Linkages, contagion and resilience: an input-output scope from the demand and supply side

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Abstract[1]

The use of linkages to compare productive structures and discover key sectors is an active focus of research in input-output field. In this paper, an extension of the called multilevel indicators (García et al., 2008) to the key sector determination is proposed. The multilevel indicators not only describe industries with a strong influence on the expansion of other sectors in an economy but the immediacy and the transmission capacity of their impacts. The proposal opens a new inquiry about how the relational structure affects the contagion diffusion and the robustness of the economic system. The empirical key sector analysis will focus on the Greek economy. The study deals with the structural change of Greek economy in the last decade (2000-2010). Conclusions about the relevance of some activities for the development of Greek economy are offered.

Key words: Input-output analysis, network theory, structural change, resilience, contagion, Greece

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1. Introduction

The analysis of the relationships between sectors within economic systems has been a fruitful research line within the Input-Output (IO) field. The development of new types of input-output multipliers is increasing (Hewings et al., 1988; Lenzen, 2001; Aroche-Reyes, 2002; Oosterhaven and Stelder, 2002; Morillas et al., 2008; Gim and Kim, 2009, among others)[2].

Some researchers have also applied concepts and techniques developed for network and graph theories, extending structural analysis within the context of the IO model (Morillas, 1983; Aroche, 2002; Montresor and Vitucci, 2009; García et al. 2010 and 2011; Semitiel and Noguera, 2012; Lopes, Dias and Amaral, 2012). The network studies have been successful in presenting mathematical descriptions of the input-output economic structure.

"The study of how network structure influences economic activity is becoming increasingly important because it is clear that many classical models that abstract away from patterns of interaction leave certain phenomena unexplained (Jackson, 2010)". General equilibrium, IO and other multisectoral models understand the economy as a system of interconnected individual components (agents), by means of the exchange of commodities. For example, an industry (i) demands some produced goods (in a broad sense) from other producing sectors, to be used as inputs in its own production process; in turn, i will also offer its output to other producing activities, which also use it as an input. In this system, sectors require interdependence in order to carry on their individual production processes. Leontief (1937) described the IO model as primarily concerned with interdependence and Qualitative Input-Output Analysis (QIOA), likewise, graph and social network theories are focused on the interdependence patterns between agents in specific phenomena under study. Network analysis has made important advances in the last few years, developing a number of methods of analysis using graph theory tools to reach robust results (Borgatti et al., 2013). The interdependence of economic agents is an important asset in planning economic policies to produce better outcomes. More than ever theoretical and practical debate about how to plan economic policies in the face of uncertainty, competing interests, scarcity resources continues to be lively.

[2] See Sánchez-Chóliz and Duarte (2003) for an overview of indicators.

In this sense, “not only the size of linkages between two sectors reveals important information, but also the “economic distance” between these two sectors. That is, if sector I largely depends on sector j, it is relevant to know whether this dependence is direct or whether it runs via one other sector, or two (or more) other sectors” (Dietzenbacher, Romero and Bosma, 2005).

In this work, we propose a theoretical framework to key sectors determination. It is useful to be able to identify ex ante the potential high growth sectors which might be suitable for economic planning. In the literature, there continues to be discussion regarding the definition and estimation of the key sectors. Traditionally, it is a sector which generates above-average input requirements from other sectors and whose output is widely used by other sectors. The utility of input-output sectoral linkages as a means of identifying them has been recognized.

Beyond the ability of measurement economic impacts too, the network theory offers interesting insights about why and how some type of economic networks serves to enable or inhibit individual and/or joint actions in the structure. In fact, the structure of relationships is related with “contagion” conditions between sectors. A better understanding of the interconnectedness offers an approximation of the type of connectivity between sectors and an assessment of the systematic risk and vulnerability of the structure.

With this aim, an extension of the Multilevel Indicators (García et al., 2008) which fulfillment the demand and supply input-output conditions is proposed. New Multilevel Indicators are derivated from a network model which evaluate the total effects exerted on the economy, the immediacy and the transmission capacity of impacts from the demand and supply side. The information of Multilevel Indicators supposes an important asset for optimizing economic policies. The two last measures –inmediative and meditative effects- open a new line of analysis into the explanation of ongoing economic systems.

Identifying the faster “spreaders” in a network is an initial step to develop more efficient policies. “There are plausible circumstances where the best spreaders do not correspond to the most highly connected or the most central agents” (Kitsak et al., 2010). It must be emphasized the convenience of study not only total impacts but the spread of “contagions” in the network. The inmediative effects provide this valuable information for planning sectoral initiatives.

The meditative effects analyze how the relationships between sectors affect the productive structure resilience to external shocks. In particular, it is focuses on sectors which vertebrate the structure. It supposes that negative external shocks in these sectors can generate potentially path disruptions. These agents represent the points in the network that produce systematic risk and are able to produce important instability in the economic structure.

The rest of the paper is organized as followed. The determination of Multilevel Indicators under the demand and supplied models is presented. The scope is applied to the Greek economy study during the last decade (2000-2010). Since the 2008 international financial crisis, Greece has been subjected to political pressures and financial urgency. The analysis of the prior and post crisis productive structures points out the structural difficulties of the Greek economy. The empirical case allows us to get some conclusions about the Greek structural change and its potential high growth sectors.

2. Multilevel indicators

A line of research on input-output relates the theories about consensus formation and group decision making with the traditional key sectors definition (García et al., 2008). This framework makes possible to evaluate the basic knowledge about the regional production organization with the determination of the total effects exerted on the economy, the immediacy – a more or less direct tie by which the sector connects with the others, and its importance as a factor in transmitting effects throughout the network. The previous approach was based only on the Leontief model and restrictive hypothesis.

The improvements of the new proposal suppose a more flexible theoretical framework. Network theory, does not always comply with the assumptions and the economic assumptions on which the IO model stands, therefore it is necessary to be aware of to the extent to which that is useful in the context of structural analysis. The previous research (García et al., 2008) considers the same influence capacity between sectors for all and doesn´t include the auto-consumption of sectors as an integrant part of the degree of sectoral influence. These are unrealistic assumptions. First, the influential performance of sectors may not be fixed conditions. Second, the lost of information can derive the non- fulfillment of input-output conditions. Now the new model makes the economic influence transfer assumption more realistic and employs all information. The greater complexity is worthwhile as hypotheses lead to the equivalence of network model to the input-output model. Such effort advance knowledge by developing links between extant theories. To authors' knowledge this is the first time to establish a theoretical equivalence between a network modeling and input-output framework.

Furthermore, the initial proposal only focuses on the demand side of the economy and doesn´t study the immediate and mediative effects exert from the supply model. In the new model, it is assumed that the economic diffusion process is not the same for the demand side or supply side of the economy. To investigate in detail the demand and supply side of the economy, we use two influence network models. So, not only the total effects but the immediate effects and mediative effects can be calculated for backward linkages and forward linkages in this proposal. The detail is presented in the next epigraphs.

2.1 Backward linkages

The initial outline developed in an input–output frame proposes (García et al., 2008):

$$x_i = \alpha\left(\tilde{a}_{i1}x_i + \ldots + \tilde{a}_{in}x_n\right) + \left(1-\alpha\right)y_i \qquad (1)$$

where x_i and y_i represent the production and demand of sector ith respectively, α weights the effect of exogenous changes in the demand to be calibrated and the consequent sectoral transactions weight and $\tilde{a}_{ij}$ represents the normalized input–output coefficients that can be calculated as the proportion of sector jth purchases to sector ith a_{ij} in terms of direct production effect of the former $\sum_{j=1}^{n} a_{ij}$. The normalized input-output coefficient denotes the probability of establish a demand linkage between sector i and j. The normalized input-output coefficients matrix is row stochastic: its entries are nonnegative and each of its rows sum to unity. The normalized input-output coefficients matrix is a Markov chain[3].

From this model, three indicators called Multilevel Indicators are calculated: total effects, immediate effects and intermediate effects. They refer jointly to three important and complementary structural features where the sectoral influence weighting plays a relevant role. In the case of the absence additional information, the usual assumption is that the α coefficient is equal for all sectors and close to one. However, this hypothesis is considered as

[3] Markov chain modeling is a versatile technique that has been applied in input-output applications related with industrial ecological economics) or inter-regional flows of products (Eckelman and Daigo, 2008; Duchin and Levine, 2010), among others.

excessively restrictive in the input–output frame where the exogenous changes in the network would affect each sector differently. Introducing different coefficients for each sector seems a reasonable assumption in an economic structure where the industry have very different degrees of influence and the final and intermediate demand weight can have an unequal dominance in sectoral production necessities induced by variations in the final demand. This analysis would allow the differentiation of coefficients between sectors with the aim of distinguishing the industry's propensity to sectoral influences. Under this assumption, the model is specified as (García et al. 2008):

$$x_i = \alpha_i \left(\tilde{a}_{i1} x_i + \ldots + \tilde{a}_{in} x_n\right) + \left(1 - \alpha_i\right) y_i \qquad (2)$$

If we consider theoretically the condition expressed in the Leontief model and we eliminate the diagonal elements, then the influence index can be estimated as (García et al.2008):

$$\alpha_i = \frac{1}{1 + \frac{1}{\sum_{j=1}^{n} a_{ij}}} \qquad (3)$$

The option of not to consider the diagonal elements in the index of influence (Garcia et al, 2008) is habitual in the graph theory (Yamaguchi, 1994) and qualitative input-output analysis (Aroche-Reyes, 2002) but it supposes a loss of information and non compliance of the input-output model conditions.

In this work, we propose a new framework in the determination of indices of influence that implies equivalence between the input-output theory and the consensus formation theory. We establish models based on network theory equivalent to input-output demand and supply models. It supposes a formal connection between the Network Theory and input-output field. The proposed models based on theories about network consensus formation will result equivalent to input-output demand and supply models.

We suggest a model in which the index of influence is different if it is associated to final or intermediate demand. Given that the final demand is exogenous in input-output models, we suppose that it is exogenous as well in the network of relations between sectors. Its contribution affects directly to the sector production $\left(\alpha_i^F = 1\right)$. So, we focus on model the sector influence derived from the structure of inter-relations or the intermediate demand $\left(\alpha_i^I\right)$:

$$x_i = \alpha_i^I\left(\tilde{a}_{i1}x_i + \ldots + \tilde{a}_{in}x_n\right) + \alpha_i^F y_i = \alpha_i^I\left(\tilde{a}_{i1}x_i + \ldots + \tilde{a}_{in}x_n\right) + y_i \qquad (4)$$
$$\alpha_i^F = 1$$

In matrix terms:

$$\mathbf{x} = \hat{\mathbf{S}}\tilde{\mathbf{A}}\mathbf{x} + \mathbf{y} \qquad (5)$$

where $\hat{S}$ is a diagonal (nxn) matrix that measures the influence coefficients for each sector:

$$\hat{\mathbf{S}} = \begin{pmatrix} \alpha_1^I & 0 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & \ldots & \alpha_n^I \end{pmatrix} \qquad (6)$$

$\tilde{\mathbf{A}} = \left\{\tilde{a}_{ij}\right\}$ is a (nxn) matrix that represents the normalized input coefficients, $\mathbf{x} = \left\{x_i\right\}$ and $\mathbf{y} = \left\{y_i\right\}$ are $(nx1)$ vectors of production and final demands of sector i, respectively.

Given the demand input-output model wherein the necessary production levels to satisfy an exogenous final demand objective are determined as:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \qquad (7)$$

where $\mathbf{A} = \left\{a_{ij}\right\}$ is a (nxn) matrix of input coefficients:

$$\mathbf{A} = \mathbf{X}\hat{\mathbf{x}}^{-1} \qquad (8)$$

X denotes the (nxn) matrix of interindustry flows and the circumflex is used to denote a diagonal matrix; we verify theoretically the fulfilment of this condition in the influence model:

$$\hat{\mathbf{S}}\tilde{\mathbf{A}}\mathbf{x} + \mathbf{y} = \mathbf{A}\mathbf{x} + \mathbf{y} \qquad (9)$$

From the definition of normalized technical coefficients $\left(\tilde{a}_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \right)$, the sectoral index influence can be established as:

$$\alpha_i = \sum_{j=1}^{n} \left(a_{ij} \right) \tag{10}$$

The index of influence of sector i (i.e. the susceptibility of sector i to the influence of others) is strongly related with the direct effects of sector i. A high technical coefficient implies a strong demand relationship of sector j from i, i.e. a strong dependence. This proposal is formally consistent not only with the input-output framework but with social networks models of information integration. In social influence network theory, the influence index is also an aggregate function of the interpersonal relations measures (Friedkin, 2001). Furthermore, the value of the influence index contributes also to explain the role of direct relations in the network studies. Researchers in the field of economics as Jackson (2005) have pointed out the relevance of direct relations in the studies of networks. Under this framework, we can derive that they really suppose an aggregate measure of influence that can affect all relations of the economic structure (direct and indirect linkages).

Given the model expression, the determination of total effects will be basically related to the number and length of the paths between sectors and their influence in the network:

$$\mathbf{V} = \left(\mathbf{I} - \hat{\mathbf{S}}\tilde{\mathbf{A}} \right)^{-1} \tag{11}$$

The measure is based on the power series:

$$\left(\mathbf{I} - \hat{\mathbf{S}}\tilde{\mathbf{A}} \right)^{-1} = \left(\mathbf{I} + \hat{\mathbf{S}}\tilde{\mathbf{A}} + \left(\hat{\mathbf{S}}\tilde{\mathbf{A}} \right)^{2} + \ldots \right) \tag{12}$$

as indicators of structural complexity (Robinson and Markandya, 1973) or other traditional linkages measures (Rasmussen, 1956). Mathematically, the matrix **V** and the inverse of Leontief $\left(\mathbf{I} - \mathbf{A} \right)^{-1}$ are equivalent.

The effects on the output $(\Delta \mathbf{x})$ due to a demand-pull ($(\Delta \mathbf{y})$) can be interpreted as a stepwise or round-by-round procedure (See equation 12). The output effects $(\Delta \mathbf{x})$ consist of an initial effect $(\Delta \mathbf{y})$, a direct effect $\left(\hat{\mathbf{S}}\tilde{\mathbf{A}}\Delta \mathbf{y} \right)$ and indirect effects $\left(\left(\hat{\mathbf{S}}\tilde{\mathbf{A}} + \hat{\mathbf{S}}\tilde{\mathbf{A}}^{2} + \ldots \right) (\Delta \mathbf{y}) \right)$ .The increasing of number of steps by which two sectors can be connected supposes a decrease of transactions, whereas for similar distances the effect depends on the strengths of the relationships and the level of sectoral influences.

The element v_{ij} of the **V** matrix represents the backward linkage of the buying industry y on the selling industry i. The total effect of a sector j can be calculated as:

$$TEC_{(j)} = \frac{\sum_{i=1}^{n} v_{ij}}{n} \tag{13}$$

The total effect of final demand changes in sector j on the whole economy will be more relevant depending on the size of this value. This measure is equivalent to the Rasmussen backward linkages indicators.

The equivalence of the network model to the Leontief model and the correspondence between classical key sector indicators with centrality measures, support the propose framework. The estimation of the influence index under the proposal presents in this work implies the fulfillment of the Leontief model.

The propose methodology includes also the evaluation of other structural features that are relevant in the evaluation of the propagation of effects throughout the industries. In this sense, the novelty of the called Multilevel Indicators (Garcia et al, 2008) is the measurement of the immediacy and the transmission capacity of the impacts. The analysis of immediate and mediative effects is related with the paths that connect the sectors.

In networks physical distance is replaced by *path length*. A *path* is a route that runs along the links of the network, its length representing the number of links the path contains. In network science paths play a central role.

In one hand, the sectors where effects are basically transmitted over lengthy sequences of economic relations have less immediate economic impact than those ones with a high number of direct linkages. In other hand, the sectors involved in many of the paths that interrelates the connecting sectors can affect the links that occur along these paths. These sectors have a mediative role facilitating the function of the economy. Both features-immediacy and mediation- may be quantified from a Markov Chain.

The matrix $\tilde{\mathbf{A}} = \{\tilde{a}_{ij}\}$ of normalized input coefficients is a Markov chain. Under the specified model the relations between sectors are corrected by an influence index $(\alpha_i \tilde{a}_{ij})$:

$$\begin{pmatrix} \alpha_1 \tilde{a}_{11} & \ldots & \alpha_1 \tilde{a}_{1n} \\ \ldots & \ldots & \ldots \\ \alpha_n \tilde{a}_{n1} & & \alpha_n \tilde{a}_{nn} \end{pmatrix} \tag{14}$$

The new matrix is not a Markov chain. With the aim of construct it, the element of this matrix are normalized by rows:

$$\frac{\alpha_i \tilde{a}_{ij}}{\sum_{j=1}^{n} \alpha_i \tilde{a}_{ij}} = \frac{a_{ij} / \sum_{j=1}^{n} a_{ij}}{\sum_{j=1}^{n} \left(a_{ij} / \sum_{j=1}^{n} a_{ij} \right)} = \tilde{a}_{ij} \tag{15}$$

So, the immediate and mediative effects are related with the matrix of relations $\tilde{\mathbf{A}} = \{\tilde{a}_{ij}\}$ but not with the possible values of the influence index. Consider that these studied features must be related with the paths, it is, the existence of links between sectors or not. But it is not suitable consider the susceptibility of sector to the influence of others in the estimation of number of paths. The degree of influence is determinant in the estimation of total effects but once they are estimated the diffusion in the network depends basically on the paths gathers in matrix $\tilde{\mathbf{A}}$. It is a Markov chain.

From the Markov chain, the elements of the mean first passage gives the expected number of periods its takes to get to state j from state i (**M**). The interpretation, the average number of steps it takes a demand-pull in industry j to affect the production in sector i, is analogous to average propagation lengths (APLS) propose by Dietzenbacher, Romero, Bosma (2005).

Furthermore, in a directed network the existence of a path from node *i* to node *j* does not guarantee the existence of a path from *j* to *i*.

The matrix of mean first passage (**M**) is the basis of the immediate and mediative effects. The calculus of indicators is detailed in Friedkin, 1991.

Immediate effects (IEC) are defined as the reciprocal of the mean length of the sequences of relations from the jth sector to others:

$$\mathrm{IEC}_{(j)} = \left(\frac{\sum_{i=1}^{n} m_{ij}}{n} \right)^{-1} \quad \forall j \tag{16}$$

where

$$\mathbf{M} = \left(\mathbf{I} - \mathbf{Z} + \mathbf{E}\hat{\mathbf{z}}_{\mathbf{dg}}\right)\hat{\mathbf{q}} \tag{17}$$

where $\hat{\mathbf{q}}$ is a diagonal matrix with elements correspond to the inverse of stationary state i, E represents a (nxn) matrix formed by 1's and **Z** is the so-called fundamental matrix whose expression is:

$$\mathbf{Z} = \left(\mathbf{I} - \tilde{\mathbf{A}} + \tilde{\mathbf{A}}^{\infty}\right)^{-1} \tag{18}$$

so that $\mathbf{A}^{\infty}$ will coincide with the matrix that collects the process stationary state of the Markov Chain and $\hat{\mathbf{z}}_{dg}$ is a diagonal matrix built from the **Z** definition.

Sectors with same total effects may vary in the immediacy of their impacts. Sectors whose effects are transmitted over lengthy paths have less immediate effects than do sectors whose effects are transmitted over short productive sequences. Sectors with greater immediacy are less dependent on other sectors. They can be sectors oriented to final demand and situated at the end of production chains. "The larger IEC, the more rapidly the total effects tend to emerge" (Friedkin, 1991).

The mediative effects indicate the importance of sector j as a transmitter or crossroad point for the economic network connection and from these equations they are calculated as:

$$\mathrm{MEC}_{(j)} = \frac{\sum_{k=1}^{n} \bar{t}_{(k)j}}{n} \tag{19}$$

where

$$\bar{t}_{(k)j} = \frac{\sum_{i=1}^{n} t_{(k)ij}}{(n-1)t_{(k)jj}} \quad i \neq j \tag{20}$$

measures the contribution of sector j in the transmission of the effects of sector k and t(j)ik is is the ikth entry in the matrix **T** in:

$$\mathbf{T}_{(j)} = \left(\mathbf{I} - \tilde{\mathbf{A}}_{(j)}\right)^{-1} \tag{21}$$

and $\tilde{\mathbf{A}}_{(j)}$ is the matrix obtained by deleting the jth row and column of the matrix $\tilde{\mathbf{A}}$. It is fullfiment that the matrix M can be decomposed in the number of steps from sector j to sector i via other intermediate sectors:

$$m_{ij} = \sum_{k=1}^{n} t_{(j)ik} \quad i \neq j \neq k \tag{22}$$

2.2. Forward linkages

Supply-driven model relates sectoral output to primary inputs:

$$\begin{aligned} x_j &= \left(d_{1j}x_1 + \ldots + d_{nj}x_n\right) + v_j \\ \mathbf{x'} &= \mathbf{v'}\left(\mathbf{I} - \mathbf{D}\right)^{-1} \end{aligned} \tag{23}$$

where output coefficients give the percentage of the output of industry i that is sold to industry j, **v** is the matrix of primary cost and $(\mathbf{I} - \mathbf{D})^{-1}$ denotes the Ghosh inverse.

Analogy to the previous demand model framework, the proposal for the supply driven model under network theory is:

$$\begin{aligned} x_j &= \beta_j\left(\tilde{d}_{1j}x_1 + \ldots + \tilde{d}_{nj}x_n\right) + v_j \\ \mathbf{x'} &= \mathbf{v'}\left(\mathbf{I} - \hat{\mathbf{B}}\tilde{\mathbf{D}}\right)^{-1} = \mathbf{v'F} \end{aligned} \tag{24}$$

where $\hat{\mathbf{B}}$ is a diagonal (nxn) matrix that measures the influence coefficients for each sector:

$$\hat{\mathbf{B}} = \begin{pmatrix} \beta_1 & 0 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & \beta_n \end{pmatrix} \quad (25)$$

v is a $(n\mathrm{x}1)$ column vector of primary inputs and $\tilde{\mathbf{D}}$ is a $(n\mathrm{x}n)$ nonnegative matrix that gathers the normalized output coefficients:

$$\tilde{d}_{ij} = \frac{d_{ij}}{\sum_{i=1}^{n} d_{ij}} \quad (26)$$

that denote the share of the output of sector i that flows to sector j in relative terms. It reflects the probability of establish a supplied linkage between sector i and j. **F** gives the increase in the output value of industry j due to a one-euro increase of the primary costs in industry i. The effect in output values change can be decomposed into a initial effect, a direct effect in the first round an indirect effects in the subsequent rounds.

If we verify theoretically the fulfilment of the supply driven input-output model in the influence supply drivel model, the sectoral index influence in the supply-driven model can be established as:

$$\beta_j = \sum_{i=1}^{n} (d_{ij}) \quad (27)$$

It gathers the direct relation between sectors. The influence index under the Ghosh model reveals where the production materials for the production of this sector come from. The output coefficients of sector i represent the dependence of the economy with respect to mentioned sector.

The derivation of indicators is analogous to the previous model. The total effect from the supply side can be calculated as:

$$TEC_{(i)} = \frac{\sum_{j=1}^{n} f_{ij}}{n} \quad (28)$$

This measure is mathematically equivalent to the forward linkages of Rasmussen (1956).

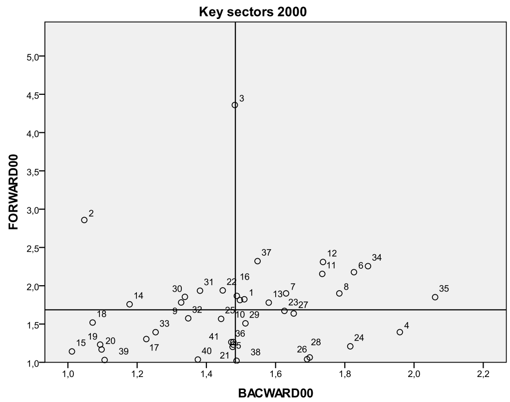
The inmediative and mediative effects can be calculated in the same way as the previous from the Markov chain defined now from the normalized output coefficients.

3. A case of study: the evolution of Greek economy

In this section, the presented above key sector analysis will focus on the Greek economy. The study deals with the structural change of Greek economy in the last decade. To undertake the analysis, use was made of the Greek input-output tables constructed for the years 2010 and 2000 and published by Eurostat. The tables were aggregated to the level of sectors 41 sectors. Appendix Tables nº A.1 and A.2 present the results of Multilevel Indicators and Influence indexes for the mentioned years respectively. The results are associated to the matrix of total coefficients.

The total effects under the Leontief and Ghosh model in 2000 are represented in Figure nº1. In input-output terms, the axes represent the backward and forward linkages. The means of both types of linkages are gathered by the perpendicular lines.

Figure nº 1. Total effect. 2000



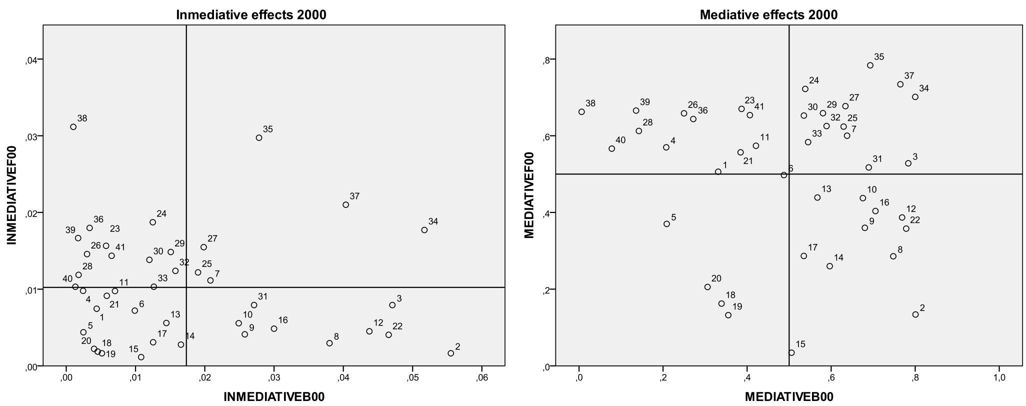
A key sector is a sector which generates above-average input requirements from other sectors and whose output is widely used by other sectors. The Greek key sectors are related with the primary sector and associated activities (1. Agriculture, hunting, forestry and fishing, 3. Mining and quarrying, 6. Wood and products of wood and cork) and some low-medium high technological intensity industrial sectors (7. Pulp, paper, paper products, printing and publishing, 8. Coke, refined petroleum products and nuclear fuel; 10. Rubber & plastics products; 11. Other non-metallic mineral products; 12. Basic metals; 13. Fabricated metal products, except machinery & equipment, 16. Electrical machinery & apparatus, neck, 34.

Renting of machinery & equipment). Only two high technological intensity activites are key sectors: 35. Computer & related activities and 37. Other Business Activities.

These results show the relevance of agriculture and the low technological industry in Greece in 2000. The agriculture has divided Greece into areas corresponding with types of this activity: the coastal regions with extensive and intensive flat lands and the mountains and island Greece with a traditional agriculture (Damianakos, 1997). In fact, "Greece appears as agricultural region with two main industrialized cities: Athens and Thessaloniki" (Siriopoulos and Asteriou, 1998). The technological performance gap between Greece and its European counterparts (Siriopoulos and Asteriou, 1998) can explain the role of industry in Greek economy. The chronic problems of technological backwardness in Greek industry and the lack of extensive training in new technologies and skills (Christodoulakis and Kalyvitis, 1998) suppose a reflex of the industrial economic impact state.

This distribution of total effects must be completed with a study on the degree of propagation (immediate effects) and the transmitter role of certain sectors (mediative effects). The Greek immediate and mediative effects in 2000 are represented in Figure nº 2.

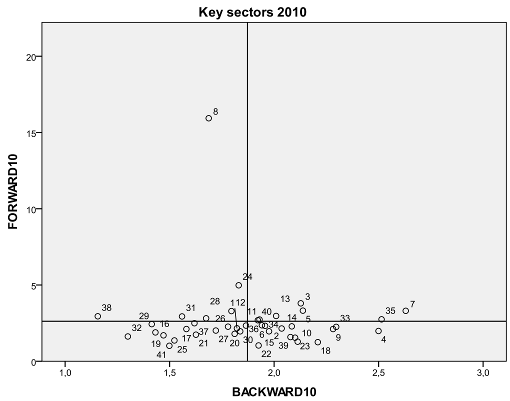
Figure nº 2. Inmediative and Mediative. 2000



Only four sectors (7, 34, 35, and 37) with high total impact can expand their effects quickly in the Greece economy. Mainly they are medium or high technological intensity activities. Furthermore, except the service sector (37. Other Business Activities), these sectors have the capacity of be crossroad point and so constitute very important connection elements for economic structure performance. The rest of the key sectors although enjoy an important pull effect, they have not an easy access to all sectors and don't vertebre the economic structure. It supposes their impact can be slowed down. Other sectors relate with transportation, telecommunications, construction and wholesale (24.Construction, 25. Wholesale & retail trade; repairs, 27. Land transport; transport via pipelines, 29. Air transport, 30. Supporting and auxiliary transport activities, 31. Post & telecommunications, 32. Finance & insurance, 33. Real estate activities) have the role of provide the performance of the Greek economy in 2000 too, although their impacts are not high in terms of total effects. To sum up, these last activities have not significant backward and forward linkages for the development of the Greek economy but their contribution to the economic vertebration and the diffusion of impacts is essential. The Greek efforts to overcome its fragmented geographical structure and to promote high technological intensity industries and services are stand out as necessary for a dynamic and cohesive economic performance. The Greek country has tried to raising the provision and quality of infrastructures in the last decade. "The Greek archipelago has more than 6000 islands and islets, of 227 are inhabited; and islands cover about 25.000 Km^2 i.e. almost a fifth of the total area of Greece" (Papatheodorou and Arvanitis, 2009). Greece has promoted the construction of highways, the renovation of railway, restructuration the mail service and/or the modernization of telecommunications for overcoming its isolation. As well, the competitiveness of the production sectors has boosted encouraging the adoption of new technologies and fostering technological innovation (Christodoulakis and Kalyvitis, 1998).

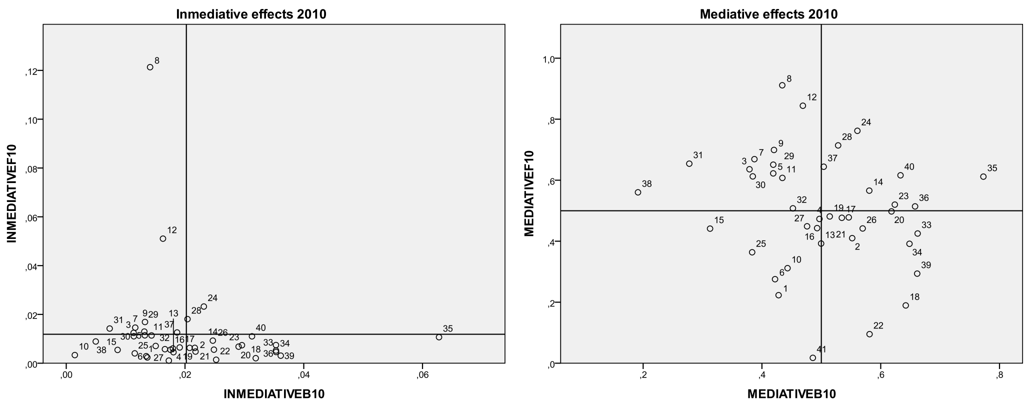
After a decade, the Greek economy presents a non dynamic structure with spoil symptoms. The total effects under the Leontief and Ghosh model in 2010 are represented in Figure nº 3. A few sectors have a large impact on the rest of the economy in 2010. The key sectors which expand above-average total demand and supply effects are only seven sectors (17%) in 2010. Most of these sectors were key sectors in the previous period too: 3. Mining and quarrying, 7. Pulp, paper, paper products, printing and publishing, 11. Other non-metallic mineral products, 13. Fabricated metal products, except machinery & equipment, 35. Computer & related activities. Only two new sectors get now become key: 5. Textiles, textile products, leather and footwear, 40. Health & social work. They concern sectors with a long history and tradition in Greece (textiles, non-metallic mineral products) or traditional intermediate goods (Pulp, paper and fabricated metal products) (Markatou, 2011). The key sector of health and social work sector must be detailed. The size of the private health sector has grown considerably in the last years in Greece. "There was an important increase in private health expenditure and new private hospitals. In the private primary health care, there was a rapid growth of diagnostic/laboratory centers and an important increase in the number of private doctors" (Tountas et al. 2005). His effects over the economy has revealed as important for the Greek economic growth.

Figure nº 3. Total effect. 2010



It must be emphasized the primary sector is not a key sector in 2010. Along the years, "Greece have been transformed itself progressively from an agricultural economy with virtually no industrial base to an economy with a significant industrial sector (Drakopoulos et al., 1991)".

Figure nº 4. Inmediative and Mediative. 2010



The figure nº 4 gathers the immediate and mediative effects in 2010 for all sectors. Although the positive evolution of the Greek secondary sector, the impact immediacy of key sectors is non high in the supply and demand side either. This supposes serious barriers to the propagation of the impact of key sectors and a slower transmission of their effects to the rest economy. Furthermore, 40% of Greek sectors present limitations in the diffusion of their possible impacts in the economy. So, the economic diffusion efficiency is very low in Greece economic structure. This fact is relevant to the economic policy planning. The efficient implementation of stimulus economic policies in Greece presents a serious spread obstacle nowadays. So, the impacts of sector policies in short time can be limited.

At the presented, the articulation of the Greek economy is based on a few activities: construction, some high technological sectors and water activities (14. Machinery & equipment, 23. Collected and purified water, services of water, 24. Construction, 28. Water transport, 35. Computer & related activities, 36. Research & development, 37. Other Business Activities, 40. Health & social work).

In this sense, Greece faces serious water scarcity problems with important impacts in economic and social activities. “A series of geomorphological, meteorological, and hydrological conditions, in addition to the particular social, economic, and administrative circumstances are currently making sustainable water management a complex task” in Greece (Mylopoulos et al., 2003). Water resource management practices and projects are trying to integrate both socio-economic development and environmental ecosystem integrity. The effects of water scarcity have repercussion on the urban centers, agricultural areas and zones dependent on tourism, mainly.

In spite of the total effects of tertiary sector have resulted limited in Greek economy, some knowledge intensive services provide the economic performance and cohesion. This applied to health care, business services or R&D, between others. The services are becoming increasingly global as a result of the increased labour mobility and technological advances. The services are subjecting to more systematic R&D efforts. In Greece, some services have been benefited from the available R&D supports by specific calls for services within the existing programmes. The KIBs, health care, IT-services among others was high on the policy agenda and was object of private business R&D (Kuusisto, 2008).

With the aim of make up a view of the role of the sectors and their effects in the Greek economy, the indexes of influence under the demand and supplied model is presented in the Figure nº 5 and 6. The index of influence gathers the susceptibility of sector to the influence of others. The index of influence in the Leontief model is denoted as α_i and in the Ghosh model as β_j

Figure nº 5. Index of influence. 2000

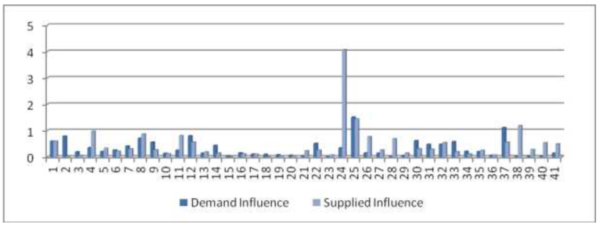
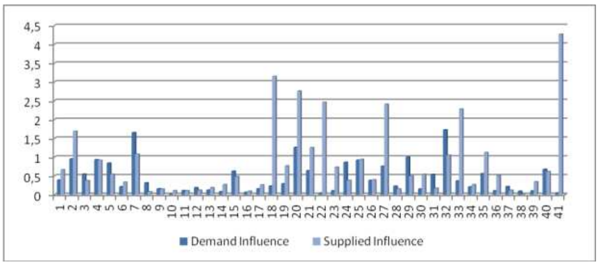


Figure nº 5. Index of influence. 2010



In 2000, the means of influence in the Leontief and Ghosh model are 0. 324 and 0.455, respectively. In general, the levels are similar between demand and supplied side of the economy and the susceptibility of being influence is low in general. Only Construction (24) shows a high degree of influence susceptibility from the supplied side. The construction showed dependence signs in 2000. Its influence index β was very above the mean. This result implies an alert over the consequences of other sectors economic in the Greek construction sector in 2000. In 2010, the influence indexes are raised especially from the supplied side. The means of influence in the Leontief and Ghosh model are 0. 461 and 0.845, respectively. In general, the degree of influence increase for all sectors, but there are sector with a strong susceptibility of being influence. The sectors 18. Medical, precision & optical instruments, 20. Other transport equipment, 22. Electrical energy, gas, steam and hot water, 27. Land transport; transport via pipelines, 33. Real estate activities and 41. Other community, social & personal services present a high influence index β. So, some environmental resources, transport, social activities and real estate are the sectors more susceptibility of being affected for the economic situation of others in 2010.

4. Conclusions

In the last years, network analysis has opened a new inquiry in economic geography and regional development (Leitner et al, 2008). Its explanatory value of the dynamics of the structures has been applied to clusters, regional innovation systems and knowledge spillovers

(Ter Wal et al., 2008). This new emerging literature suggests the relevance of path-disrupting effects in the economic growth (Glückler, 2007).

The diffusion speed of the recent financial crisis has stimulated this scope. The analysis of the conditions under which contagion can produce in structures is now recognized as a strategic information tool in the design of economic policies. Domino effects or cascading failures (Watts, 2002), resilience to shocks (Cainelli et al., 2012) or stable configurations of risk-sharing networks (Bramoullé and Kranton, 2007; Fafchamps and Gubert, 2007) have focused the interest of the academics in financial research.

In input-output field, structural analysis has made extensive use of graph theory and network theory yielding powerful insights on the relationships existing between industries in an economic system. However, to authors' knowledge non attempts have been made to investigate the systematic risk and instabilities that are generated endogenously in the structure. Network theory is able to provide a huge explanatory power about how the relational structure affects the contagion diffusion and the robustness of the economic system.

With this aim, this work presents a proposal that complements the traditional measurement of key sectors with the study of spreaders and resilience conditions from the demand and supply side of the economy. Furthermore, the method proves its consistency in relation to input-output framework. The approach adopted here draws not only on the study of the size of the production flow but also on the number of production relationships and the paths between sectors. In the input–output field, there is a body of literature dealing with this question of structural complexity and lengths of chains (Robinson and Markandya 1973; Dietzenbacher et al. 2005; García et al., 2010; Oosterhaven and Bouwmeester, 2013, among others), Production chains have already been pointed out in economic theories.Vertical specialization, also called slicing up the value chain, outsourcing or fragmentation, among others, has been studied extensively by the economists (Humphrey and Schmitz 2002; Jones and Kierzkowski, 2005). This fragmentation of production process can be in relationship with the changes driven by globalization and evolving manufacturing patterns, such as JIT (Just-in-Time Delivery), new business opportunities linked to telematics, trends to lowering service-link costs and or constructing efficient vertical value chains (Humphrey and Schmitz 2002; Jones and Kierzkowski, 2005).

Multilevel Indicators not only describe industries with high backward and forward impacts but the immediacy and the transmission capacity of their demand and supply impacts.

In this sense, the Multilevel Indicators offer some potential advantages for both understanding the structure of economies, and also for the design of appropriate policy-making. Authorities can exploit the network logic by undertaking a rigorous assessment of impacts, capabilities and competences of sectors to transfer the impacts. From the available Multilevel Indicators information, it is possible to determine in which directions the policy mixed should be reformulated to get more efficient and less vulnerable combinations of economic activity.

The proposal key sector analysis is focused on the structural change of Greek economy in the last decade (2000-2010). The Greek economic structure is based on agriculture and low-medium technological industries in 2000. The medium technological intensity sectors are the only key sectors that can transmit the effects quickly and act as cross-points in the economy. Other sectors relate with transportation, telecommunications, construction and wholesale have the role of provide the performance of the Greek economy in 2000 too, although their impacts are not high in terms of total effects. The projects and investment in these fields aim to gear the Greek economy onto a more articulated and vertebrated economic structure.

It can be emphasized the low impact of tertiary sector in Greek economy, especially the tourism activities. The tourism contribution to the transformation of local socioeconomic systems depends on the structure of the industry itself as well as on the particularities of local economies.The Greece's tourism is characterized by spatial polarization, high degree of seasonality and low quality of services (Leontidou, 1994). For these reasons, "most researchers agree on the need for a change in the direction of the state's intervention in tourism" in Greece (Galani-Moutafi, 2004).

In 2010, the Greek economic base is not the agriculture sector. "Greece have been transformed itself progressively from an agricultural economy with virtually no industrial base to an economy with a significant industrial sector (Drakopoulos et al., 1991)". Industrial sectors with a long history and tradition in Greece and some traditional intermediate goods are key sectors in 2010. Furthermore, some knowledge intensive services provide the Greek economic performance and cohesion. Greece "has for some time been active in developing strategies and instruments for supporting R&D in services (…) and are also carrying out a varying range of activities that seek to address services related R&D, either directly or indirectly" (Kuusisto, 2008). This role of this type of services in the Greek economy can be in relationship with the changes driven by globalization and evolving manufacturing patterns, such as JIT (Just-in-Time Delivery) and new business opportunities linked to telematics. It supposes a reflect of the nowadays production/distribution mechanics built around a competitive edge in developing subcontracting system, exploring modulation techniques, and constructing efficient vertical value chains (Jones and Kierzkowski 2005).

Although the positive evolutions of the Greek secondary and tertiary sectors, a few sectors have generated higher effects in the economy and the impact immediacy of key sectors is non high in the supply and demand side either. This supposes serious barriers to the propagation of the scarce impact of key sectors and a slower transmission of their effects to the rest economy. Furthermore, 40% of Greek sectors present limitations in the diffusion of their possible impacts in the economy. The efficient implementation of stimulus economic policies in Greece presents a serious spread obstacle nowadays. So, the impacts of sector policies in short time can be limited. The economics performance and cohesion is based on high technological intensity activities which require of high investment efforts and the development of efficient R&D policies. Remove the economic support to these industries can suppose increase the vulnerability of Greek economy. If the vulnerability goes up past some critical level, the network structure will break down into a sparse and hierarchical structure.

5. References

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1. Annex

Table nº A1. Multilevel Indicators and Influence indexes. 2000

	DEMAND MODEL				SUPPLY MODEL			
SECTORS	TOTAL	IMMEDIATE	MEDIATIVE	INFLUENCE INDEX	TOTAL	IMMEDIATE	MEDIATIVE	INFLUENCE INDEX
1. Agriculture, hunting, forestry and fishing	1.510	0.007	0.506	0.602	1.823	0.004	0.331	0.597
2. Mining and quarrying (energy)	1.047	0.002	0.134	0.795	2.858	0.056	0.801	0.030
3. Mining and quarrying (non-energy)	1.482	0.008	0.528	0.196	4.360	0.047	0.784	0.057
4. Food products, beverages and tobacco	1.959	0.010	0.570	0.355	1.394	0.002	0.208	0.981
5. Textiles, textile products, leather and footwear	1.478	0.004	0.370	0.208	1.265	0.002	0.209	0.332
6. Wood and products of wood and cork	1.826	0.007	0.497	0.264	2.177	0.010	0.488	0.215
7. Pulp, paper, paper products, printing and publishing	1.630	0.011	0.600	0.414	1.900	0.021	0.638	0.307
8. Coke, refined petroleum products and nuclear fuel	1.784	0.003	0.286	0.717	1.900	0.038	0.748	0.871
9.Chemicals	1.327	0.004	0.360	0.564	1.782	0.026	0.680	0.270
10.Rubber & plastics products	1.497	0.006	0.437	0.135	1.813	0.025	0.676	0.121
11. Other non-metallic mineral products	1.735	0.010	0.574	0.258	2.155	0.007	0.421	0.810
12. Basic metals	1.737	0.005	0.387	0.807	2.310	0.044	0.769	0.562
13. Fabricated metal products, except machinery & equipment	1.580	0.006	0.439	0.141	1.780	0.014	0.567	0.191
14. Machinery & equipment, nec	1.178	0.003	0.260	0.438	1.758	0.017	0.597	0.146
15. Office, accounting & computing machinery	1.012	0.001	0.034	0.046	1.142	0.011	0.506	0.003
16. Electrical machinery & apparatus, nec	1.488	0.005	0.404	0.155	1.867	0.030	0.705	0.119
17. Radio, television & communication equipment	1.227	0.003	0.287	0.110	1.304	0.013	0.535	0.104
18. Medical, precision & optical instruments	1.071	0.002	0.162	0.099	1.519	0.005	0.339	0.022
19. Motor vehicles, trailers & semi-trailers	1.093	0.002	0.132	0.084	1.232	0.005	0.355	0.044
20. Other transport equipment	1.097	0.002	0.206	0.065	1.168	0.004	0.306	0.045
21. Manufacturing nec; recycling (include Furniture)	1.476	0.009	0.557	0.052	1.201	0.006	0.384	0.236
22. Electrical energy, gas, steam and hot water	1.447	0.004	0.358	0.514	1.939	0.047	0.779	0.255
23. Collected and purified water, distribution services of water	1.626	0.016	0.670	0.026	1.672	0.006	0.387	0.072
24. Construction	1.816	0.019	0.722	0.349	1.209	0.012	0.538	4.073
25. Wholesale & retail trade; repairs	1.443	0.012	0.624	1.511	1.567	0.019	0.630	1.439

26. Hotels & restaurants	1.699	0.015	0.658	0.158	1.064	0.003	0.250	0.768
27. Land transport; transport via pipelines	1.652	0.015	0.677	0.140	1.637	0.020	0.634	0.263
28. Water transport	1.691	0.012	0.612	0.031	1.040	0.002	0.142	0.691
29. Air transport	1.513	0.015	0.659	0.061	1.509	0.015	0.580	0.149
30. Supporting and auxiliary transport activities; activities of travel agencies	1.338	0.014	0.653	0.617	1.855	0.012	0.535	0.312
31. Post & telecommunications	1.382	0.008	0.517	0.481	1.935	0.027	0.689	0.295
32. Finance & insurance	1.348	0.012	0.625	0.483	1.575	0.016	0.589	0.544
33. Real estate activities	1.253	0.010	0.583	0.580	1.393	0.013	0.545	0.196
34. Renting of machinery & equipment	1.867	0.018	0.701	0.215	2.256	0.052	0.800	0.112
35. Computer & related activities	2.061	0.030	0.784	0.204	1.851	0.028	0.693	0.252
36. Research & development	1.472	0.018	0.644	0.065	1.264	0.003	0.272	0.073
37. Other Business Activities	1.548	0.021	0.734	1.117	2.321	0.040	0.765	0.564
38. Public admin. & defence; compulsory social security	1.487	0.031	0.662	0.020	1.020	0.001	0.006	1.191
39. Education	1.106	0.017	0.666	0.032	1.030	0.002	0.136	0.283
40. Health & social work	1.375	0.010	0.566	0.026	1.036	0.001	0.078	0.542
41. Other community, social & personal services	1.478	0.014	0.654	0.144	1.231	0.007	0.407	0.500
Mean	1.484	0.010	0.500	0.324	1.686	0.017	0.500	0.455
Third quartil	1.652	0.015	0.654	0.483	1.900	0.026	0.680	0.562
Min	1.012	0.001	0.034	0.020	1.020	0.001	0.006	0.003
Max	2.061	0.031	0.784	1.511	4.360	0.056	0.801	4.073

Table nº A1. Multilevel Indicators and Influence indexes. 2010

	DEMAND MODEL				SUPPLY MODEL			
SECTORS	**TOTAL**	**IMMEDIATE**	**MEDIATIVE**	**INFLUENCE INDEX**	**TOTAL**	**IMMEDIATE**	**MEDIATIVE**	**INFLUENCE INDEX**
1. Agriculture, hunting, forestry and fishing	1.822	0.014	0.428	0.389	2.159	0.002	0.223	0.665
2. Mining and quarrying (energy)	2.036	0.022	0.552	0.951	2.148	0.005	0.410	1.689
3. Mining and quarrying (non-energy)	2.128	0.011	0.379	0.548	3.797	0.012	0.636	0.373
4. Food products, beverages and tobacco	2.500	0.018	0.497	0.931	1.984	0.006	0.473	0.915
5. Textiles, textile products, leather and footwear	2.138	0.013	0.419	0.840	3.319	0.011	0.622	0.546
6. Wood and products of wood and cork	1.941	0.013	0.422	0.212	2.357	0.003	0.275	0.332
7. Pulp, paper, paper products, printing and publishing	2.630	0.012	0.387	1.654	3.308	0.015	0.669	1.079
8. Coke, refined petroleum products and nuclear fuel	1.687	0.014	0.434	0.318	15.933	0.121	0.911	0.078
9.Chemicals	2.282	0.013	0.420	0.159	2.112	0.017	0.699	0.149
10.Rubber & plastics products	2.113	0.001	0.443	0.026	1.283	0.003	0.312	0.112
11. Other non-metallic mineral products	1.930	0.014	0.434	0.112	2.734	0.011	0.608	0.105
12. Basic metals	1.796	0.016	0.469	0.188	3.290	0.051	0.844	0.117
13. Fabricated metal products, except machinery & equipment	2.010	0.018	0.500	0.122	2.969	0.005	0.392	0.186
14. Machinery & equipment, nec	2.085	0.025	0.581	0.081	2.288	0.009	0.566	0.268
15. Office, accounting & computing machinery	1.976	0.009	0.313	0.627	1.962	0.005	0.441	0.485
16. Electrical machinery & apparatus, nec	1.432	0.018	0.493	0.061	1.891	0.006	0.443	0.092
17. Radio, television & communication equipment	1.580	0.021	0.535	0.156	2.113	0.006	0.477	0.261
18. Medical, precision & optical instruments	2.209	0.032	0.642	0.233	1.251	0.002	0.189	3.149
19. Motor vehicles, trailers & semi-trailers	1.471	0.019	0.514	0.290	1.699	0.006	0.481	0.766
20. Other transport equipment	1.811	0.029	0.618	1.261	1.796	0.007	0.498	2.759
21. Manufacturing nec; recycling (include Furniture)	1.626	0.022	0.546	0.640	1.742	0.006	0.478	1.254
22. Electrical energy, gas, steam and hot water	1.926	0.025	0.581	0.041	1.035	0.001	0.095	2.461
23. Collected and purified water, distribution services of water	2.100	0.030	0.624	0.104	1.546	0.007	0.520	0.734
24. Construction	1.830	0.023	0.561	0.862	4.979	0.023	0.762	0.383
25. Wholesale & retail trade; repairs	1.523	0.012	0.384	0.920	1.364	0.004	0.364	0.939
26. Hotels & restaurants	1.779	0.025	0.570	0.381	2.268	0.006	0.442	0.398
27. Land transport; transport via pipelines	1.721	0.017	0.476	0.761	2.013	0.006	0.449	2.410

28. Water transport	1.675	0.020	0.528	0.227	2.815	0.018	0.714	0.154
29. Air transport	1.414	0.013	0.419	1.000	2.435	0.013	0.651	0.496
30. Supporting and auxiliary transport activities; activities of travel agencies	1.838	0.011	0.385	0.152	1.961	0.011	0.613	0.543
31. Post & telecommunications	1.559	0.007	0.278	0.538	2.938	0.014	0.654	0.174
32. Finance & insurance	1.300	0.015	0.452	1.724	1.625	0.007	0.508	1.053
33. Real estate activities	2.297	0.035	0.662	0.370	2.254	0.005	0.425	2.278
34. Renting of machinery & equipment	1.957	0.035	0.648	0.209	2.324	0.005	0.392	0.268
35. Computer & related activities	2.514	0.063	0.773	0.560	2.748	0.011	0.612	1.126
36. Research & development	1.865	0.035	0.658	0.106	2.338	0.007	0.514	0.510
37. Other Business Activities	1.619	0.019	0.504	0.217	2.493	0.013	0.644	0.118
38. Public admin. & defence; compulsory social security	1.156	0.005	0.191	0.092	2.948	0.009	0.560	0.011
39. Education	2.078	0.036	0.661	0.101	1.585	0.003	0.294	0.343
40. Health & social work	1.922	0.031	0.633	0.677	2.687	0.011	0.616	0.617
41. Other community, social & personal services	1.499	0.017	0.486	0.044	1.014	0.001	0.018	4.269
Mean	1.873	0.020	0.500	0.461	2.622	0.012	0.500	0.845
Third quartil	2.085	0.025	0.581	0.677	2.748	0.011	0.622	1.053
Min	1.156	0.001	0.191	0.026	1.014	0.001	0.018	0.011
Max	2.630	0.063	0.773	1.724	15.933	0.121	0.911	4.269