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The electronics, computing, telecommunications and mass media sectors in the sectoral structure of the Mexican economy in 2008: a focus on graph theory in input-output analysis.

Category: Input-output and the network theory

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ABSTRACT

This text analyzes the Mexican economy with information from 2008, using the input-output matrix from the perspective of network theory, to find properties that are hidden in the traditional analysis of Leontief ´s matrix. In this way, we identified all sectors with great effect on the demand and supply system and therefore, they constitute the basis for the economic growth and development. In particular we will find how the Electronic, Information, Communication Technologies and Mass Media sectors (E&ICT-MM) in Mexico are positioned, and the role they play in relation to other sectors in 2008, whether in a relationship of domestic and foreign markets, using indexes, measures and other network analysis tools. Some of the measures assessed by these systems are: degree of influence, centrality and cohesion of the different sectors. With these tools we make an approximation to understand the performance and Interconnection of these sectors in the economy of Mexico. Centrality measures, or at least popular interpretations of these measures, make implicit assumptions about the manner in which traffic flows through a network.

Keywords: Structural analysis; Input-Output; Graph Theory.

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1. INTRODUCTION

The input-output tables (IOT) are an accounting description integrated by purchases (intermediate and factor inputs) and sales (products whose destination are intermediate demand and final demand), which define the inter-industry structure of a system economic. Meanwhile the input-output model allows introducing hypotheses that characterize the interdependence of economic sectors and those with institutional sectors.

The traditional input-output model proposed by Leontief allows quantification of the coefficients that define the relations between sectoral variables, and by the Leontief inverse matrix we can know the direct and indirect production requirements needed to generate a unit of final demand, that is to say, we can know the value of linkages and impacts caused from a sector above the production of others (backward linkages) and the influence of demand for different sectors on a particular sector (forward linkages); with this we can classify the key industries based on the value of such linkages .

However, traditional analysis is incomplete when you want to perform further analysis on the influence, circularity, hierarchy and centrality relations of certain sectors, which can be known from qualitative analyzes such as Graph Theory, as it makes perceptible certain properties of the structures contained in IOT, which are not shown in the traditional input-output analysis and calculation of linkages.

The objective of this work is to apply graph theory to the analysis of the corresponding IOT for Mexico to 2008 (domestic, total and imported inputs), in order to perform a qualitative study on the inter-industry structure of the Mexican economy and highlight a characterization of Electronics, Information, Communications Technologies and Mass Media industries (E&ICT-MM), which are the economic basis of the dynamics of the new phase of development in the global economy guided by the called Knowledge Economy (KE).

First, the traditional input-output model is exposed and the calculations of backward and forward average linkages inspired Hirschman-Rasmussen approach are shown, and based on it we present a classification of key industries for the E&ICT-MM sector.

Then, an introduction to graph theory applied to the analysis of the IOT is presented, and thus some of the main qualitative indicators are defined, the first results are compared with the classification of traditional analysis of key industries.

The third chapter is devoted to presenting and discussing the results of indicators that define the hierarchy and centrality relations that are relevant to the focus of Graph Theory.

Finally, conclusions are presented.

2. TRADITIONAL ANALYSIS OF AVERAGE LINKAGES AND KEY INDUSTRIES CLASSIFICATION

The traditional quantity input-output model proposed by Leontief based in demand, implies the following system of linear equations:

(1) $x = Z^N \iota + f^N$

Where x=vector of sectorial gross production; Z^N = matrix of domestic intermediate inputs; f^N = vector of domestic final demand components; ι = unit vector.

If we incorporate the Leontief hypothesis about the existence of a fixed coefficients matrix of intermediate inputs of domestic origin per unit of production:

(2) $A^N = Z^N \hat{x}^{-1}$

We have the solution for the quantity model given by the demand:

(3) $x = (I - A^N)^{-1} f^N = L^N f^N$

Where L^N is the Leontief inverse matrix for domestic inputs.

In order to contrast the linkages given by the domestic intermediate inputs (incorporating imports) we define the model of total demand:

(4) $x + m = Z^N \iota + Z^M \iota + f^N + f^M = Z^T + f^T$

Where imports $m = Z^M \iota + f^M$ are resulted of the sum of import intermediate inputs plus imported final demand. We generalize Leontief hypothesis (Equation 2) for total intermediate inputs (domestic and plus imported), then: $A^M = Z^M \hat{x}^{-1}$ and $A^T = Z^T \hat{x}^{-1}$, and we have a solution for the model of total demand,

(5) $x + L^T m = L^T f^T$

Where $L^T = (I - A^T)^{-1}$ is the Leontief inverse for total inputs (domestic plus imported).

Now we define backward and forward average linkages (Hirschman -Rasmussen), both for the traditional model of demand and for the total demand, as the average of the industry, relative to the average of the economy, they are represented in Table 1.

Table1: Hirschman-Rasmussen average rate linkages		
MODEL	**Dispersion indices (backward linkages average)**	**Sensibility indices (forward linkages average)**
Domestic inputs	$U_d^N = \iota' L^N \frac{n}{\iota' L^N \iota}$	$U_s^N = L^N \iota \frac{n}{\iota' L^N \iota}$
Total inputs (domestic plus imported)	$U_d^T = \iota' L^T \frac{n}{\iota' L^T \iota}$	$U_s^T = L^T \iota \frac{n}{\iota' L^T \iota}$

The classification of key industries considered simultaneous value of both average indices, it ranging around one in both cases, according to Table 2.

Table 2: Key industries classification			
Key industry	Driving industry	Driven industry	Relatively disconnected industry
$U_d > 1; U_s > 1$	$U_d > 1; U_s < 1$	$U_d < 1; U_s > 1$	$U_d < 1; U_s < 1$

Calculations for average dispersion and sensitivity indices for domestic input and for total inputs (domestic plus imported) of E%ICT-MM sectors are presented in Chart 1, which allows us to arrive at a classification of key industries in Chart 2.

Chart 1: Average Index values of dispersion and sensibility to the national and total inputs. E&ICT-MM; 2008.					
SCIAN	DESCRIPCIÓN	2008		2008	
		$U^N d$	$U^N s$	$U^T d$	$U^T s$
3341	COMPUTERS AND EQUIPMENT	0.76	0.72	1.95	1.10
3342	COMMUNICATIONS EQUIPMENT	0.72	0.70	2.11	1.50
3343	AUDIO AND VIDEO EQUIPMENT	0.70	0.66	2.04	1.16
3344	ELECTRONIC COMPONENTS	0.85	0.67	1.94	3.17
3345	MEASURING INSTRUMENTS	0.76	0.69	1.36	1.07
3346	MAGNETIC MEDIA AND OPTICAL	0.80	0.69	1.67	0.81
5111	NEWSPAPERS AND MAGAZINES	1.01	1.04	0.87	0.82
5112	SOFTWARE	0.78	0.66	0.64	0.50
5113	FILM AND VIDEO	1.12	0.99	1.05	0.76
5122	SOUND INDUSTRY	0.88	0.72	0.83	0.55
5151	RADIO AND TELEVISION	1.13	0.68	1.01	0.52
5152	CABLE TV AND SATELLITE	1.25	0.66	1.05	0.51
5171	WIRED TELECOMMUNICATIONS	0.86	2.20	0.83	1.90
5172	WIRELESS TELECOMMUNICATIONS	0.84	1.49	0.96	1.26
5174	SATELLITE SERVICES	0.83	0.68	0.79	0.52
5179	TELECOMMUNICATIONS SERVICES	0.96	0.87	0.82	0.68
5182	COMPUTERS AND WEB	0.97	0.74	0.80	0.58
5191	OTHER INFORMATION SERVICES	1.07	0.69	0.87	0.53

Table 2: Ranking of key Industries of national and total inputs of the E&ICT-MM industries: 2008.			
SCIAN	DESCRIPCIÓN	MID	MIT
		2008	2008
3341	COMPUTERS AND EQUIPMENT	DiSCONNECTED	KEY
3342	COMMUNICATIONS EQUIPMENT	DiSCONNECTED	KEY
3343	AUDIO AND VIDEO EQUIPMENT	DiSCONNECTED	KEY
3344	ELECTRONIC COMPONENTS	DiSCONNECTED	KEY
3345	MEASURING INSTRUMENTS	DiSCONNECTED	KEY
3346	MAGNETIC MEDIA AND OPTICAL	DiSCONNECTED	DRIVING
5111	NEWSPAPERS AND MAGAZINES	KEY	DiSCONNECTED
5112	SOFTWARE	DiSCONNECTED	DiSCONNECTED
5113	FILM AND VIDEO	DRIVING	DRIVING
5122	SOUND INDUSTRY	DiSCONNECTED	DiSCONNECTED
5151	RADIO AND TELEVISION	DRIVING	DRIVING
5152	CABLE TV AND SATELLITE	DRIVING	DRIVING
5171	WIRED TELECOMMUNICATIONS	DRIVEN	DRIVEN
5172	WIRELESS TELECOMMUNICATIONS	DRIVEN	DRIVEN
5174	SATELLITE SERVICES	DiSCONNECTED	DiSCONNECTED
5179	TELECOMMUNICATIONS SERVICES	DiSCONNECTED	DiSCONNECTED
5182	COMPUTERS AND WEB	DiSCONNECTED	DiSCONNECTED
5191	OTHER INFORMATION SERVICES	DRIVING	DiSCONNECTED

Average indices of Hirschman-Rasmussen linkages have been undergoing a series of reviews, because its value varies according to the level of aggregation and they do not consider the scattering of its values, however, however they are a first indicator about backward and forward average linkages.

Classification of key sectors on E&ICT-MM industries is presented in Chart 2, the following results were observed:

- The electronic industry is composed of the first six branches (3341-3346), in them the structural change is shown immediately; for domestic inputs all branches are relatively disconnected from the domestic economy on their average backward and forward linkages (standing on a low level in both indicators, it is 0.52 for totally disconnected industries); however, when considering the total inputs (domestic and imported) these industries are positioned such as key industries with higher average rates (with the exception of 3346 industry which becomes driving). This reflects a pattern of outward integration in providing of imported inputs, it is a characteristic of linked industry to assembly export strategy (maquiladora industry).

- Wired and wireless Telecommunications, dominated by wireline and wireless telephony correspondingly, are activities that are strongly dominated by the demand coming from other activities, although wireless telecommunications will receive a slight boost from the external sector in the provision of imported inputs; on their own, Satellite services, Other telecommunications services, Computing and Web services and Other information services are branches that are relatively disconnected from the domestic economy and particularly little influenced by demand from other industries.

- The Newspapers and magazines, Software and Sound Industry branches are relatively disconnected (although the first is placed at the key industry if we consider only domestic inputs), while the second and third receive little influence from other industries demand. The video and film industries, Radio and Television and Cable and Satellite Television are classified as drivers, with significant backward average linkages; while for the latter two, there are weak effects from demand from other industries in their average values for total inputs.

3. 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 $X \cdot X$, 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:

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

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

The incidence matrix came from transforming IOT 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.

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). If $d^+ (x_i) = 0$, it is a well vertex. 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 incidence matrix), if $d^- (X_i) = 0$ is a source vertex and 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 degree of integration or the degree of influence is given by: $d = \frac{d^+(x_i)}{d^-(x_i)}$, if it is greater than one, it means the industry is more seller than buyer and vice versa.

The results of the out-degree [$d^+ (X_i)$], in-degree [$d^- (X_i)$], the grade [$d (x_i) = d^+ (x_i) + d^-$] and the degree of integration [d^+/d^-] are presented in Chart 3 in percentage terms, as a measure of density with respect to possible cases, which are respectively for semi-degree 250 (or possible connections) and 500 for the degree. This presentation allows better visualization of the indicators.

Cuadro 3: Out-degree (*d+*), In-degree (*d-*), Degree (*d*) and Degree of integration (*d+/d-*) of E&ICT-MM, for the domestic inputs (MIN), total inputs (MIT) and imported inputs (MIM): 2008.

SCIAN	RAMA	MIN 2008	MIT 2008	MIM 2008	MIN 2008	MIT 2008	MIM 2008	MIN 2008	MIT 2008	MIM 2008	MIN 2008	MIT 2008	MIM 2008
		d^+	d^+	d^+	$d-$	$d-$	$d-$	$d=(d^++d^-)$	$d=(d^++d^-)$	$d=(d^++d^-)$	d^+/d^-	d^+/d^-	d^+/d^-
3341	COMPUTERS AND EQUIPMENT	94%	94%	45%	82%	84%	30%	88%	89%	38%	1.14	1.11	1.47
3342	COMMUNICATIONS EQUIPMENT	91%	92%	41%	79%	80%	30%	85%	86%	35%	1.16	1.14	1.39
3343	AUDIO AND VIDEO EQUIPMENT	40%	57%	24%	79%	80%	29%	60%	68%	27%	0.51	0.71	0.84
3344	ELECTRONIC COMPONENTS	93%	93%	39%	78%	80%	34%	86%	87%	37%	1.18	1.16	1.13
3345	MEASURING INSTRUMENTS	87%	88%	47%	75%	78%	30%	81%	83%	38%	1.15	1.13	1.59
3346	MAGNETIC MEDIA AND OPTICAL	64%	74%	44%	78%	79%	26%	71%	76%	35%	0.82	0.93	1.70
5111	NEWSPAPERS AND MAGAZINES	99%	99%		79%	79%	10%	89%	89%	5%	1.25	1.25	-
5112	SOFTWARE	82%	82%		56%	56%	5%	69%	69%	2%	1.48	1.48	-
5113	FILM AND VIDEO	96%	96%		78%	78%	9%	87%	87%	4%	1.24	1.24	-
5122	SOUND INDUSTRY	61%	61%		54%	54%	6%	58%	58%	3%	1.13	1.13	-
5151	RADIO AND TELEVISION	67%	67%	0%	80%	80%	12%	74%	74%	6%	0.84	0.84	0.03
5152	CABLE TV AND SATELLITE	1%	1%		40%	40%	2%	21%	21%	1%	0.03	0.03	-
5171	WIRED TELECOMMUNICATIONS	99%	99%	0%	84%	84%	7%	92%	92%	4%	1.18	1.18	0.06
5172	WIRELESS TELECOMMUNICATIONS	94%	94%		85%	85%	6%	90%	90%	3%	1.11	1.11	-
5174	SATELLITE SERVICES	70%	70%	0%	46%	47%	4%	58%	58%	2%	1.50	1.49	0.11
5179	TELECOMMUNICATIONS SERVICES	99%	99%		68%	68%	5%	84%	84%	2%	1.46	1.46	-
5182	COMPUTERS AND WEB	89%	89%		63%	63%	2%	76%	76%	1%	1.41	1.41	-
5191	OTHER INFORMATION SERVICES	90%	90%		58%	58%	6%	74%	74%	3%	1.55	1.55	-

Chart 3 shows the following results:

- As to the 6 branches of the electronics industry the degrees of integration are high for Computers and equipment, Communications equipment, Electronic components and Measuring instruments, in domestic, imported and total inputs. That way it be classified as seller industries; while Measuring instruments and Audio & video equipment show lower incidence levels and they are buyers, also with high imported inputs.

- In a second group the wire and wireless telecommunications and other telecommunications services industries, show higher levels of incidence in both domestic and total inputs, and can be classified as seller industries; in a second group, Web and Other Computer and information services with intermediate levels of incidence are classified as sellers; even possess high degree of integration of imported inputs; Finally Satellite services has a lower level of incidence also as a sales branch. In all of them low incidence level is perceived in imported inputs, with the exception of Satellite telecommunications services and that tend to be buyer of imported inputs.

- About branches of Mass media, there are high levels of incidence, newspapers and magazines, and Film and video industry, with medium levels of impact the film and Software and Industry of sound, them all are sellers; finally, particularly with low incidence, Radio and television; and with less incidence, Cable and satellite TV are buyers.

With the incidence matrix we can construct the path matrix array (accessibility matrix). It provides information on the existence of the ways in which x_j is accessible to $x_{i.}$ Thus all vertices descendants from $x_{i.}$ are known as the transitive closure, which is defined as $\hat{f}$ (x_i) and we have:

$$\hat{f}(x_i) = \{\, x_i \; u \; f(x_i) U \, f^2(x_i) \; U \; \dots \}$$

The path matrix *R (D)* is an array of elements r_{ij} such that:

$$r_{ij} = 1, \qquad sii \; x_j = \hat{f}\,(x_i)$$

$$r_{ij} = 0, \qquad sii \; x_j \neq \hat{f}\,(x_i)$$

The connectivity matrix shows what kind of connection exists between two vertices of the graph if there is one-way if there are two directions (circuit) or if they are not linked. The elements C_{ij} are obtained from the path matrix. Note that in a input output matrix, of each vertex is both their own offspring (loop on each element of the main diagonal).

The connectivity matrix shows the type of connection between two vertexes, if in one or both directions, forming a circuit. If $r_{ij}= r_{ji}= 1$ then they are strongly connected components.

If all vertices of the graph satisfy this condition (all vertices are mutually accessible) the graph is strongly connected.

In order to calculate the feature centrality of the various sectors, it defines the outer separation as $e^{+}_{(i)} = Max\ e_{ij}$, and inner separation as $e^{-}_{(j)} = Max\ e_{ij}$, where a sector has more influence as is lower the outer separation, and receives more influences the lower is inner separation. Additionally centrality indices ($c^{+}_{=}$ influent sector), anti centrality (c^{-}=sector affected) and the overall net influence separation *D* (ratio of both) are defined. Among smaller *D* means that the sector is influenced more influential.

$$c_i^{+} = \frac{\sum_i \sum_j e_{ij}}{\sum_j e_{ij}}$$

$$c_i^{-} = \frac{\sum_i \sum_j e_{ij}}{\sum_i e_{ij}}$$

$$D_i = \frac{c_i^{+}}{c_i^{-}}$$

Calculations for centrality index are defined in Chart 4:

Table 4: Summary of centrality indexes, outer and inner, central, and overall net uncentrality; domestic, total and imported inputs. 2008.

SCIAN	DESCRIPCIÓN	MIN 2008			MIT 2008			MIM 2008		
		c+	c-	c+/c-	c+	c-	c+/c-	c+	c-	c+/c-
3341	COMPUTERS AND EQUIPMENT	269.76	264.72	1.02	269.11	270.14	1.00	134.02	322.49	0.42
3342	COMMUNICATIONS EQUIPMENT	263.74	257.05	1.03	264.09	260.21	1.01	130.96	318.51	0.41
3343	AUDIO AND VIDEO EQUIPMENT	179.16	257.05	0.70	199.37	258.31	0.77	118.34	316.55	0.37
3344	ELECTRONIC COMPONENTS	267.72	256.12	1.05	268.09	260.21	1.03	129.00	343.99	0.38
3345	MEASURING INSTRUMENTS	253.38	248.06	1.02	255.51	252.77	1.01	136.14	318.51	0.43
3346	MAGNETIC MEDIA AND OPTICAL	210.52	253.38	0.83	226.12	255.51	0.88	132.98	299.99	0.44
5111	NEWSPAPERS AND MAGAZINES	283.78	256.12	1.11	283.10	255.51	1.11	-		
5112	SOFTWARE	244.64	211.78	1.16	244.06	211.27	1.16	-		
5113	FILM AND VIDEO	276.05	254.29	1.09	275.39	253.68	1.09	-		
5122	SOUND INDUSTRY	206.24	209.28	0.99	205.74	208.78	0.99	-		
5151	RADIO AND TELEVISION	215.64	260.83	0.83	215.12	260.21	0.83			
5152	CABLE TV AND SATELLITE	143.33	189.70	0.76	142.98	189.24	0.76			
5171	WIRED TELECOMMUNICATIONS	284.92	270.79	1.05	284.24	270.14	1.05			
5172	WIRELESS TELECOMMUNICATIONS	271.82	271.82	1.00	271.17	271.17	1.00			
5174	SATELLITE SERVICES	220.33	198.17	1.11	219.80	198.25	1.11			
5179	TELECOMMUNICATIONS SERVICES	284.92	232.61	1.22	284.24	232.05	1.22			
5182	COMPUTERS AND WEB	258.93	224.51	1.15	258.31	223.97	1.15			
5191	OTHER INFORMATION SERVICES	261.79	215.64	1.21	261.17	215.12	1.21			

The results show a high centrality for all sectors except: Audio and video equipment, Magnetic and optical media, Sound industry, Radio and television, and Cable and satellite television. The most influential sectors were: Other telecommunications services, Other information services, Editing Software, Satellite Services, Computing and Web, Publishing of newspapers and magazines; and less Wired and wireless telecommunications, Computers and equipment, Communications equipment, Electronic components, Measuring instruments and Film and video industry .

Finally, interdependence topological indicators are based on the distance matrix. This index is an inverse function of the separation of the vertices of the graph: a greater distance between them, the connection will be the weaker.

$$R= \frac{1}{n(n-1)} \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{1}{eij} = \frac{1}{n(n-1)} \sum_{i} \sum_{j} \frac{1}{eij} + \frac{1}{n(n-1)} \sum_{i} \sum_{j} \frac{1}{eij} = DR + IR$$

DR = Direct relations, Indirect Relations IR e_{ij}=1 e_{ij}≠0

The maximum value of R = 1 and is given when all indices are connected, e_{ij}=1 for all $i \neq j$. Then the structure will be completely interdependent. If its minimum value is zero, it means that all vertices are isolated and then $e_{ij} = \infty \ \forall i \neq j$. R consists of two summands, DR and IR. If RD are stronger, the links will be stronger.

Table 5 shows the degree of cohesion of the whole economy with respect to the TIO for total domestic and imported inputs :

Table 5: Topological Indicators
MIN, MIT y MIM. 2008.

IO-Table	RD	RI	R
MIN 2008	0.753	0.095	0.848
MIT 2008	0.755	0.094	0.849
MIM 2008	0.138	0.152	0.290

Table 5 contains the results about the cohesion indicators which show high cohesion for the economy as a whole, underlining the important of Direct Relations, without significant differences between the domestic inputs and total inputs, the cohesion obtained by imports has a considerable weight.

3. CONCLUSIONS

The qualitative indicators given by Graph Theory contrast sharply with the results of analysis of quantitative linkages from the traditional approach, because while the electronics industry linkages are important in the classification of key industries, and these are confirmed by the qualitative indices of connectivity, centrality is given especially for services, particularly by the following branches: Other telecommunications services, other information services, Editing Software, Satellite

Services, Computig and Web, Publishing of newspapers and magazines; and less wired and wireless telecommunications.

This work represents a first approximation of the qualitative analysis of the branches that make up the SE- IT- MM revealing the importance of a set of service industries that are crucial in the new development phase of capitalist knowledge, while reinforcing the hypothesis of a high depth of the branches of the electronics industry that are tightly integrated to the external sector in the provision of import intermediate inputs.

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