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The energy and telecommunications sectors in the input-output matrix for 2003, 2008 and 2012. A network approach.

Eric Hernández, José Luis Mateos, Oscar Córdoba, Ana Belén Ríos, Mariana Velázquez and Rafael Bouchain[1]

Category: Input-output and network theory

Abstract

The Network Theory has shown as a great tool for Input-Output Analysis. In the last years, this theory is becoming more relevant among the economists. This is because it helps to find out which are the dominant sectors in a network, in a group of sectors,in economic circuits, in trade groups, etc. In this paper we are going to analyze the Mexican economic structure from a network theory perspective. The purpose is to study the role of energy and telecomunication sectors, before the goverment starts with the application of the structural reforms that were approved in 2014. The Networks approach is a qualitative kind of analysis. It is very useful for finding some properties that are hidden in a quantitative analysis of interindustry linkages and key industries. In this way, by taking this theory we can carry out a set of centrality measures such as: Degree, Closeness, Betweenness and Eigenvector centrality, Shortest path, and Influence. For this analysis we are using Mexico´s Input-Output tables for the years 2003, 2008, and 2012 all of them are added and homogenized into 250 branches. Thus, we are going to identify the important sectors in the economic system.

1. Introduction

Input-output tables are an accounting description of purchases (intermediate inputs and factors) and sales (products whose destination are intermediate demand and final demand), which define the inter-industrial structure of an economic system. Moreover, the input-output model allows the introduction of hypotheses that characterize the interdependence of economic sectors.

The input-output model proposed by Leontief allows quantification of the coefficients that define the relationships between sectoral variables. The Leontief inverse can know the direct and indirect production requirements needed to generate one unit of final demand is say, we know the value of the impacts caused by the production sector in other sectors (backward linkages) and the influence of demand from different sectors on a particular

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sector (forward linkages); with this we can classify the key industries based on the value of those links.

However, the traditional analysis is inadequate when you want to perform a qualitative analysis of the influence, circularity, hierarchy and centrality of certain sectors. This can be done from network theory as it makes perceptible certain properties of the structures contained in the input-output tables, which are not shown in the input-output analysis and calculation of traditional chains.

The aim of this paper is to apply network theory to the analysis of input-output tables for Mexico in the years 2003, 2008 and 2012, in order to conduct a study on the inter-industrial structure of the Mexican economy and highlight the importance of the energy, electronic, computer, communications technologies and mass media.

This paper calculated some measures of centrality: degree, closeness, betweenness and eigenvector centrality.

This paper is divided into three sections. The first is an introduction to network theory applied to the analysis of input-output tables, defining measures of centrality. After the results of the measures of centrality calculated for these sectors are presented. Finally, conclusions are presented.

2. GRAPH THEORY APPROACH IN THE INPUT-OUTPUT ANALYSIS

A Graph is define as follows:

$G = (X, U)$

Where X = finite set of elements called vertices or nodes or (industries in our case); and U = represents a set of n^2 elements called arcs (sales) that are a part of the cartesian product $X \bullet X$, in the case of directed graphs, we have that $U \in X^2$. The orientation of the arc indicates the direction of the relation between the vertices (sales and purchases between economic branches).

When two vertices x_i and x_j are related, we can say that $x_j = f(x_i)$, and the arc goes from x_i to x_j, where f is an application of X in X. x_i is the initial extremity and x_j the final extremity, then we say x_i and x_j are adjacent, which means that:

$$\forall \left(x_i, x_j\right) \in X \;\; \Leftrightarrow x_i \;\; R \, x_j \,; \quad x_j \; = f(x_i)$$

A vertex may be related to himself what we call loop (reflexive property).

The adjacent matrix came from transforming input output tables into binary matrix of the same dimension, such that if x_j=$f(x_i)$=1 and if $x_j \neq f(x_i)$=0 and it be for itself industry x_i=$f(x_i)$=1.

In network analysis the centrality of a graph refers to a measure of a node in this graph, which determines their relative importance within it. The centrality is not a specific nodes' attribute is a structural attribute. That is, the centrality measures the contribution of a node based on its location in the network.

They have proposed several measures of centrality of a node. There are four of these measures that are widely used in network analysis: Degree centrality, Closeness centrality, Betweenness centrality and Eigenvector centrality.

Degree centrality is the first and simplest of the centrality measures. It is the number of links has a node with others.

The out-degree of a vertex is the number of arcs whose initial extremity is the vertex $d^+(x_i)$ (sum by rows in the incidence matrix).

The in-degree of a vertex is the number of arcs that have like final extremity this vertex $d^-(x_i)$ (sum by columns in the adjacent matrix).

The degree of a vertex is the sum of the both semi-degrees $d(x_i) = d^+(x_i) + d^-(x_i)$. Si $d(x_i) = 0$ is an isolated vertex and this has no economic significance.

The closeness centrality is based on calculating the sum or the average of the shortest distances from one node to all others. In a flow network this measure can be interpreted as the time of arrival at destination of something that flows through the network. It can also be interpreted as the speed that will spread information from one node to all others. Closeness measures the accessibility of a node on the network.

$$l_i = \frac{1}{n}\sum_j d_{ij}$$

Where d_{ij} is the length of the geodesic path from I to j. Average over all vertices j in the network.

Betweenness centrality is a measure that quantifies the frequency or number of times a node acts as a bridge along the shortest path between two nodes. Nodes and arcs with high betweenness, often play a critical role in the network structure. Nodes that have a intermediary position somehow are also controllers or regulators of information flow.

$$x_i = \sum_{st} \frac{n_{st}^i}{g_{st}}$$

Where n_{st}^i; number of geodesic paths from s to t that pass through i. g_{st} is the total nuber geodesic paths from s to t.

The eigenvector centrality measures the influence of a node in a network. Nodes that have a high value of this measure are attached to multiple nodes which in turn are connected. The most central nodes in this regard correspond to centers of large cohesive groups. While in the case of degree centrality, each node weighs the same within the network, in this case the connection weights of the nodes differently.

$$\boldsymbol{X} = k_1^{-1}\boldsymbol{Ax}$$

for x_i

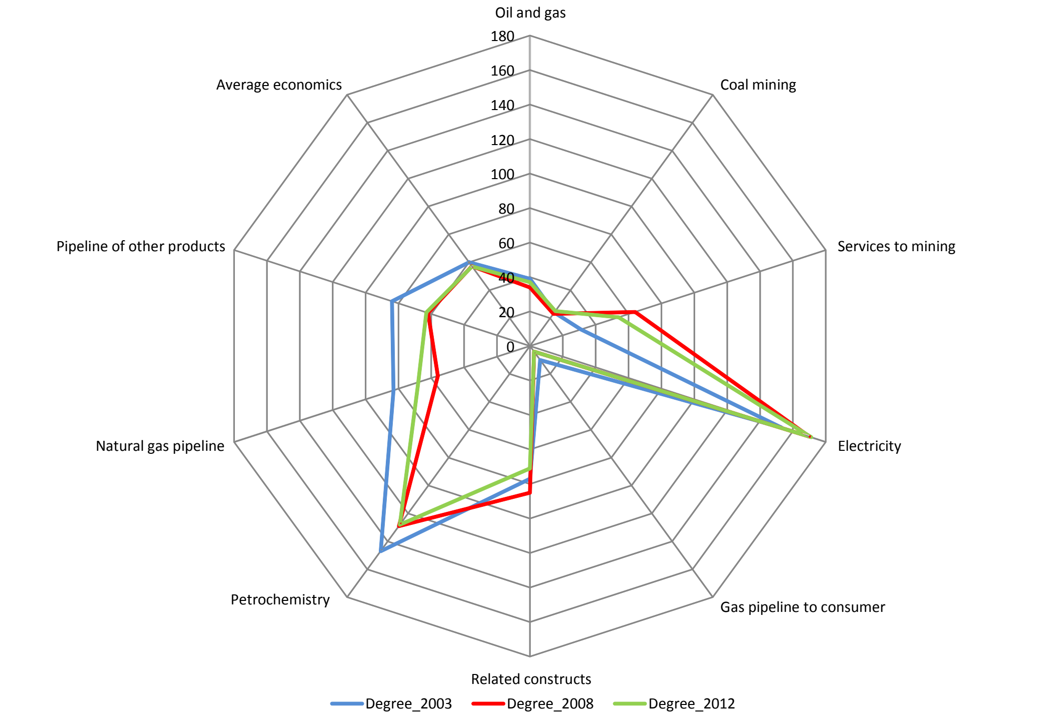
$$x_i = k_1^{-1} \sum_j A_{ij} x_j$$

3. Centrality measures for selected sectors for Mexico in 2003, 2008 and 2012

Using input-output tables for 2003, 2008 and 2012 deflated at 2008 prices, we calculate four measures of centrality: degree, closeness centrality, betweenness centrality and eigenvector centrality. With these measures we analyze the following sectors: Energy, Automotive industry, Electronic industry, Mass media and Telecommunications.

3.1 Degree Centrality

Graph 3.1.1 Degree of Energy and related industries in Mexico. 2003, 2008 & 2012.



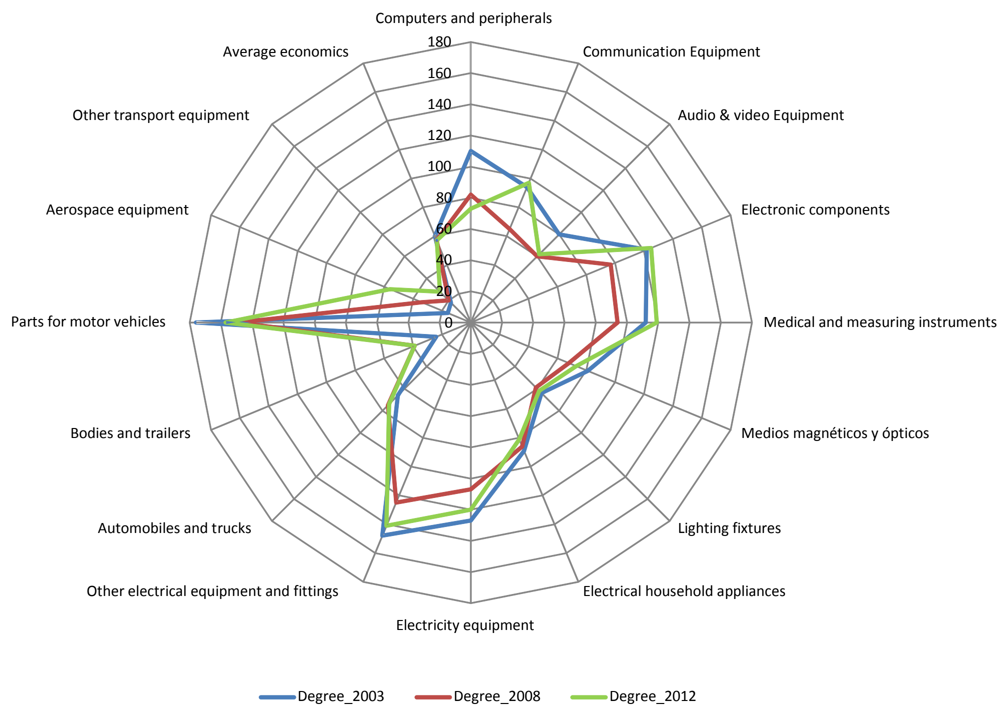
The results obtained for the degree centrality show the branches that have a greater connection with the other branches of the economy, sectors that are above average. Electricity and Petrochemistry have the greatest degree; although connections have been reduced in the latter sector from 2003-2008, which means it loses connections.

Another important sector are Related constructs also lost connections by reducing their degree.

The same case of decoupling is presented for both sectors, Pipeline transportation for natural gas and Pipeline of other products, both decreased by 2003 to 2012.

Moreover, both sectors, Coal mining and Gas to pipeline to consumer are below the average for the economy.

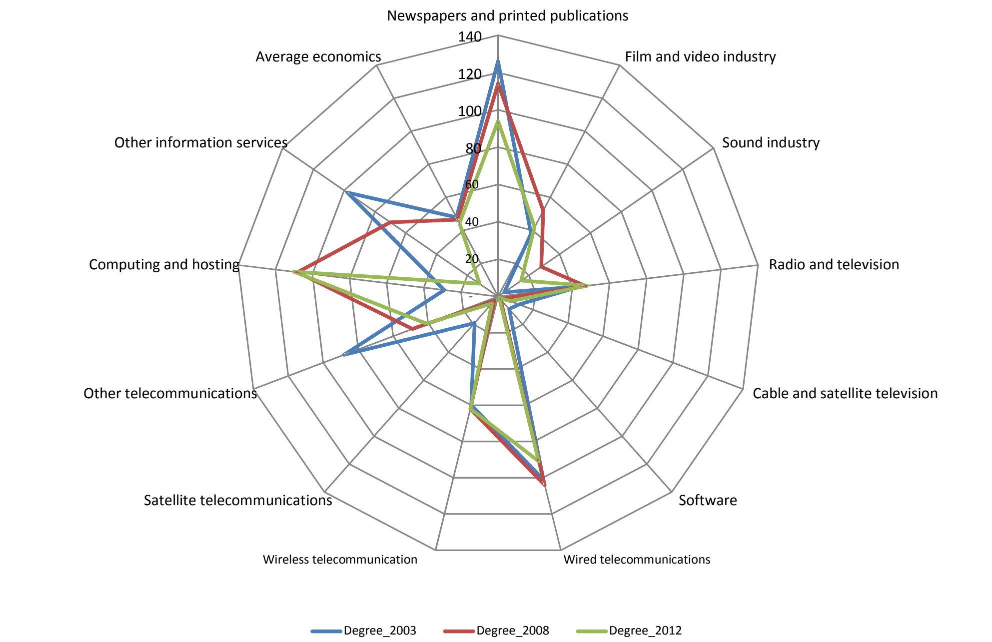
Gráfico 3.1.2 Degree of Electronic, Electrical and Automotive industries in Mexico. 2003, 2008 & 2012.



The results obtained for the degree centrality show that old branches have a greater connection above average, sectors with higher connections are: Manufacture of automotive parts, Other electrical equipment, They have a higher degree. The sectors that follow them are Electricity equipment, Computers and peripherals. Electronic components, Medical and measuring instruments and Communication Equipment.

Two sectors are somewhat behind but above the average of the economy are: Audio and Video Equipment and Lighting fixtures. Finally two sectors are below the average level of the economy, showing their low connectivity to other sectors, these are: Other transport equipment and Aerospace equipment.

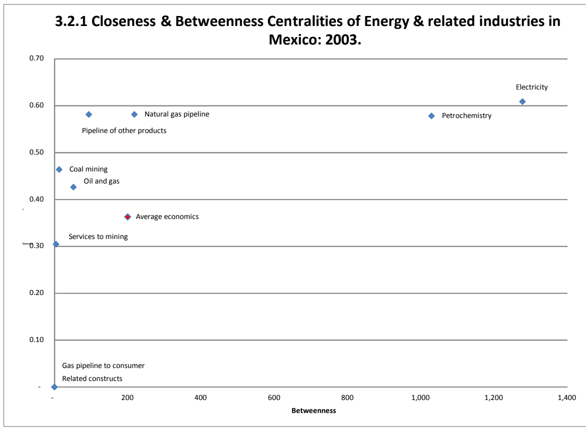
Graph 3.1.3 Degree of Mass media & ITC industries in Mexico. 2003, 2008 & 2012.



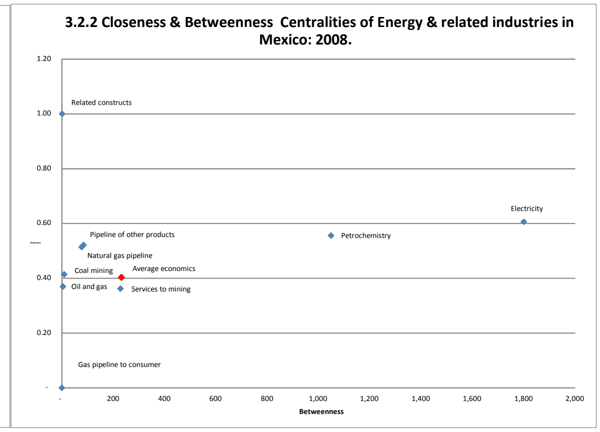
This chart shows the mass media and ITC industries. The branches with the highest degree are Newspaper and printed publications, computing and hosting, and Wired telecommunications. Newspaper and printed publications decrease through the time.

A second group is composed of the following industries: Wireless telecommunications, Other communications, Other information services and Computing and hosting, which increases its connections with the rest of the economy Wired telecommunications is connected with approximately 100 nodes in every period.

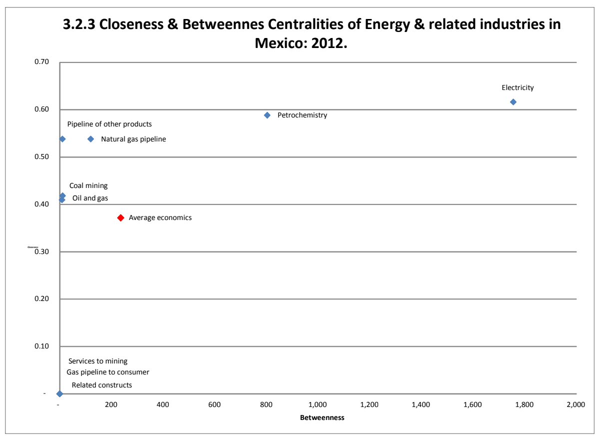
3.2 Betweenness and Closeness Centrality



3.2.1 Closeness & Betweenness Centralities of Energy & related industries in Mexico: 2003.



3.2.2 Closeness & Betweenness Centralities of Energy & related industries in Mexico: 2008.



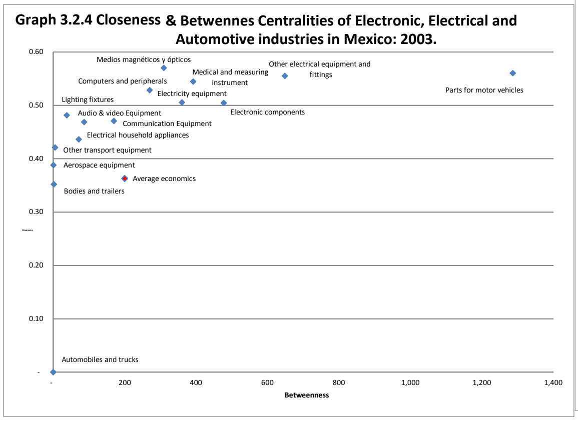
3.2.3 Closeness & Betweennes Centralities of Energy & related industries in Mexico: 2012.

The Graphics 3.2.1, 3.2.2 and 3.2.3 show the results for the closeness centrality and betweenness centrality for the energy sector. In 2003, 2008 and 2012 the sectors with greater centrality in both measures are the Electricity and Petrocemistry.

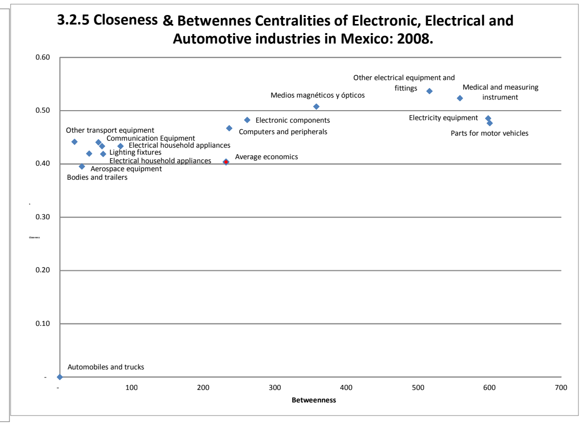
Followed by Pipeline of other products, Natural gas pipeline Coal mining, and to a lesser extent Oil and gas. These industries show higher than average values in your nearness and generally below average values in your betweenness measure.

Therefore, power energy sector that interacted with the different energy sectors, so the energy is consumed more electricity. The same trend holds for 2008 and 2012, electricity is best positioned within the economy. Another area highlight is the petrochemicals, which also meets high closeness centrality both as betweenness, well, we can see that this sector is of paramount importance in industrial production.

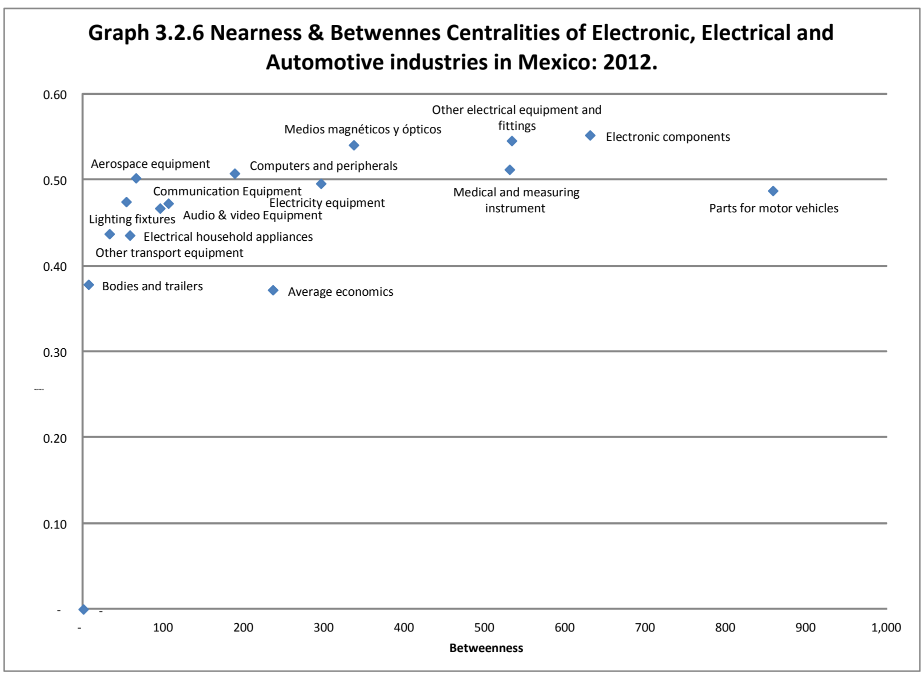
In the following graphs (3.2.4, 3.2.5 and 3.2.6) we present the measures of closeness and brokerage of Electronics, Electrical and automotive industries.



Graph 3.2.4 Closeness & Betwennes Centralities of Electronic, Electrical and Automotive industries in Mexico: 2003.



3.2.5 Closeness & Betwennes Centralities of Electronic, Electrical and Automotive industries in Mexico: 2008.

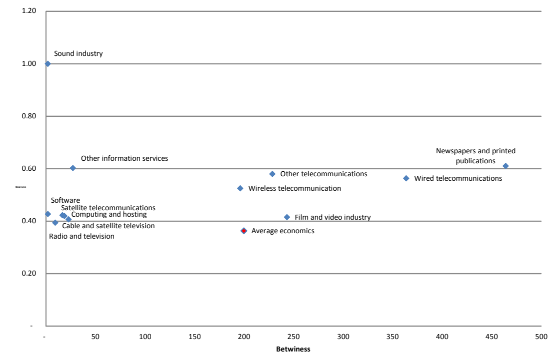


Graph 3.2.6 Nearness & Betwennes Centralities of Electronic, Electrical and Automotive industries in Mexico: 2012.

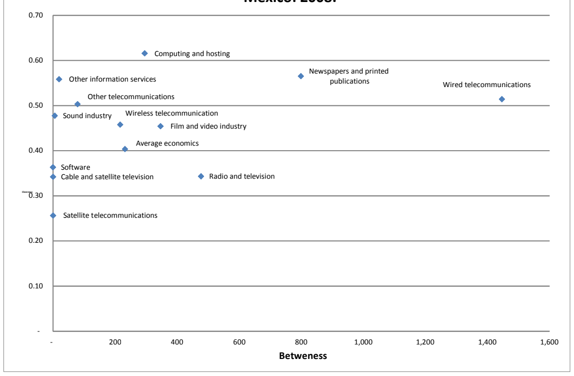
For the analysis of closeness and betweenness centrality for there are several sectors with high values. For 2003 do best positioned in the two types of centrality is: Auto parts sector, Electronic components, Medical and measuring instruments, Other electrical equipment and fittings, Computers and peripherals and Electric equipment. There are also other sectors that have a high value of centrality by proximity, most concerning electronic and medical instruments, and electrical equipment. For 2008 the auto parts sector remains a very relevant and being the other electrical equipment the highest centrality along with medical instruments. Therefore we can see that there was a change in the economic structure within these sectors, where electronic industries are more embedded in the economy that preserves auto parts.

In the following graphs (3.2.4, 3.2.5 and 3.2.6) we present the measures of closeness and brokerage of Mass media and ITC industries.

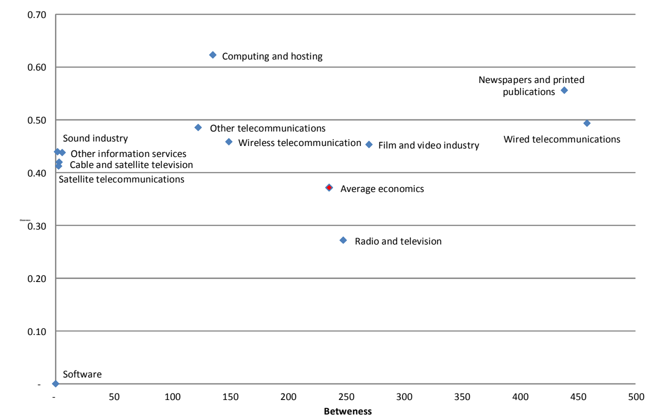
Graph 3.2.7 Closeness & Betweenness Centralities of Mass media and ITC industries in Mexico: 2003.



Graph 3.2.8 Closeness & Betweenness Centralities of Mass media and ITC industries in Mexico: 2008.



Graph 3.2.9 Closeness & Betwennes Centralities of Mass media and ITC industries in Mexico: 2012.



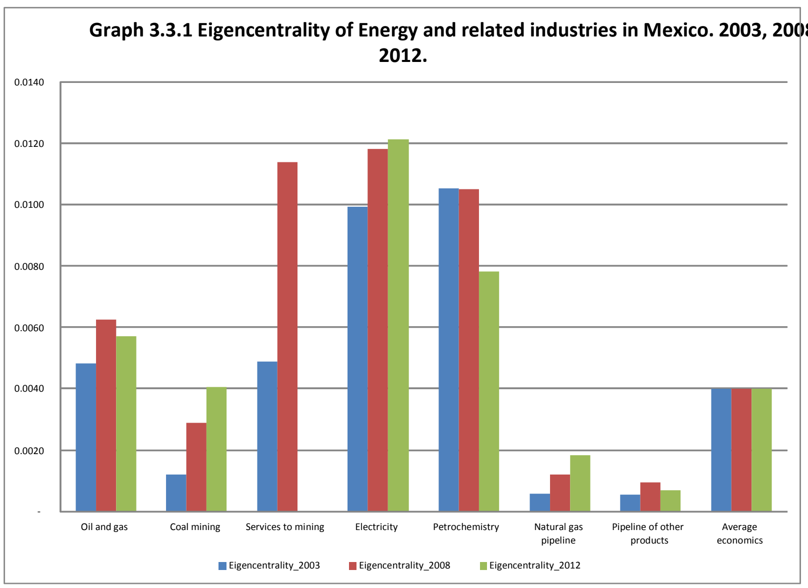
The most important branches for their nearness and betweenness measures are: Newspapers and printed publications, Wired telecommunications and Film and video industry. A second group is composed of the following industries: Computing and hosting, Other telecommunications and Wireless telecommunications. These sectors have a higher value of closeness that betweenness.

The most important branches e see that for 2003 the newspapers and publications sector is showing a better closeness centrality both as intermediary. For 2008 the sector has the greatest centrality is the computer. This goes hand in hand with technological advances, where newspapers can be consulted from the web without having to buy physical.

The other sectors show a level above the average in their nearness, but a low value of their intermediation capacity, these are: Sound industry, Other information services, Cable and satellite television Satellite communications and Software.

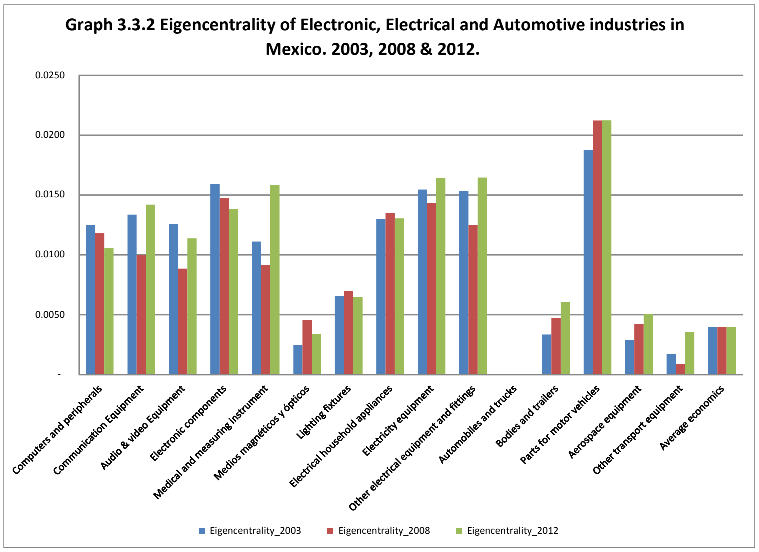
3.3 Eigenvector centrality

In the following three Graphs we show the results for eigencentrality measures for each of the groups of industries selected.

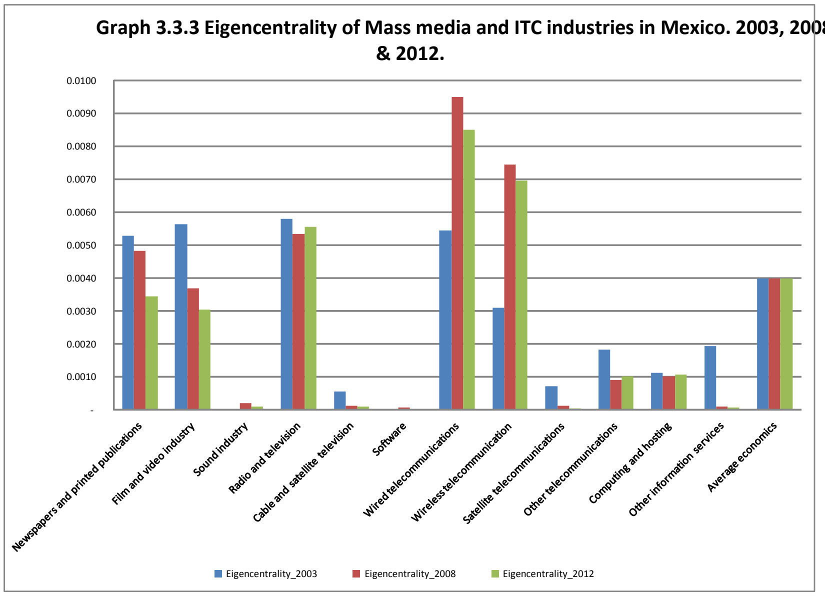


The eigenvalue centrality for the electricity sector remains the one with the highest value. Thus, not only it is connected to many industry sectors, but these in turn are with good links in the economy. This may be due more to the power sector interacts with most sectors, a key position in strategic sectors. In the other hand, the Petrochemical sector also have a good linkages with the other sectors, but with over the years the connection with the economy it is weaker.

Another sector is above average is Oil and gas.



The centrality by eigenvalue differs results of closeness and betweenness centrality. Here, auto parts holds the top position for this three years, this means that although the auto parts sector has the highest centrality, this contains links with key sectors of the economy, so the auto parts sector is relevant in of the Mexican economy. Other sectors with important links are that referring to electricity, like Electricity equipment, Electrical household appliances and Electronic components. This is consistent with the results found for the energy sectors, where the energy more used in the economy is the electricity.



The centrality by eigenvalue for telecommunications remains the same behavior as for closeness centrality and betweenness centrality. In 2003 newspapers, radio and television are the sectors that interact in the economy; However for 2008 and 2012 the sectors that connect key sectors are the communications cable and the signals are not wired like the Internet or cell phones. It being understood that technological advances are essential to position these sectors.

Conclusions

Network analysis applied to the input-output is a powerful tool in the classification of key industries if we consider the qualities of interconnection of industries, as well as the ability to flow effects to shocks.

First highlights the importance of industries where high levels of centrality match all measures, as Electricity and Petrochemistry in the first group.

In second group they include Manufacture of automotive parts, Other electrical equipment. The sectors that follow them are Electricity equipment, Computers and peripherals, Electronic components, Medical and measuring instruments and Communication Equipment.

In the third group the most centrality sectors are Newspaper and printed publications, computing and hosting, and Wired telecommunications.

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