p1* model can be expressed as the log probabilities corresponding to the dyad:

|  |  |
| --- | --- |
|  | (4) |

subject to the following constraints:

|  |  |
| --- | --- |
|  | (5) |

This model is log linear. It can be viewed too as an analogue of the linear models arising in the analysis of the variance (Wasserman and Faust, 1994).

We acknowledge that model *p1* has some limitations; for example, it assumes that all sectors show a uniform reciprocity parameter; which is not realistic, particularly in the context of IO and economic models: it is unlikely that in principle all sectors have comparable connectivity patterns. Another weakness is the fact that the model is bound 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 *i* and *k* say or between *k* and *j*. Yet, the results we reach are interesting and it remains for further research whether it would be relevant to analyse the connectivity between groups of sectors in the system; in principle, direct connections suffice for our purposes.

1. **THE *p1* MODEL IN THE GREEK ECONOMY**
	1. **A few IO data[[4]](#footnote-4)**

Greece evolved from a mainly rural country in the 1950’s to urban and wealthy a few decades later (Drakoupoulos and Theodossiou, 1991), with *per capita* Gross Domestic Product (GDP) reaching 20,582 Euros (current prices) in 2010, which made Greece a higher income country[[5]](#footnote-5) (IMF data). The Greek economy has ranked among the fastest growing economies in the OECD and the European Union for decades, until 2009. The average annual growth rate was about 3% between the 1990s and 2009 (at constant 2000 prices). Nontheless, it has been evident for long that the economy showed serious structural failures. (Athanassiou, 2009) shows that growth has been driven by a fast expanding domestic demand -based upon public sector deficit and private indebtness- while the external sector has contributed negatively as the economy dependence of imports grew has not receded (Aroche, 2014). Certainly, the economy seems to have been unable to take advantage of its membership to the European single market and use it as a tool to build productive capacities in accordance to its level of income.

Services are about 75% of the GDP and grow faster than any other sector (4% annual average), while industry contributes with 20% (growing 2% per annum), and rural activities represent 6% Growth, but decreased at -0.3% per annum (measured by sectoral Value Added, VA between 1995 and 2000) is unevenly distributed and it is rather unstable for the three sectors comprising the system. Services have grown faster, together with the industry (at about 4% and 2% per year between 1995 and 2009), but agriculture, hunting, forestry and fishing. The larger sectors (which include lower and medium technology industries) tended to stagnate and even to decrease. In a word, the composition of the economy seems to slowly change in a desirable direction, but higher technology industries are rather small and do not lead the dynamics of the system.

Greek exports are mainly manufacturing (84%), where textiles, food, beverages and tobacco, coke, refined petroleum products and nuclear fuel and basic metals make the largest contribution; agricultural products represent over 12% of total exports. Imports are also mainly manufacturing (84%), but their profile is different from than that of exports. High and medium high technology manufactures take the largest proportion as sources of foreign supply. Domestic production has not expanded as fast as internal demand, for which it has been replaced by imports, which may be cheaper and more suitable both to consumers’ tastes and producer’s needs for intermediate goods.

Employment grew at a lower pace than GDP; hence output per employee has expanded on the overall. Output per employee in the whole economy grows at around 2% per annum, overall in the high technological sectors: On the overall, the performance of this variable would also explain economic growth before 2011 (Aroche, 2014).

Figure 1 shows the composition of total demand (intermediate plus final demand by component) in 2005 and 2010 as defined in the IO tables. First of all, results are consistent with the scattered data discussed previously in this section: there were no significant changes within the observed period. Secondly, it is not a surprise that intermediate consumption is the largest component because in developed economies sectors are increasingly interdependent -as the system progressively turns more complex. Further, as it has been largely discussed in the literature on the Greek economy, domestic demand is the target of most output and it is also the biggest explanatory variable to growth. The average openness degree for the sixty-five sectors in the economy is almost 13% in 2005 and 12% in 2010[[6]](#footnote-6). The latter is also revealed by the weight of exports in total output. In parallel, consumption by households, government and non-profit organizations is high in both years.

**Figure 1**

**Total Demand Composition: Greece 2005 and 2010**

A few high and medium high technology intensity sectors diminished their imports propensity between 2005 and 2010, presumably due to increased competitivity, which resulted in increased exports to imports rate as shown in Figure 2, amongst the sectors where such changes occur are (3) fisheries and other fishing products; aquaculture products; support services to fishing, (12) basic pharmaceutical products and pharmaceutical preparations, (15) basic metals, (18) electrical equipment, (40) computer programming, consultancy and related services; information services, (41) financial services, except insurance and pension funding, (62) repair services of computers and personal and household goods. It has been argued, however that many of these sectors are rather small to change the general tendencies while most sectors –particularly the largest- remain inward-looking (Aroche, 2014) showing stable or even decreasing exports propensity (equal to sectoral exports over sectoral output), which happened in sectors such as (17) computer, electronic and optical products and (21) other transport equipment, where the exports to imports rate decreased.

**Figure 2**

**Exports to Imports Rate**

Aroche (2014) shows that Value Added (VA) represents 58% out of total output in 2005 and imports reach 10%. Services and agriculture show the higher proportions, while –as expected- industry is more input-intensive. It is interesting to note that the faster growing industries are also more import-dependent and –on the contrary- some of the larger branches are also slower growers.

The total multiplier for the whole economy in 2005 is 0.86, the domestic one reaches 0.45: If final demand in any industry grows in one Euro, domestic supply would expand in 45 centimes and imports would do so in 0.41 Euros. This is one undesired characteristic of the Greek economy, its high dependency on imports and thus, the proclivity to transfer abroad growth impulses derived from demand expansion.

The average employment coefficient in Greece is 0.15, i.e., there are that many employees per Euro of output. It results then that the internal employment multiplier is 0.22 and the total one (including imports) is 0.27. Since the difference is not high, it could be expected that similar imported and domestically produced goods use comparable technologies. Yet, the economy is dependent upon imports and jobs are not created in the land.

It remains a question whether the connectivity patterns between sectors and the general complexity of the economy have changed in the observed period. Those results could be used in designing economic policies and predicting impacts of changes in final demand in some sectors. The following focuses on the sectoral topology and its modelling to explain how the economic network functions.

* 1. **Topological Measures**

Table 2 shows three non-stochastic topological measures for the economy as a whole[[7]](#footnote-7): density, clustering coefficient and reciprocity index, calculated by means of UCINET version 6.445 on the 2005 and 2010 domestic transactions Greek tables, published by EUROSTAT.

Density indicates the proportion of dyadic actual connections in the network over the number of all possible connected pairs in a network of given size (Wasserman and Faust, 1994). The Greek economy shows a low index in 2005, which rises for 2010, as a result of the existence of a large –if decreasing- number of nil entries in the corresponding matrices **A**. Morillas (1983) explains that classical structural parameters can be distorted in sparse matrices of the sort.

The clustering coefficient assumes that sectors in the economy are not uniform or symmetrically interdependent; instead, industries are expected to gather in smaller groups more densely connected and the attached graph to show various components which need not be isolated, just more loosely linked to other ones. There is a single clustering coefficient a graph and it indicates how closely the specific net is to be perfectly dense (when one bidirectional connection exists for each pair of vertices). The overall clustering coefficient equals the mean of the clustering of the nodes. The clustering coefficient of a node is the density of its open neighbourhood (Borgatti et al., 2013). Results in Table 1 indicate that the Greek sectors construct dense local clusters with large numbers of sectors, but those local clusters seem to be demising.

The reciprocity index calculates the amount of reciprocal dyadic liaisons in the network, relative to the total number of links actually existing between pairs of sectors. A relationship is reciprocal when a link connecting sector *i* to *j* is accompanied by another connecting those sectors on the opposite direction. In 2005 only 5% of the total relationships between pairs of sectors are reciprocal and 12% in 2010.

**Table 1**

**Cohesion indicators**

Figures 3 and 4 show the levels and the changes in the sectoral out- and in-degrees between 2005 and 2010. The vertical axis corresponds to the number of direct supply and demand linkages; the x- axis shows the sixty five sectors. Each arrow points to the value observed in 2010. An upward triangle indicates an increase in the value of the degree; if it is downward the value has decreased. The length of the segment associated to the triangle is proportional to the degree variation during the period under study[[8]](#footnote-8).

**Figure 3**

**Changes in the Sectoral Out-degrees**

In Greece the direct demand links between sectors are rather scarce. Only eleven sectors (related with construction, wholesale, printing, video, financial and information services, scientific research) present higher out-degrees, by demanding inputs from a larger amount of branches; although most of these industries reduced their outward connections towards the end of the period. Three sectors have null out-degree and in-degree so they are isolated (after filtering the matrix). Forty sectors do not demand inputs significantly from any other industry, although they supply to other producers. In Greece, most sectors show low but sluggishly rising out-degrees. Figure 4 shows that in general most sectors are better connected through higher in-degrees: they tend to be more supply-orientated, besides those degrees have grown towards 2010. In-degrees are a measurement of the incident arcs to the nodes in the graph.

**Figure 4**

**Changes in the Sectoral In-degrees**

* 1. **Estimating Model p1**

In the Greek economy the connectivity parameter **equals -2.5 in 2005 and -1.9 in 2010, indicating that the actual connections between pairs of sectors are statistically independent from such pattern. For example, we have discussed the presence of many nil as well as rather small inter-sectoral relationships (*aij*) in the Greek tables, unable to influence the integration configuration of the net; therefore, an observed connection between any two sectors cannot be explained as a part of the general tendency of the sectors in to be linked with other branches. Accordingly, industries are randomly connected; there are not reasons to expect a clear cut scheme of sectoral relationships in the system, such as vertical integration from the production of raw materials (iron ores) to final demand goods (rail roads and rail equipment) and related services (transport). The latter implies that the economy does not appear to be clearly specialised in some production line. On the contrary, parameter **is positive and significant: it equals 0.7 in 2005 and 0.5 in 2010[[9]](#footnote-9). Therefore, according to model *p1* one can say that any two sectors will be reciprocally linked in the Greek economy with higher probability as a result of the patterns found in the system.

It has been explained that the values of parameters *αi.* and *β.j* are related to the sectoral tendency to shows demand or supply connections. Those depend on the nature of each sector or the kind of goods it produces, for example, a consumer goods producer would mainly demand inputs from the rest of the sectors (and show higher *αi.*) whereas a producer of raw materials would preferably maintain supply connections (and a higher *β.j*). Neither *αi.* or *β.j* equal zero if sectors are interdependent. Figure 5 shows the relative distribution of those parameters in the Greek economy in 2005 and 2010. It is apparent that the distribution of parameters *αi* and *βj* differ. In the two periods under consideration some 20% of sectors show null *αi*, but only 5% have null *β.j*. Over 30% of the sectors show positive *αi*; that is, demand connections of those sectors are explained by the connectivity pattern of the system in general; however over 45% of sectors have negative *αi* and their demand connections are independent from the general tendency. In opposition, over 60% of branches exhibit a propensity to establish supply liaisons with other sectors related to the general propensity of the economy (having positive *βj* parameter) and over 30% show independent connectivity, by a negative parameter.

**Figure 5**

**Relative Distribution of Parameters** ***αi* and *βj***

**Greece 2005 and 2010**

Table 2 disaggregates the former results by groups of sectors of different technological level, according to the definition by Eurostat based on the Statistical classification of economic activities in the European Community (NACE), 2-digit level.[[10]](#footnote-10). First of all, according to the classification employed, 66% of all sectors are services, either knowledge intensive (KIS) or otherwise. Both KIS and the low technology industries show markedly negative *αi* coefficients, whereas other services and the medium-low technology manufacturing industries tend to show more mixed results. On the contrary, most sectors show positive *βj* coefficients, except for the medium-low technology industries in 2005, when those were negative. Another important structural change appears to be that the high and medium high technology industries show a higher proportion of null *αi.* coefficients in 2010 and overwhelmingly positive *βj*coefficients.

**Table 2**

**Statistical distribution of parameters αi and βj by technological level**

**Greece 2005 and 2010**

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 system. Indeed the two service blocks seem to have higher ability to establish such relationships with other sectors, as they relate to 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 a different 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. The medium low technology branches are orientated in the opposite direction and tend to establish relationships following the propensity of the whole set of sectors; next, 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 *αi*, which means that the connectivity pattern of these industries as input consumers is not explained by the pattern observed in the whole structure. Despite that competitiveness has been 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 have limited the generation of important demand relationships by the high technological intensity sectors (Christodoulakis and Kalyvitis, 1998).

We have written above that the distribution of the parameters *αi* and *βj* 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 consequence of the financial turmoil in Greece after 2008.

Results support the idea that inter-sectoral connections in the Greek economy can be studied by means of our model, since they follow the expected schemes with high probability. We postulate that sectors with estimated null *αi* and *βj* parameters are contingent to the formation of new intersectoral relationships in the near future, subject to favourable technological and structural changes, since they do not show a propensity, neither to follow the general, nor to follow independent tendencies. According to Table 3 sectors with estimated null parameters in 2005 and 2010 are basically the same.

**Table 3**

**Null Parameters Distribution**

Structural change can also emerge on the demand side, except for a few services with limited significance. Lower intensive knowledge services could also facilitate those changes, together with medium and higher technology manufacturing industries related to machinery and equipment. After 2010 primary sectors could also play a role in changing the Greek economic structure. “It is a common theoretical view that the primary sector plays a critical role in the regional 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, 2006 p.58 ).

* 1. **Goodness of Fit**

The performance a goodness of fit analysis allows evaluating whether model *p1* results fit with the observed input-output data. The stochastic properties of the model ensure that parameters αi. and β.jallow estimating the expected adjacency matrices for Greece in 2005 and 2010. A generalised practice in network literature (e.g. Wasserman and Faust, 1994) is to approximate the value of the entries of the adjacency matrix either to zero -if the model generates expected values under 0.5- or to one -otherwise. Those expected values can be compared with the observed values in the Boolean matrix derived from the technical coefficients matrix used in the first place, in order to calculate the indicator of goodness of fit. 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.

1. **CONCLUSIONS**

Structural analysis has also made extensive use of topological, graph and network theory, yielding interesting insights concerning the relationships between industries in the economic systems: those are the channels through which growth impulses travel from industry to industry and they are the backbone of the economic structure. However, research into networks implies not only studying their topological features, but also discovering the dynamics of the processes that may take place within. In input-output analysis a few studies have documented regularities of the connecting patterns between members in the networks, detecting statistical distributions (McNerney et al., 2012; Semitiel and Noguera, 2012).

In this paper we apply a model that systemises the connectivity patterns between industries in a structure and constructs probabilistic distributions by means of a log-linear model that uses a minimum amount of independent variables commonly used in QIOA. *p1* model explores the ability of sectors to link up the economic system as a whole, as well as to create new connections and –potentially- change the economic structure.

Combining IO analysis and stochastic methods is not new; nevertheless, most papers concerned with that combination use a quantitative approach; i.e., they assume that as any statistical database, IO tables are random observations and the question is about the distribution properties followed by the coefficients matrix. On the contrary, the method we use in this paper is qualitative and we assume that the connections between industries can be derived from stochastic processes, if we assume that observed connections follow some patterns of connections that help to study the structure as a whole.

The model stands on some restrictive hypotheses as set out above, let alone the fact that it has been developed to study social networks, which not always are comparable to economic ones. Therefore not every tool developed for network analysis is useful in the context of economic analysis. Nevertheless this paper shows that *p1* model can be extended satisfactorily into economic structural analysis. Besides, our goodness of fit analysis shows that the model predictions fit the IO Greek data.

Empirically interesting implications can be also drawn in terms of the generation of linkages in the structure. Recent studies have focused on various features of Greek society, as well as on its economy, explaining the economic crisis burst in 2008, as a result of turmoil in the international financial markets. Greece had been amongst the fastest growing in the OECD for decades. However, few studies include a structural perspective, which provide deeper insights into the functioning of the Greek economic system.

Our results show that the economic structure is relatively dispersed and industries lack of systematic connectivity patterns. That is also related to the lack of a clear specialization profile of the economy. As expected for a high-income economy in Greece the service sectors play an important role weaving the economic structure, regardless of their technology content. Greece has also made an effort to develop a high technology services sector, though it also remains small compared to the size of the economy.

Manufacturing industries are also input intensive and therefore show higher multipliers and more complex connectivity patterns. The manufacturing industries show different behaviour by levels of technological intensity. The lower technology activities, which includes some of the largest sectors, tend to establish dispersed relationships, and do not help to define a clear pattern of relationships perhaps because of the backwardness of the technology they use. The higher technological segments are more dynamic and tend also to establish more tighten links with the rest of the productive sectors. They were however relatively small in 2010, so the general outcome was dominated by the lower technological sectors.

Apparently the structure of the productive sector is turning more complex and more able to sustain growth. That is seldom a fast process and Greece seems to be in a slow track. The latter coexists with a backward agriculture and rural economy and the persistence of small firms all over the economy, which often are reluctant to modernise their technology and enterprise practices. Hopefully the economic crisis in the economy and the austerity policies that governments often implement in such circumstances allow a new structural profile of the economy.

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**Figures**

**Figure 1**

**Total Demand Composition: Greece 2005 and 2010**

Source: Own elaboration from Greek IOT

**Figure 2**

**Exports to Imports Rate**

Source: Own elaboration from Greek IOT

**Figure 3**

**Changes in sectoral out- degrees**

Source: Own elaboration from Greek IOT.

**Figure 4**

**Changes in in-degrees**

Source: Own elaboration from Greek IOT.

**Figure 5**

**Distribution of parameters** ***αi* and *βj* in relative terms**

**Greece 2005 and 2010**

****

Source: Own elaboration from Greek IOT.

**Table 1. Cohesion indicators**

|  |  |  |
| --- | --- | --- |
|  | **2005** | **2010** |
| **Density** | 0.13 | 0.18 |
| **Overall graph clustering coefficient** | 0.64 | 0.41 |
| **Reciprocity** | 0.057 | 0.12 |

Source: Own elaboration.

**Table 2**

**Statistical distribution of parameters αi and βj by technological level**

**Greece 2005 and 2010**

|  |  |  |  |
| --- | --- | --- | --- |
|  | % Positive coefficients | % Negative coefficients | % Null coefficients |
| 2005 | 2010 | 2005 | 2010 | 2005 | 2010 |
|  | % | αi | βj | αi | βj | αi | βj | αi | βj | αi | βj | αi | βj |
| KIS\* | 40 | 42 | 61 | 42 | 54 | 54 | 39 | 54 | 46 | 4 | 0 | 4 | 0 |
| Less KIS\* | 26 | 35 | 71 | 36 | 53 | 24 | 11 | 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

**Table 3**

**Null Parameters Distribution**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Services** | **Industry** | **Agriculture** |
| **Demand**αi | **2005** | Employment services |  |  |
| **2005****and****2010** | Social work services of which: imputed rents of owner-occupied dwellingsPublic administration and defence services; compulsory social security servicesServices furnished by membership organisationsOther personal servicesServices of households as employers; undifferentiated goods and services produced by households for own useServices provided by extraterritorial organisations and bodies | Machinery and equipment n.e.c.Motor vehicles, trailers and semi-trailersOther transport equipmentComputer, electronic and optical products |  |
| **2010** |  | Electrical equipment | Products of forestry, logging and related servicesFish and other fishing products; aquaculture products; support services to fishing |
| **Supply**βj | **2005** |  |  |  |
| **2005****and****2010** | Social work services of which: imputed rents of owner-occupied dwellingsServices of households as employers; undifferentiated goods and services produced by households for own useServices provided by extraterritorial organisations and bodies |  |  |
| **2010** |  |  |  |

Annex

**Table nºA1. Model p1.**

|  |  |  |
| --- | --- | --- |
|  | **2005** | **2010** |
|  |  |   |  |  |  |  |
|  |  |   | -2,083 | 0,6953 | -1,89 | 0,5237 |
|  |  **Code** | **Products** |  |  |  |  |
| **1** | **CPA\_A01** | **Products of agriculture, hunting , related services** | -0,449 | -0,231 | -0,724 | -0,204 |
| **2** | **CPA\_A02** | **Products of forestry, logging, related services** | -2,548 | -0,665 | 0 | 0,034 |
| **3** | **CPA\_A03** | **Fish and other fishing products; aquaculture products; support services to fishing** | -2,526 | -1,267 | 0 | 0,034 |
| **4** | **CPA\_B** | **Mining and quarrying** | -1,163 | 0,93 | -2 | 0,875 |
| **5** | **CPA\_C10-C12** | **Food products, beverages and tobacco products** | -0,306 | 0,186 | -0,964 | 0,549 |
| **6** | **CPA\_C13-C15** | **Textiles, wearing apparel and leather products** | -1,438 | 0,241 | -2 | 0,215 |
| **7** | **CPA\_C16** | **Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials** | -1,838 | -0,415 | -2 | -0,181 |
| **8** | **CPA\_C17** | **Paper and paper products** | -0,857 | 0,013 | -1 | 0,387 |
| **9** | **CPA\_C18** | **Printing and recording services** | 1,029 | -0,359 | 0,651 | 0,124 |
| **10** | **CPA\_C19** | **Coke and refined petroleum products**  | 2,436 | -1,946 | 2 | -2 |
| **11** | **CPA\_C20** | **Chemicals and chemical products** | -0,158 | 0,176 | -0,236 | -0,02 |
| **12** | **CPA\_C21** | **Basic pharmaceutical products and pharmaceutical preparations** | -1,861 | 0,047 | -2 | 0,031 |
| **13** | **CPA\_C22** | **Rubber and plastics products** | -1,460 | 0,611 | 0,008 | 0,512 |
| **14** | **CPA\_C23** | **Other non-metallic mineral products** | -1,087 | -0,438 | -2 | 0,031 |
| **15** | **CPA\_C24** | **Basic metals** | 0,127 | -0,273 | 0,165 | -0,711 |
| **16** | **CPA\_C25** | **Fabricated metal products, except machinery and equipment** | 0,567 | -0,313 | 0,912 | 0,289 |
| **17** | **CPA\_C26** | **Computer, electronic and optical products** | 0 | 0,037 | 0 | 0,034 |
| **18** | **CPA\_C27** | **Electrical equipment** | -1,449 | 0,432 | 0 | 0,034 |
| **19** | **CPA\_C28** | **Machinery and equipment n.e.c.** | 0 | 0,037 | 0 | 0,034 |
| **20** | **CPA\_C29** | **Motor vehicles, trailers and semi-trailers** | 0 | 0,037 | 0 | 0,034 |
| **21** | **CPA\_C30** | **Other transport equipment** | 0 | 0,037 | 0 | 0,034 |
| **22** | **CPA\_C31\_C32** | **Furniture; other manufactured goods** | -2,618 | 0,633 | -2 | 0,73 |
| **23** | **CPA\_C33** | **Repair and installation services of machinery and equipment** | 0,455 | -0,081 | -0,752 | 0,543 |
| **24** | **CPA\_D35** | **Electricity, gas, steam and air-conditioning** | 3,272 | -1,621 | 3 | -1 |
| **25** | **CPA\_E36** | **Natural water; water treatment and supply services** | -1,426 | 0,035 | -1 | -0,41 |
| **26** | **CPA\_E37-E39** | **Sewerage; waste collection, treatment and disposal activities; remediation activities and other waste management services**  | -0,158 | 0,176 | -0,1 | -0,026 |
| **27** | **CPA\_F** | **Constructions and construction works** | 0,907 | 0,455 | 0,351 | 0,323 |
| **28** | **CPA\_G45** | **Wholesale and retail trade and repair services of motor vehicles and motorcycles** | 2,156 | -0,241 | 2 | -0,154 |
| **29** | **CPA\_G46** | **Wholesale trade services, except of motor vehicles and motorcycles** | 4,010 | 0,184 | 4 | 0,706 |
| **30** | **CPA\_G47** | **Retail trade services, except of motor vehicles and motorcycles** | 3,584 | 0,207 | 3 | 0,626 |
| **31** | **CPA\_H49** | **Land transport services and transport services via pipelines** | 0,408 | 0,834 | 0,34 | 0,657 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  **Code** | **Products** |

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| **32** | **CPA\_H50** | **Water transport services** | -1,873 | 0,252 | -3 | -0,165 |
| **33** | **CPA\_H51** | **Air transport services** | -0,225 | 1,324 | -0,596 | 1 |
| **34** | **CPA\_H52** | **Warehousing and support services for transportation** | -1,163 | 0,93 | -0,112 | 0,347 |
| **35** | **CPA\_H53** | **Postal and courier services** | 0,158 | -1,061 | 0,033 | -0,239 |
| **36** | **CPA\_I** | **Accommodation and food services** | 0,879 | 0,942 | 0,668 | -0,501 |
| **37** | **CPA\_J58** | **Publishing services** | -0,492 | 0,569 | 0,382 | -0,724 |
| **38** | **CPA\_J59\_J60** | **Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services** | -1,163 | 0,93 | -1 | 0,716 |
| **39** | **CPA\_J61** | **Telecommunications services** | 1,165 | 0,429 | 2 | 0,236 |
| **40** | **CPA\_J62\_J63** | **Computer programming, consultancy and related services; information services** | -0,502 | 0,739 | -0,568 | 0,536 |
| **41** | **CPA\_K64** | **Financial services, except insurance and pension funding** | 5,153 | -1,329 | 6 | -0,669 |
| **42** | **CPA\_K65** | **Insurance, reinsurance and pension funding services, except compulsory social security** | -0,611 | -0,721 | -0,912 | -0,922 |
| **43** | **CPA\_K66** | **Services auxiliary to financial services and insurance services** | -1,838 | -0,415 | -1 | -0,914 |
| **44** | **CPA\_L68B** | **Real estate services** | 4,597 | -2,824 | 4 | -3 |
| **45** | **CPA\_L68A** | **Of which: imputed rents of owner-occupied dwellings** | 0 | 0 | 0 | 0 |
| **46** | **CPA\_M69\_M70** | **Legal and accounting services; services of head offices; management consulting services** | 3,700 | 0,512 | 3 | -0,202 |
| **47** | **CPA\_M71** | **Architectural and engineering services; technical testing and analysis services** | -0,725 | 1,350 | 0,082 | 2 |
| **48** | **CPA\_M72** | **Scientific research and development services** | -1,963 | 1,650 | -1 | 1 |
| **49** | **CPA\_M73** | **Advertising and market research services** | 1,182 | 1,458 | 0,941 | 2 |
| **50** | **CPA\_M74\_M75** | **Other professional, scientific and technical services; veterinary services** | 0,601 | 0,97 | -0,745 | 0,373 |
| **51** | **CPA\_N77** | **Rental and leasing services** | 0,3 | 0,843 | 0,251 | 0,147 |
| **52** | **CPA\_N78** | **Employment services** | 0 | 0,037 | -1 | -2 |
| **53** | **CPA\_N79** | **Travel agency, tour operator and other reservation services and related services** | -0,742 | 1,618 | -1 | 1 |
| **54** | **CPA\_N80-N82** | **Security and investigation services; services to buildings and landscape; office administrative, office support, other business support services** | 2,634 | 0,443 | 3 | 1 |
| **55** | **CPA\_O84** | **Public administration and defence services; compulsory social security services** | 0 | 0,037 | 0 | 0,034 |
| **56** | **CPA\_P85** | **Education services** | -1,004 | -3,976 | -1 | -2 |
| **57** | **CPA\_Q86** | **Human health services** | -1,415 | -0,186 | -1 | -0,642 |
| **58** | **CPA\_Q87\_Q88** | **Social work services** | 0 | 0,037 | 0 | 0,034 |
| **59** | **CPA\_R90-R92** | **Creative, arts and entertainment services; library, archive, museum and other cultural services; gambling and betting services** | -1,064 | -0,985 | -0,896 | -2 |
| **60** | **CPA\_R93** | **Sporting services and amusement and recreation services** | -0,697 | 0,91 | -0,77 | 1 |
| **61** | **CPA\_S94** | **Services furnished by membership organizations** | 0 | 0,037 | 0 | 0,034 |
| **62** | **CPA\_S95** | **Repair services of computers , personal, household goods** | -2,504 | -2,017 | -3 | 0,23 |
| **63** | **CPA\_S96** | **Other personal services** |   | 0,037 |   | 0,034 |
| **64** | **CPA\_T** | **Services of households as employers; undifferentiated goods and services produced by households for own use**  | 0 | 0 | 0 | 0 |
| **65** | **CPA\_U** | **Services provided by extraterritorial organisations and bodies** | 0 | 0 | 0 | 0 |

1. Universidad Nacional Autónoma de México, e-mail: aroche@unam.mx [↑](#footnote-ref-1)
2. Universidad de Oviedo, e-mail: asgarcia@uniovi.es

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3. Different form network economics, related to the study of relationships between agents through information technologies. [↑](#footnote-ref-3)
4. We are grateful to an annonymous referee that suggested the inclusión of these data. They provide a more complete picture of the Greek economy. For further information on sectoral and branch behaviour the reader can refer to Aroche (2014), which unfortunately studies a different period to this paper. [↑](#footnote-ref-4)
5. That amounts to 75% of the European Union average. [↑](#footnote-ref-5)
6. The formula employed to calculate it is: . , *ei* stands for sectoral exports, *mi* for sectoral imports and *xi* for sectoral total output. Results go from 0 to 100, values approximating 0 indicate that output is sold in the internal market and the economy approximates total closure. [↑](#footnote-ref-6)
7. The sectoral disaggregation and the results of the model are available in the Annex. [↑](#footnote-ref-7)
8. Needless to say, these measurements indicate the number of incident and stemming arcs to and from each sector; i.e., the number of positive entries in each row and column in the coefficients matrix **A**.On the contrary, quantitative indicators such as forward and backward linkages involve the size of the coefficients as well. [↑](#footnote-ref-8)
9. For the matter, in an unpublished exercise for the European economy in 2000, parameter ** equals -2.6 and **0.7 in an IO table aggregated into 25 sectors, published by Eurostat: Greece and Europe show comparable integration patterns. [↑](#footnote-ref-9)
10. See <http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/Annexes/hrst_st_esms_an9.pdf> for a detail. [↑](#footnote-ref-10)