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An Economic Network in North America

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Abstract: Economic structures can be studied as networks of industries linked through flows of commodities that - in turn - the consuming sectors use as inputs. The Input-Output (IO) model is a suitable framework for analysing those structures, because its main target is the study of interdependence between sectors. In this paper we use a North American multi-region IO table in order to identify an economic regional network that results from a subset of the links between sectors in the countries involved. Those are defined by the exchange of goods between industries. Further, a density measure is used as an indicator of the network complexity, explained by the integration level and shape between those economies. Our results show that the US is by far the most integrated economy in North America; it also determines the shape of the network structure. In contrast, Canada and Mexico maintain scarce direct relationships.

Keywords: Economic structure, economic network, Input-Output model, North America

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An Economic Network in North America

Qualitative Input-Output Analysis (QIOA) has been often employed to study economic structures; this methodology has yielded deep insights on the way industries interact within an economy (Czamanski and Ablas, 1979; Huriot, 1974; Campbell; 1975, Holub and Schnabl, 1985; Aroche, 1996). More recently, such analysis has been extended to construct networks, accepting concepts and methods originally developed in other social sciences (Semitel, 2006). Both the Input-Output (IO) model and Network Theory (NT) are mainly concerned with the structure of connections existing among the set of agents in the phenomenon under study (Leontief, 1951). The IO model is thus easily translated into a network framework: the technical coefficient matrix (**A**) provides information about the pattern of relationships between members of the structure (Aroche, 1996). Despite formal similarities between both approaches, it is important to stress that some particular assumptions valid for NT are not always suitable for IO analysis, due to specific premises each model is built on. For example, a social network can be symmetrical; not so an interindustry model, since IO relationships are always directed and not necessarily reciprocal —for instance, an industry i may demand inputs from another j, but j does not need to purchase materials from i or else those flows do not need to be of equal value.

Economic models are often demand driven, assuming that consumers influence the behaviour of producers (e.g., demand determines output size); in turn, consumers demand produced goods from firms, according to their needs, while producers demand also goods to use them as inputs in their production processes. Such interdependency between agents deepens as the system becomes more complex and agents specialise in the production of some good, to the point that every industry maintains direct and indirect relationships with each other and with each consuming unit. The system attains the maximum possible complexity.

The IO model is always related to some geographical area; originally the model was concerned with national economies (Leontief, 1951), but it was soon extended to study regional systems (Isard, 1951); a region can be understood as a state, province or city, as a group of states or provinces in one country or, finally, as a country within a set of interrelated countries.

As a consequence of the linear nature of the model, it is possible to attach various regional matrices in one array, when those regions are interrelated, else, to partition an IO matrix in a way that it reflects how regions interact, for example when different industries locate in specific regions in a country (Isard, 1951; Miller and Blair, 2009). In any case, the matrix will be useful to analyse the relations between industries within a region, but also the connections between industries in different regions. The economic features of the IO model will not change; multipliers and coefficients will be analogous in single or multiple regions models provided that industries remain the same (Miller and Blair, 2009).

Canada, the US and Mexico have tightened their economic relationships in recent decades (Curzio, 2009, Weintraub, 2004), therefore North America can be studied as a single economic area, i.e., as a supra-region comprising three national economies -or regions. Every economy can be regarded as a system of industries or sectors, related through flows of intermediate demand. At the same time, each sector in any country demands inputs from industries within the supra-region, as well as from producers located beyond such economic space, i.e. importing goods from the rest of the world. This paper analyses the North American economic structure and presents graphs of the fundamental substructructure, showing through a subset of the intesectoral connections, fundamental features of the economy. The regional IO model provides the theoretical framework to carry out that analysis; using methods and results of the QIOA it will be possible to find a network within the North American economic structure. The latter is further analysed to characterise the actual supra-regional economy.

The rest of the paper is organised as follows: Section 1 presents the regional model for North America. Section 2 discusses "important coefficients" as indicators of integration between multiple regions. Section 3 presents the database and the North American economic network, comparing also the three countries in the area. Finally, section 4 describes the network defined by the trade relationships between the three North American countries. It is expected that —to a large extent— the US economic structure will be shaping the North

American economy as a whole, owing to its relative size, as well as to its internal cohesion, which can also be explained by its higher level of development (Carter, 1970).

1. North America as an Economic Area

Canada and the US, on the one hand, and the US and Mexico, on the other, have been economic partners for decades. The intense exchange of merchandises and factors, the economic policies in each country, as well as the enforcement of a free trade agreement in 1994 comprising these three countries, among other facts, have been instrumental to make up a trilateral economic area (even if no intention of further formal or institutional integration has been conveyed by any of the partners). Such an economic structure will be studied with the aid of a regional IO model. To begin with, the vector of the North American (NA) output will be:

$$x^{NA} = \begin{bmatrix} x^C \\ x^U \\ x^M \end{bmatrix}$$

where $\mathbf{x}^C$, $\mathbf{x}^U$ and $\mathbf{x}^M$ are the output vectors of each country, Canada (*C*), the US (*U*) and Mexico (*M*). Those vectors will be of the same order, as they bear a uniform industrial classification. Sectoral outputs in each country can be expressed as:

$$
\begin{aligned}
x_i^C &= \left[z_{ii}^{CC} + z_{i(i+1)}^{CC} + \cdots + z_{ij}^{CC}\right] + \left[z_{ik}^{CU} + z_{i(k+1)}^{CU} + \cdots + z_{il}^{CU}\right] + \left[z_{im}^{CM} + z_{i(m+1)}^{CM} + \cdots + z_{in}^{CM}\right] + f_i^C \\
&\vdots \\
x_j^C &= \left[z_{ji}^{CC} + z_{j(i+1)}^{CC} + \cdots + z_{jj}^{CC}\right] + \left[z_{jk}^{CU} + z_{j(k+1)}^{CU} + \cdots + z_{jl}^{CU}\right] + \left[z_{jm}^{CM} + z_{j(m+1)}^{CM} + \cdots + z_{jn}^{CM}\right] + f_j^C \\
x_k^U &= \left[z_{ki}^{UC} + z_{k(i+1)}^{UC} + \cdots + z_{kj}^{UC}\right] + \left[z_{kk}^{UU} + z_{k(k+1)}^{UU} + \cdots + z_{kl}^{UU}\right] + \left[z_{km}^{UM} + z_{k(m+1)}^{UM} + \cdots + z_{kn}^{UM}\right] + f_k^U \\
&\vdots \\
x_l^U &= \left[z_{li}^{UC} + z_{l(i+1)}^{UC} + \cdots + z_{lj}^{UC}\right] + \left[z_{lk}^{UU} + z_{l(k+1)}^{UU} + \cdots + z_{ll}^{UU}\right] + \left[z_{lm}^{UM} + z_{l(m+1)}^{UM} + \cdots + z_{ln}^{UM}\right] + f_l^U \\
x_m^M &= \left[z_{mi}^{MC} + z_{m(i+1)}^{MC} + \cdots + z_{mj}^{MC}\right] + \left[z_{mk}^{MU} + z_{m(k+1)}^{MU} + \cdots + z_{ml}^{MU}\right] + \left[z_{mm}^{MM} + z_{m(m+1)}^{MM} + \cdots + z_{mn}^{MM}\right] + f_m^M \\
&\vdots \\
x_n^M &= \left[z_{ni}^{MC} + z_{n(i+1)}^{MC} + \cdots + z_{nj}^{MC}\right] + \left[z_{nk}^{MU} + z_{n(k+1)}^{MU} + \cdots + z_{nl}^{MU}\right] + \left[z_{nm}^{MM} + z_{n(m+1)}^{MM} + \cdots + z_{nn}^{MM}\right] + f_n^M
\end{aligned}
$$

with $i = 1 \ldots j, k = (j+1) \ldots l$ and $m = (l+1) \ldots . n$

$\mathbf{x}_i^C$ is the output value of Canada's sector *i*, it equals the sum of sales of goods to each sector (1, 2, ..., *i, ... j, k, ..., l, m, ..., n*), in Canada (*C*), the US (*U*) and Mexico (*M*), plus the sales to the Canadian final demand ($\mathbf{f}^C$). Likewise output value of sector *k* in the US and sector *m* in Mexico can be defined as $\mathbf{x}_k^U$ and $\mathbf{x}_m^M$, while final demand vectors will be, accordingly, $\mathbf{f}^U$ and $\mathbf{f}^M$. Hence, the system can be represented in matrix form as:

$$x^{AN} = Z^{AN}\,\iota' + f^{AN}$$

$\mathbf{Z}^{AN}$ is the matrix of transactions between industries in North America, which will be partitioned for the three countries taken into account, while $\mathbf{f}^{NA}$ is the supra-regional final demand vector, which will be partitioned likewise and ι' is a transposed unit vector that allows adding on the rows of the multiplying matrix $\mathbf{Z}^{AN}$. The latter and $\mathbf{f}^{NA}$ can be written in a partitioned way as:

$$
\mathbf{Z}^{NA} = \begin{bmatrix} \mathbf{Z}_{ij}^{CC} & \mathbf{Z}_{il}^{CU} & \mathbf{Z}_{in}^{CM} \\ \mathbf{Z}_{kj}^{UC} & \mathbf{Z}_{kl}^{UU} & \mathbf{Z}_{kn}^{CM} \\ \mathbf{Z}_{mj}^{MC} & \mathbf{Z}_{ml}^{MU} & \mathbf{Z}_{mn}^{MM} \end{bmatrix}
$$

and

$$\mathbf{f}^{\mathrm{NA}} = \begin{bmatrix} \mathbf{f}^{\mathrm{C}} \\ \mathbf{f}^{\mathrm{U}} \\ \mathbf{f}^{\mathrm{M}} \end{bmatrix}$$

Both the North American technical coefficient matrix ($\mathbf{A}^{\mathrm{NA}}$) and the Leontief inverse ($\mathbf{L}^{\mathrm{NA}}$) follow the standard definitions and can be arranged in accordance to the criteria used above; therefore, those matrices can be can be expressed as:

$$\mathbf{A}^{\mathrm{NA}} = \begin{bmatrix} \mathbf{A}_{\mathrm{ij}}^{\mathrm{CC}} & \mathbf{A}_{\mathrm{il}}^{\mathrm{CU}} & \mathbf{A}_{\mathrm{in}}^{\mathrm{CM}} \\ \mathbf{A}_{\mathrm{kj}}^{\mathrm{UC}} & \mathbf{A}_{\mathrm{kl}}^{\mathrm{UU}} & \mathbf{A}_{\mathrm{kn}}^{\mathrm{CM}} \\ \mathbf{A}_{\mathrm{mj}}^{\mathrm{MC}} & \mathbf{A}_{\mathrm{ml}}^{\mathrm{MU}} & \mathbf{A}_{\mathrm{mn}}^{\mathrm{MM}} \end{bmatrix}$$

and

$$L^{NA} = \begin{bmatrix} L_{ij}^{CC} & L_{il}^{CU} & L_{in}^{CM} \\ L_{kj}^{UC} & L_{kl}^{UU} & L_{kn}^{CM} \\ L_{mj}^{MC} & L_{ml}^{MU} & L_{mn}^{MM} \end{bmatrix}$$

Accordingly, the solution to the model is:

$$\mathbf{x}^{\mathrm{NA}} = (\mathbf{I} - \mathbf{A}^{\mathrm{AN}})^{-1}\mathbf{f}^{\mathrm{NA}} = \mathbf{L}^{\mathrm{NA}}\,\mathbf{f}^{\mathrm{NA}}$$

As has been stated above, sectors in a regional model can demand inputs either within their own region or outside of it. As a result, output changes in one region can cause output changes in another region, due to regional spillovers. In turn, part of such changes can spread to other regions and even return to the one that initiated the whole process. Growth can thus reinforce from region to region. Isard (1951) proposed to study the interregional multipliers in order to measure these effects; these, however, are beyond the scope of this paper.

2. Networks and Important Coefficients

Graph theory has been widely used in QIOA applications; these are concerned with the patterns of connections between sectors, rather than with their intensity, let alone the behaviour of agents. The economic structure is then depicted as a graph (G): industries become nodes and positive coefficients a_{ij} in matrix **A** are represented as arcs, stemming from demanding sectors i to t suppliers j. Then, G is a directed non-symmetrical graph or —properly— a digraph. In other words, G is attached to a non-symmetrical matrix of adjacencies **W**: if sector i demands inputs from j, it is said that i is adjacent to j and $w_{ij} \in \mathbf{W}$ equals 1. Matrix **A** is thus transformed into a Boolean —or binary— array, **W**, showing the liaisons between industries, regardless of their size.

Any IO table disaggregated into a meaningful number of sectors will contain a large amount of non-zero coefficients, so the graph associated to such a table will display a large number of connections between nodes, to the point of producing an unworkable diagram. It is advisable to pick a subset of the connections between industries in order to produce a meaningful graph. A few algorithms in the literature have been proposed in order to select such a subgroup (e.g. Czamanski and Ablas, 1979, Defourny 1982, Schnabl, 1995, Aroche, 1996). In a word, these algorithms suggest that coefficients complying with certain conditions are equalised to 1, while the rest become zero. Czamanski and Ablas (1979) suggest selecting those entries in **A** that are larger than certain number —taken as a filter ϕ. Such a formula, however, has been widely criticised because "the largest" coefficients are not always the most significant; alternative and more sophisticated algorithms follow different criteria to pick a subset of relevant liaisons, according to each of the targets of each study, or rather, according to some criteria of "relevance". Nevertheless, they all eliminate information contained in the original matrix; i.e. whenever a positive coefficient $a_{ij} > 0$ becomes $w_{ij} = 0$, two actually adjacent industries in **A** appear unattached in **W**, for which the structure related to **W** will be different from the original represented by **A**.

Further, in order to understand the whole model as a qualitative construction, a good point of departure is the well-known approximation to the inverse Leontief matrix as a power series of **A**:

$$(\mathbf{I} - \mathbf{A})^{-1} \approx \mathbf{A}^0 + \mathbf{A}^1 + \mathbf{A}^2 + \ldots + \mathbf{A}^n + \ldots$$

In terms of the liaisons between industries in the structure, $\mathbf{A}^0$ shows that each sector is related to itself; thus equalising the identity matrix. The positive entries in $\mathbf{A}^1$ show the direct connections between industries, or paths of length 1 between any two industries; $\mathbf{A}^2$ will contain the indirect connections between any two industries, mediated by some other sector (paths of length *2*) and so on. Therefore, the addition of the power series yields a matrix that shows the number of direct and indirect connections of any lenght between any two industries ($\alpha_{ij} \in \mathbf{L}$). Following this idea, the approximation to the matrix $(\mathbf{I} - \mathbf{A})^{-1}$ graphically as a power series of **W** (Aroche, 1996) has been also suggested:

$$(\mathbf{I} - \mathbf{W})^{-1} \approx \mathbf{W}^0 + \mathbf{W}^1 + \mathbf{W}^2 + \ldots + \mathbf{W}^n + \ldots$$

In principle, $(\mathbf{I} - \mathbf{W})^{-1} = [\omega_{ij}]$ is a binary array and if $\omega_{ij} = 1$, sectors *i* and *j* are connected by at least one path, either directly or indirectly. Leaving aside Boolean algebra, $\mathbf{W}^k$ shows the number of indirect paths of length *k* between any two industries and $(\mathbf{I} - \mathbf{W})^{-1}$ will show the total number of paths between any pair of industries. Nevertheless, if transforming matrix **A** into **W** causes loss of information, so will do the latter procedure; furthermore, filtering **A** in order to produce **W**, yields in fact different structures, since connected sectors in **A** appear disconnected in **W**. That may even induce inaccurate results.

H. Schnabl (1995) has proposed a method known as Minimal Flow Analysis (MFA), in order to build the relevant substructure, also avoiding the use of exogenous filter ϕ that might introduce arbitrary changes to the structure. In short, Schnabl suggests a model using the power series approximation of matrix $(\mathbf{I} - \mathbf{A})^{-1}$, as:

$$(\mathbf{A}^0 + \mathbf{A}^1 + \mathbf{A}^2 + \cdots + \mathbf{A}^n)\hat{\mathbf{f}}$$

Next, the author suggests building a filter ϕ using data within the model, for which he calls ϕ "endogenous" and whenever t ($\in$ Ak $\hat{\mathrm{f}}$) < ϕ, t = 0, otherwise t = 1. Further, those nonnegative elements are used to build binary matrices W on which the analysis of the relevant substructure of the economy is performed:

$$W \approx W^0 + W^1 + W^2 + \ldots + W^n$$

Vector **f** does not need to be the final demand, but any other variable relevant to the phenomenon under study; **W** shows then the way in which the impacts transmitted from that variable spread along the structure. However, de Mesnard (1995 and 2001) criticises this proposal, on the grounds that the technique provides no further information to that contained in the original technical coefficients table or the multipliers matrix; besides, it can be also demonstrated that since **A** is filtered at each step, Schnabl's method picks up just the largest coefficients.

Important Coefficients (ICs) have also been used to construct a relevant substructure of the economy (Aroche, 1996). Indeed, ICs appear whenever a technical coefficient a_{ij} that connects sectors i and j directly is –at the same time– one element of a large number of paths (of any length) linking sectors *i* and *j* indirectly (e.g. a_{gh}, a_{hi}, ...,a_{ij}, ..., a_{jk}, a_{kl}). The importance of a coefficient is directly related to the amount of paths it involves; it has to do with the structural position or the coefficient, rather than to its size (Schinkte and Stäglin, 1988). The proportion of ICs in the total has also been used as an indicator of the structure's complexity and more complex structures are expected to contain larger proportions of ICs, because they comprise more indirect connections between any two sectors (Carter, 1970, Försell, 1983). The complexity of the structure has also been interpreted as an indicator of the degree of development of the economy: i.e., more developed economies are expected to be more complex because industries are more highly specialised and therefore, each one will exchange goods more intensely with the rest of the sectors.

In order to identify ICs, Schinkte and Stäglin (1988) suggest that in the standard IO model that can be used to simulate output responses to changes in the variables:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$$

Instead of following the convention and assume that matrix **A** is fixed and **f** is variable, it is possible to take final demand as fixed and allow changes within each coefficient $a_{ij} \in \mathbf{A}$. This will also result in changes to the production level in a subset of sectors, related to industries i or j, due to the indirect liaisons between sectors that each coefficient implies. The more important a coefficient, the larger output variations it will cause in a larger number of industries; for that reason, coefficients can be classified according to the potential change they cause in output, assuming uniform variations in each coefficient. Such potentiality is measured by the sensitivity index (Forsell, 1983, Skolka, 1983) and it is expressed as:

$$r_{ij} = \frac{1}{a_{ij}\left[\propto_{ji} + \left(\propto_{ii}/x_i\right) x_j\right]}$$

where as usual, $a_{ij} \in \mathbf{A}$, α_{ji} and α_{ii} are entries in the inverse Leontief matrix; and x_i, x_j stand for output values in sectors i and j. It is customary to take as ICs those that when changing 20% cause changes in output of at least *1*%.

As explained above, if each important coefficient in **A** is made equal to *1* and the rest to zero, matrix **A** becomes **W**, which will be attached to a graph (*G*) that contains the core of the economic structure, i.e., showing the most complex connections between sectors. The analysis of *G* can be performed through graph theory indicators. For example, Harary (1969) and Gould (1988) measure density in a network as the number of arcs connecting the nodes in *G*. That is an absolute measurement, but a graph with more nodes may show a higher density compared to a smaller diagram, even if these are sparser. On the contrary, it can be suggested that the ratio of that sum to the size of the graph and to the maximum potential complexity in a complete graph[1] yields a measurement that allows direct comparisons between different graphs, even of different size. For matrix **W**, the total density (δ) in a network can be measured as:

$$\delta = \boldsymbol{\kappa} \, (n^2 - n)^{-1}$$

$$\kappa = \boldsymbol{\iota} \, \mathbf{W} \, \boldsymbol{\iota}'$$

ι is a sum vector column, **W** is the adjacency matrix, *n* stands for the order of the matrix (and thus, the size of *G*), κ is a scalar equal to the sum of positive entries in **W**, which is also the number of arcs in *G*. Indeed, in QIOA, loops (arcs going from one sector back to themselves) are not considered, because the analysis aims at intersectoral connections, so the main diagonal in **W** is nil. Therefore, $(n^2 - n)$ is the maximum number of possible arcs in a complete graph, with no loops. If there are n nodes perfectly interconnected in a directed graph, there will be n^2 arcs and there will be n entries on the null main diagonal. If *G* is complete, δ will be equal to *1*.

Density can be also split by the direction of the arcs in *G*; i.e. it is possible to define density by intermediate demand, which in graph theory language is called either the outdegree or indegree of each node (Harary, 1969). The outdegree density vector of *G* shows the amount of arcs through which each sector demands inputs to the economy, and thus influences other sectors. It is the number of arcs found on the columns of matrix **W** (**ιW**), relative to the maximum possible amount of arcs on the columns of **W**, provided the main diagonal of **W** is null:

$$\mathbf{d}^{O} = \boldsymbol{\iota} \, \mathbf{W} \, (n - 1)^{-1}$$

Conversely, the indegree vector will be:

$$\mathbf{d}^{I} = \mathbf{W} \, \boldsymbol{\iota}' \, (n - 1)^{-1}$$

[1] In a complete directed graph two arcs of opposite directions connect every pair of nodes.

and shows the complexity of the structure, considering the amount of arcs incident to each node in the graph; i.e., it shows how each sector is influenced by intermediate demand. Both $\boldsymbol{d}^o$ and $\boldsymbol{d}^i$ are also ratios over the total potential density; note that $\boldsymbol{\delta}$, $\mathbf{d}^o$ and $\boldsymbol{d}^i$ are vectors of order (n) and adding over each one of them yields the same scalar[2], but the meaning of each one is different. A sector showing higher density is better connected to the network or more integrated to the economy, while there can be sectors mainly connected by the intermediate demand they exert (outdegree) or by the intermediate demand they supply (indegree).

3. The North American Economic Network

The database used in this paper is a square IO table of the North American supra-region that puts together the IO tables of the three countries in North America and makes explicit the trade relationships by sector of origin and destiny existing within the area, as well as the commercial links that each industry in the North American area maintains with the rest of the world. This array derives from two sources: the OECD Input-Output Database, 2002 edition, which provides the 1997 tables for Canada and the US; the Mexican matrix being a 1996 update of the 1980 original. The OECD edition contains the IO matrices disaggregated into 42 industries; the Mexican table comprises 72 branches. All three matrices were aggregated to 32 uniform sectors; Table 1 shows the criteria employed to define those. The intermediate import matrices by country of origin have been estimated from the original import matrices, taking into account the proportion of imports by product and country of origin. Such proportions were taken from the World Trade Atlas, gathering the original information by product into 32 sectors, in accordance to the transactions tables. Imported intermediate services were estimated using national averages of intermediate imports by country of origin, since no data is available on the actual services trade.

Furthermore, the domestic transactions and import tables were originally valued in the corresponding national currency; imports by sector and country of origin were valued in current US dollars. Therefore, it was necessary to convert all data to a uniform currency, the US dollar was chosen, using the annual average exchange rates for the corresponding year

[2] $\Sigma\delta^O = \Sigma\delta^I = \delta$

(1.5 Canadian dollars to 1 US dollar and 7.9 Mexican pesos to 1 US dollar). Unfortunately, the resulting matrix turns out to be imbalanced, i.e. the sums across the columns are not equal to those across the rows, which can be explained by the manipulation of data and statistical discrepancies, among other reasons. The matrix was then balanced using a standard RAS algorithm.

Table 1
Aggregation criteria

	Agregated Industry	**Industries in the National IO Tables**		
		Canada	**USA**	**Mexico**
1	AGRICULTURE, HUNTING, FORESTRY AND FISHING	[1]	[1]	[1, 2, 3, 4]
2	MINING AND QUARRYING	[2]	[2]	[5, 6, 7, 8, 9, 10]
3	FOOD PRODUCTS, BEVERAGES AND TOBACCO	[3]	[3]	[11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23]
4	TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR	[4]	[4]	[24, 25, 26, 27, 28]
5	WOOD AND PRODUCTS OF WOOD AND CORK	[5]	[5]	[29, 30]
6	PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	[6]	[6]	[31, 32]
7	COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	[7]	[7]	[33, 34]
8	CHEMICALS EXCLUDING PHARMACEUTICALS	[8]	[8]	[35, 36, 37, 39, 40]
9	PHARMACEUTICALS	[9]	[9]	[38]
10	RUBBER AND PLASTICS PRODUCTS	[10]	[10]	[41, 42]
11	OTHER NON-METALLIC MINERAL PRODUCTS	[11]	[11]	[43, 44, 45]
12	IRON & STEEL	[12]	[12]	[46]
13	NON-FERROUS METALS	[13]	[13]	[47]
14	FABRICATED METAL PRODUCTS, EXCEPT MACHINARY AND EQUIPMENT	[14]	[14]	[48, 49, 50]
15	MACHINERY AND EQUIPMENT, N.E.C.	[15]	[15]	[51]
16	OFFICE AND ELECTRICAL MACHINARY	[16]	[16]	[52]
17	RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	[17, 18]	[17, 18]	[53, 54, 55]
18	MANUFACTURING NEC AND MEDICAL INSTRUMENTS	[19, 24]	[19, 24]	[56, 57, 58]
19	MOTOR VEHICULES, SHIPS AND BOATS, AIRCRAFT AND SPACECRAFT; AND ROAILROAD EQUIPMENT	[20, 21, 22, 23]	[20, 21, 22, 23]	[59]
20	ELECTRICITY, GAS AND WATER SUPPLY	[25]	[25]	[60]
21	CONSTRUCTION	[26]	[26]	[61]
22	WHOLESALE AND RETAIL TRADE; REPAIRS	[27]	[27]	[62]
23	HOTELS AND RESTAURANTS	[28]	[28]	[63]
24	TRANSPORT AND STORAGE	[29]	[29]	[64]
25	POST AND TELECOMMUNICATIONS	[30]	[30]	[65]
26	FINANCE, INSURANCE	[31]	[31]	[66]
27	REAL ESTATE ACTIVITIES	[32]	[32]	[67]
28	RENTING, MACHINARY ,COMPUTER, RESEARCH,	[33, 34, 35,	[33, 34,	[68]

	PUBLIC ADMINISTRATION PUBLIC AND PRIVATE HOUSEHOLDS	37]	35, 37]	
29	OTHER BUSINESS ACTIVITIES	[36]	[36]	[69]
30	EDUCATION	[38]	[38]	[70]
31	HEALTH AND SOCIAL WORK	[39]	[39]	[71]
32	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	[40, 41]	[40, 41]	[72]

Table 2A illustrates the resulting data ensemble. Going through the columns, one finds the internal transactions matrix (**Z**) for each country (*C, US*, and *M*, respectively), together with the intermediate imports made by each country from each of its partners and from the rest of the world. Adding over the columns, a total input table can be defined as well (domestic plus imported inputs). Further down, there appears a value added matrix (including three rows: compensation to employees, gross operating surplus and net taxes on production; and 32 columns: all the industries considered). Summing up the total inputs and the value added, a gross output value (GO) is thus solved. In an analogous fashion, an internal transactions table appears for each country on each row, showing the intermediate domestic sales to each industry. The other four matrices show exports by sector and country of origin (within North America and the rest of the world). These export matrices are, of course, the imports arrays found on each row: it is assumed that imports for the demanding industry equal exports for the supplier abroad. A final demand matrix is also determined, which is disaggregated by final demand source (household final consumption, non-profit institutions serving households, general government final consumption and gross fixed capital formation) and the 32 sectors. On the Rest of the World column, domestic transactions and value added accounts are missing; the sum across the column corresponds to exports from each country to the rest of the world. Similarly, the final demand account is absent from the row corresponding to this area. The sums across the rows are the total imported inputs from various countries and the rest of the world to each North American country. Matrix $\mathbf{Z}^{NA}$ corresponds to North America's internal transactions as a whole: it equals the sum of the domestic transactions in each country plus the exchanges between those ones in the economic area.

Table 2 A Trilateral IO Table for North America 1996												
	(A) Schematic Table						(B) The Output Composition (%)					
Exports / Imports	**C**	**US**	**M**	**ROW**	**FD**	**GO**	**C**	**US**	**M**	**ROW**	**FD**	**GO**
Canada (C)	Z^{CC}	Z^{CUS}	Z^{CM}	Z^{CW}	Y^{C}	X^{C}	29.82	0.65	0.71	22.76	4.38	8.02
United States (US)	Z^{USC}	Z^{USUS}	Z^{USM}	Z^{USW}	Y^{US}	X^{US}	15.96	39.94	19.19	67.50	95.52	87.93
Mexico (M)	Z^{MC}	Z^{MUS}	Z^{MM}	Z^{MW}	Y^{M}	X^{M}	0.43	0.29	28.43	9.74	0.10	4.05
Rest of the World (ROW)	Z^{WC}	Z^{WUS}	Z^{WM}			M^{NA}	8.56	1.99	6.40			5.65
Total inputs	Z^{C}	Z^{US}	Z^{M}			Z^{NA}	54.78	42.87	54.72			2.70
VA	VA^{C}	VA^{US}	VA^{M}			VA^{NA}	45.22	57.13	45.27			55.69
GO	X^{C}	X^{USA}	X^{MX}	E^{NA}	Y^{NA}	X^{AN}	100	100	100	100	100	100

Table 2B shows the column composition of the actual IO North American matrix (every column adds to 100). These figures call for some considerations on the economic structure of North America. First of all, for each country, domestic transactions are larger than imports; secondly, both Canadian and Mexican imports take larger output quotas (16% for Canada and 19% for Mexico), while these countries maintain their main trade liaisons within North America. Indeed, for the US, imports are a smaller share of gross output and imports from the rest of the World are larger than those coming from North America. Exports to the rest of the world are also heavily determined by the US (67.5% of the total for the supra-region). Likewise, the US proportion in terms of final demand and gross output is massive if compared to the rest of the countries. Going back to the columns by country, Canada and Mexico show similar proportions of valued added and intermediate input to gross output; while value added is higher in the US and intermediate inputs represent a lower proportion.

Concerning the disaggregated IO table, 292 ICs were found in the IO table for the North American area; 253 of these (i.e. 3.16% of the total 9216 entries) are located in the three domestic matrices, while 39 ICs are placed in intermediate trade matrices within North America. Therefore, no ICs correspond to intermediate imports from the rest of the world: those links are accessory to the regional relationships in terms of the composition of the productive structure. As a result of the distribution of ICs, Figures 1, 2 and 3 show the internal network of input exchange for each country; each arrow corresponds to a flow of input demand and a thick double-pointed connection corresponds to a reciprocal relationship between two industries.

Figure 1
The Canadian Economic Network

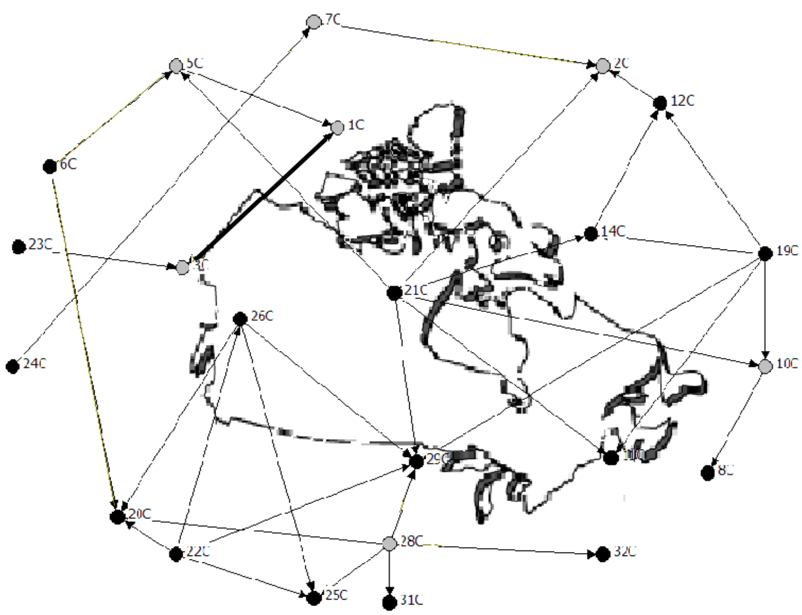


Figure 2
The US Economic Network

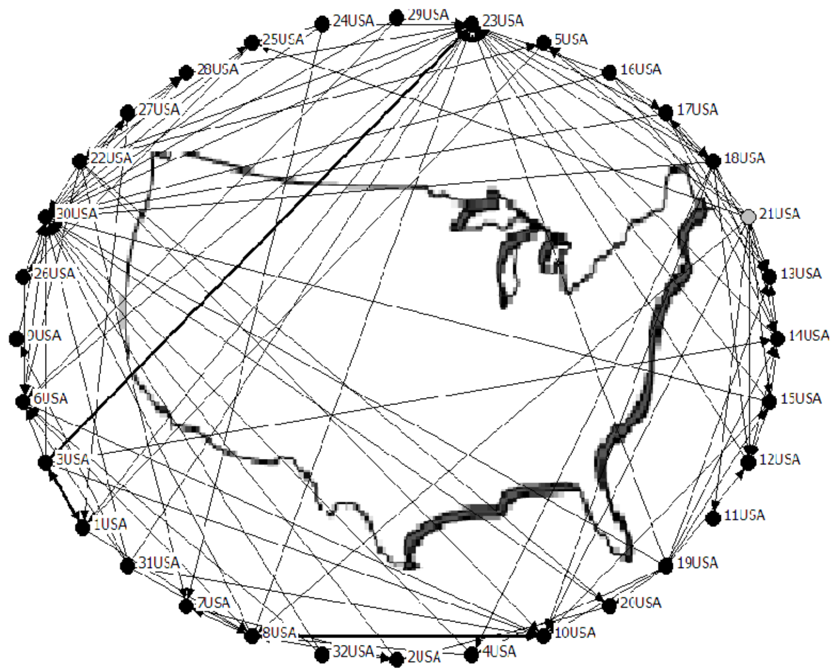
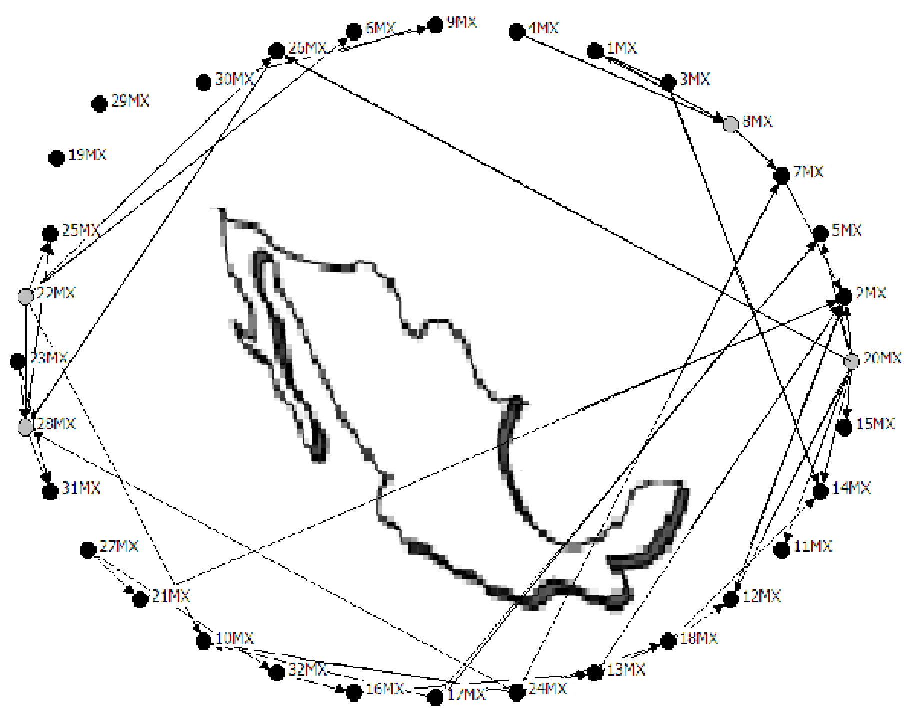


Figure 3
The Mexican Economic Network

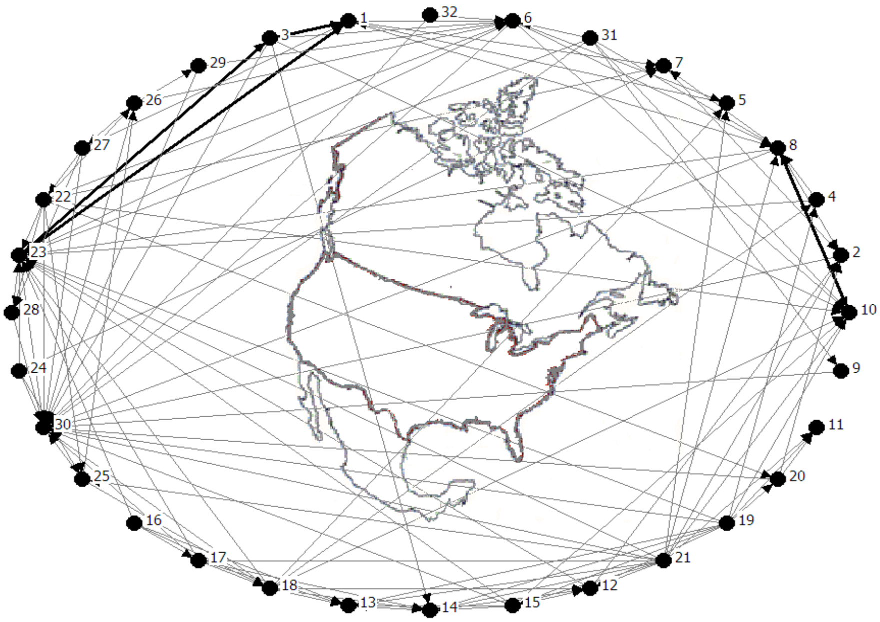


Sectors			
1	AGRICULTURE, HUNTING, FORESTRY AND FISHING	17	RADIO, TELEVISION AND COMMUNICATION EQUIPMENT
2	MINING AND QUARRYING	18	MANUFACTURING NEC AND MEDICAL INSTRUMENTS
3	FOOD PRODUCTS, BEVERAGES AND TOBACCO	19	MOTOR VEHICULES,SHIPS AND BOATS, AIRCRAFT AND SPACECRAFT; AND ROAILROAD EQUIPMENT
4	TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR	20	ELECTRICITY, GAS AND WATER SUPPLY
5	WOOD AND PRODUCTS OF WOOD AND CORK	21	CONSTRUCTION
6	PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	22	WHOLESALE AND RETAIL TRADE; REPAIRS
7	COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	23	HOTELS AND RESTAURANTS
8	CHEMICALS EXCLUDING PHARMACEUTICALS	24	TRANSPORT AND STORAGE
9	PHARMACEUTICALS	25	POST AND TELECOMMUNICATIONS
10	RUBBER AND PLASTICS PRODUCTS	26	FINANCE, INSURANCE
11	OTHER NON-METALLIC MINERAL PRODUCTS	27	REAL ESTATE ACTIVITIES
12	IRON & STEEL	28	RENTING, MACHINARY ,COMPUTER, RESEARCH, PUBLIC ADMINISTRATION PUBLIC AND PRIVATE HOUSEHOLDS
13	NON-FERROUS METALS	29	OTHER BUSINESS ACTIVITIES
14	FABRICATED METAL PRODUCTS, EXCEPT MACHINARY AND EQUIPMENT	30	EDUCATION
15	MACHINERY AND EQUIPMENT, N.E.C.	31	HEALTH AND SOCIAL WORK
16	OFFICE AND ELECTRICAL MACHINARY	32	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES

At first glance, it is clear that the largest proportion of ICs appears in the US internal IO table, which is also the economy that connects the whole economic area and it is known to be, by far, a more developed economy. The US chart shows one hundred and thirty eight (138) arcs; the Canadian one contains fifty four (54); and the Mexican one includes sixty one (61) arcs. The Canadian graph shows nine disconnected sectors; the Mexican one just two; and the US shows no disconnected industries. As a result, density accounts for 0.053 in the Canadian graph; 0.134 in the US; and 0.059 in the Mexican one. Surprisingly, the Canadian and Mexican economies show comparable levels of complexity, despite the well-known differences in *per capita* income and development levels.

Figure 4 shows the economic network for an aggregated North American economy containing 32 similar sectors. There are one hundred and forty five (145) arcs in the graph and ICs (out of 1024 coefficients in the matrix), which means that the density in the graph amounts to 0.142. This graph is more complex than any of the national ones considered above; yet, differences with the US figure are not big. This is equivalent to say that the US economy is supplemented by its trade partners, which is a consequence of the size gaps existing between them.

Figure 4
The North American Economic Network



Searching for indicators of the way each national structure is built, a feature to be taken into account is whether each of those makes up a solid block or contains a number of isolated or weakly connected subsystems—in the limit, each sector might be disconnected. According to Graph 2, there are seven cut-points in the Canadian network; i.e. if these sectors disappear, they split the graph into eight disconnected subgraphs or components. In the US, there is only one cut-point: sector 21 (construction)[3]. It is a sector that demands inputs from branch 11 (other non-metallic products) but, in turn, does not provide inputs to any other industry, so that the demise of sector 11 would isolate sector 21. In Mexico, there are four industries linking other sectors with the core of the system, for which they appear as cut-points in the graph: sector 8 (chemicals, excluding pharmaceuticals), 20 (electricity, gas and water supply), 22 (wholesale, retail and repairs) and 28 (renting machinery, computer research, public administration and public and private households); while sectors 19 (motor

[3] The construction sector often shows peculiar characteristics due to the statistical treatment of data; moreover this is a sector that may be considered as not selling intermediate goods.

vehicles, ships and boats, aircraft, spacecraft and railroad equipment) and 29 (other business activities) are the ones isolated in the domestic table. These results account for the complexity of each national graph: the Canadian network is the least integrated, although integration is far from solid in the Mexican one.

Table 3 shows the sectoral density of economic networks for the domestic transactions tables in each country and for North America as a whole. Density by sector indicates the degree to which each sector is integrated to the system as a whole. This can be paired to the study of the influence that each industry receives from the rest, through its incident arcs, or —conversely— by the influence each sector transmits through the arcs to the rest. Dependency is a close concept, although it is not used here, since this paper stresses the qualitative aspects of the IO model and does not present quantitative measures. In the Canadian network sectors with higher density by indegree are: 19 (motor vehicles, ships and boats, aircraft, spacecraft and railroad equipment), 21 (construction), 22 (wholesale, retail and repairs), 26 (finance and insurance) and 28 (renting machinery, computer research, public administration and public and private households). These five sectors are, at the same time, the largest output producers, thus being mainly input suppliers. Therefore, they are the sectors that receive the strongest influence through intermediate demand, measured here by the number of ICs incident to them. By outdegree, the denser sectors are: 2 (mining and quarrying), 20 (electricity, gas and water supply), 25 (posts and telecommunications) and 29 (other business activities). Sectors 2 and 29 are above the average size in terms of output; the rest are also large industries. It can be said that the most integrated sectors are at the same time the largest. Those are mainly input consuming sectors, in other words, they mainly transmit influence both to their input providers and to the whole economic structure through their demand for produced goods.

Table 3 Sectoral Density by Country									
Sectors		**North America**		**Canada**		**Estados Unidos**		**Mexico**	
		In	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
1	AGRICULTURE, HUNTING, FORESTRY AND FISHING	18.8	15.6	6.5	9.7	12.9	12.9	6.5	6.5
2	MINING AND QUARRYING	18.8	6.3	3.2	12.9	12.9	6.5	19.4	3.2
3	FOOD PRODUCTS, BEVERAGES AND TOBACCO	9.4	21.9	6.5	9.7	9.7	22.6	3.2	9.7
4	TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR	9.4	9.4	3.2	3.2	9.7	12.9	3.2	6.5
5	WOOD AND PRODUCTS OF WOOD AND CORK	12.5	6.3	6.5	9.7	12.9	6.5	9.7	3.2
6	PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	21.9	21.9	9.7	3.2	22.6	16.1	6.5	3.2
7	COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	15.6	6.3	6.5	6.5	12.9	6.5	9.7	6.5
8	CHEMICALS EXCLUDING PHARMACEUTICALS	21.9	18.8	3.2	6.5	22.6	19.4	9.7	6.5
9	PHARMACEUTICALS	6.3	6.3	0.0	0.0	6.5	6.5	3.2	0.0
10	RUBBER AND PLASTICS PRODUCTS	31.3	6.3	6.5	9.7	32.3	6.5	12.9	3.2
11	OTHER NON-METALLIC MINERAL PRODUCTS	12.5	3.1	3.2	9.7	6.5	3.2	6.5	3.2
12	IRON & STEEL	18.8	9.4	6.5	9.7	19.4	6.5	9.7	6.5
13	NON-FERROUS METALS	25.0	3.1	0.0	0.0	25.8	3.2	12.9	6.5
14	FABRICATED METAL PRODUCTS, EXCEPT MACHINARY AND EQUIPMENT	21.9	9.4	6.5	9.7	22.6	12.9	12.9	3.2
15	MACHINERY AND EQUIPMENT, N.E.C.	9.4	21.9	3.2	3.2	9.7	22.6	3.2	0.0
16	OFFICE AND ELECTRICAL MACHINARY	3.1	15.6	0.0	0.0	3.2	19.4	3.2	3.2
17	RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	9.4	18.8	3.2	3.2	6.5	16.1	3.2	12.9
18	MANUFACTURING NEC AND MEDICAL INSTRUMENTS	12.5	28.1	0.0	0.0	9.7	29.0	6.5	12.9
19	MOTOR VEHICULES,SHIPS AND BOATS, AIRCRAFT AND SPACECRAFT; AND ROAILROAD EQUIPMENT	3.1	34.4	19.4	3.2	3.2	32.3	3.2	3.2
20	ELECTRICITY, GAS AND WATER SUPPLY	6.3	9.4	0.0	12.9	6.5	6.5	0.0	22.6
21	CONSTRUCTION	0	40.6	19.4	0.0	0.0	38.7	6.5	6.5
22	WHOLESALE AND RETAIL TRADE; REPAIRS	3.1	28.1	12.9	0.0	3.2	29.0	0.0	16.1
23	HOTELS AND RESTAURANTS	53.1	12.5	3.2	0.0	61.3	9.7	0.0	6.5
24	TRANSPORT AND STORAGE	0	12.5	6.5	3.2	0.0	12.9	0.0	12.9
25	POST AND TELECOMMUNICATIONS	12.5	12.5	3.2	12.9	12.9	9.7	6.5	0.0
26	FINANCE, INSURANCE	9.4	15.6	12.9	6.5	6.5	12.9	9.7	6.5
27	REAL ESTATE ACTIVITIES	6.3	15.6	0.0	0.0	6.5	16.1	0.0	6.5
28	RENTING, MACHINARY ,COMPUTER, RESEARCH, PUBLIC ADMINISTRATION PUBLIC AND PRIVATE HOUSEHOLDS	6.3	6.3	16.1	0.0	6.5	6.5	16.1	9.7
29	OTHER BUSINESS ACTIVITIES	6.3	9.4	3.2	19.4	3.2	12.9	0.0	0.0
30	EDUCATION	68.8	3.1	0.0	0.0	77.4	3.2	0.0	3.2
31	HEALTH AND SOCIAL WORK	0	18.8	0.0	3.2	0.0	19.4	9.7	3.2
32	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	0	6.3	3.2	6.5	0.0	6.5	3.2	3.2

In the US, sectors 10 (rubber and plastic products), 13 (non-ferrous metals), 23 (hotels and restaurants) and 30 (education) show the largest amount of incident arcs; they are input providers to the rest of the economy. Their production, however, is below the average output by sector. Perhaps, this is linked to the fact that the US has become an input importer and the impulses from the rest of the system to input producers are not fully transmitted to these relatively smaller activities. On the other hand, sectors with higher density by outdegree are: 3 (food products, beverages and tobacco), 18 (manufacturing N.E.C and medical instruments), 19 (motor vehicles, ships and boats, aircraft, spacecraft and railroad equipment), 21 (construction) and 22 (wholesale, retail and repairs). Sectors 3, 19, 21 and 22 are also among the sectors with above-average contribution to gross output. It is worth highlighting that sectors transmitting influence through intermediate demand seem to be more functional to the dynamics of the economy.

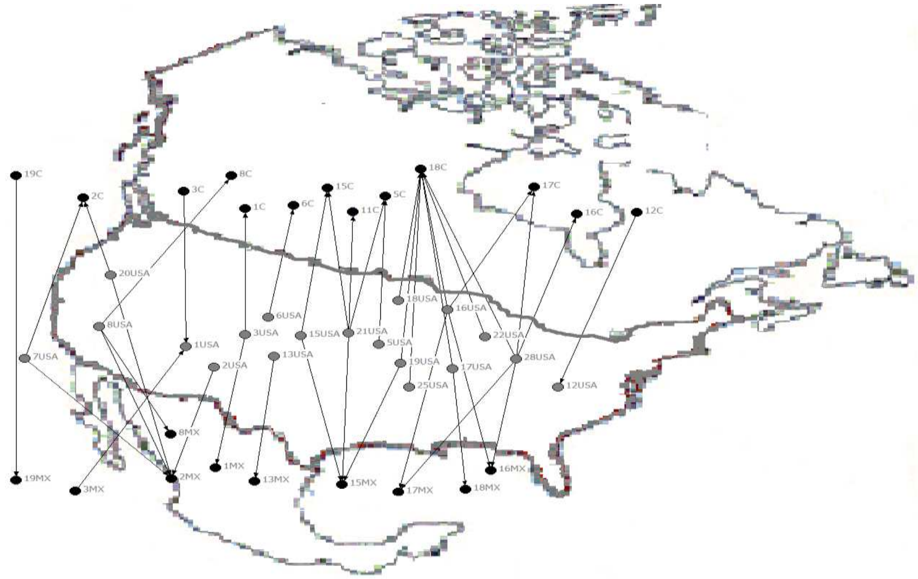
In Mexico, sectors 2 (mining and quarrying), 10 (rubber and plastic products), 13 (non-ferrous metals), 14 (manufactured metal products, except machinery and equipment) and 28 (renting machinery, computer research, public administration and public and private households) show the highest indegrees within the network, while sector 28 is the only one with a higher than average output contribution. In terms of intermediate demand, the integration pattern of the economy seems to suffer from a similar disease as the US does: input supplying sectors are small, so imports must be a major source of commodities. In a less developed economy that does not seem functional to the construction of a specialisation profile, sectors 17 (radio, television and communication equipment), 18 (manufacturing N.E.C and medical instruments), 20 (electricity, gas and water supply), 22 (wholesale, retail and repairs) and 24 (transport and storage) have the highest outdegree density. All of these sectors share above the average weights in the total output. The most integrated sectors in terms of transmission of influence are also the biggest industries, as it happens in Canada by recipients of influence.

4. Trade Patterns in North America

According to results above, international trade represents a smaller proportion of economic transactions for each country, if compared to domestic exchanges; the US being the most autarchic country in the bloc. Figure 5 shows the graph of the IC resulting from the six tables of imports and exports within North America. First, as it has been said above, there are thirty-nine connections only. Second, there is one direct link from the Canadian to the Mexican industries, connecting sectors 19 (motor vehicles, ships and boats, aircraft, spacecraft and railroad equipment) in each of these countries. This sector, however, happens to be dominated by US automobile firms located in both countries and producing massive intrafirm trade, although Canada is also an important producer of railroad equipment, which Mexico is keen to import. On the contrary, sector 19 in Mexico is disconnected from the rest of the domestic economy. Indeed, this is mainly an international sector located within the Mexican territory.

The rest of the 38 international links involve US industries connected bilaterally with either Canadian or Mexican sectors or trilaterally, involving simultaneously industries located in both countries. Seven cut-points found in the US economy link industries in the three countries: (once again) North American industries are interconnected through the US. Canada and Mexico show two cut-points each, which connect industries located in two different countries only: sectors 5 (wood and wood products and cork) and 18 (manufacturing and medical instruments) in Canada and sectors 2 (mining and quarrying) and 15 (machinery and equipment) in Mexico. Finally, there are nineteen Canadian industries with no links to other sectors in North America, neither as consumers nor as suppliers of inputs through ICs. There are also thirteen US industries disconnected to foreign trade and twenty Mexican sectors that do not trade with the rest of the bloc; i.e. trade is concentrated in fewer industries in Canada and Mexico, if compared to the US.

Figure 5
The North American Trade Patterns



Sectors			
1	AGRICULTURE, HUNTING, FORESTRY AND FISHING	17	RADIO, TELEVISION AND COMMUNICATION EQUIPMENT
2	MINING AND QUARRYING	18	MANUFACTURING NEC AND MEDICAL INSTRUMENTS
3	FOOD PRODUCTS, BEVERAGES AND TOBACCO	19	MOTOR VEHICULES,SHIPS AND BOATS, AIRCRAFT AND SPACECRAFT; AND ROAILROAD EQUIPMENT
4	TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR	20	ELECTRICITY, GAS AND WATER SUPPLY
5	WOOD AND PRODUCTS OF WOOD AND CORK	21	CONSTRUCTION
6	PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	22	WHOLESALE AND RETAIL TRADE; REPAIRS
7	COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	23	HOTELS AND RESTAURANTS
8	CHEMICALS EXCLUDING PHARMACEUTICALS	24	TRANSPORT AND STORAGE
9	PHARMACEUTICALS	25	POST AND TELECOMMUNICATIONS
10	RUBBER AND PLASTICS PRODUCTS	26	FINANCE, INSURANCE
11	OTHER NON-METALLIC MINERAL PRODUCTS	27	REAL ESTATE ACTIVITIES
12	IRON & STEEL	28	RENTING, MACHINARY ,COMPUTER, RESEARCH, PUBLIC ADMINISTRATION PUBLIC AND PRIVATE HOUSEHOLDS
13	NON-FERROUS METALS	29	OTHER BUSINESS ACTIVITIES
14	FABRICATED METAL PRODUCTS, EXCEPT MACHINARY AND EQUIPMENT	30	EDUCATION
15	MACHINERY AND EQUIPMENT, N.E.C.	31	HEALTH AND SOCIAL WORK
16	OFFICE AND ELECTRICAL MACHINARY	32	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES

Table 4 contains the density indicators by sector of the above graph. The indegree (In) shows the relative amount of incident arcs to an industry, that is, the number of demanding relations a sector actually maintains as a proportion of the total possible incident arcs. Through this indicator of regional trade, a sector receives influence from producers located abroad, thus inducing it to export goods. In this sense, sectors with higher indegrees in a given economy benefit from some competitive advantage; so, other sectors would seek them as input suppliers. The outdegree (Out) would then show the number of arcs stemming from a sector to the rest of the system: through this indicator, a sector transmits influence by demanding goods from producers abroad. Sectors with higher outdegrees link industries within the system.

The Canadian sectors with higher indegrees in the international North American network are: 2 (mining and quarrying), 5 (wood and products of wood and cork), 15 (machinery and equipment n.e.c.), 17 (radio, television and communication equipment) and 18 (manufacturing n.e.c. and medical instruments). No sector shows a significant outdegree density: industries do not transmit influence (through imports) to their input suppliers located abroad. Canada appears to be a fairly specialised economy, which is able to supply a defined profile of goods to consumers abroad.

In the US, sectors showing higher density by indegree are: 8 (chemicals excluding pharmaceuticals), 16 (office and electrical machinery) and 21 (construction). These receive influence from abroad and export products. Therefore, the whole structure takes advantage of the structural connections of these sectors. On the contrary, sectors transmitting influence through intermediate imports and showing higher outdegrees are: 10 (rubber and plastic products), 13 (nonferrous metals), 23 (hotels and restaurants) and 30 (education).

Finally, in Mexico, sectors 2 (mining and quarrying), 15 (machinery and equipment n.e.c.) and 16 (office and electrical machinery) show the highest outdegree density. These are the sectors that transmit higher influence to their input suppliers by means of intermediate inputs. Contrary to Canada, no Mexican productive sector shows a significant indegree: sectors do not receive significant influence from abroad through exports (intermediate demand). Thus, from a structural point of view, it can be said that the economy is not neatly specialised in any specific area of production. This is quite significant, taking into account that Mexico has adopted an export-led growth strategy, but such decision has not been accompanied with the construction of an integrated productive structure. Hence, to a large extent, the country exports goods assembling imported inputs.

Table 4
Sectoral Density by Country in the Intraregional Trade

	Sectors	Canada		United States		Mexico	
		In	Out	In	Out	In	Out
1	AGRICULTURE, HUNTING, FORESTRY AND FISHING	1.0	0.0	0.0	6.3	1.0	0.0
2	MINING AND QUARRYING	2.1	0.0	1.0	4.2	4.2	0.0
3	FOOD PRODUCTS, BEVERAGES AND TOBACCO	0.0	1.0	2.1	3.1	0.0	1.0
4	TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR	0.0	0.0	0.0	3.1	0.0	0.0
5	WOOD AND PRODUCTS OF WOOD AND CORK	2.1	0.0	1.0	4.2	0.0	0.0
6	PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	1.0	0.0	1.0	7.3	0.0	0.0
7	COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	0.0	0.0	2.1	4.2	0.0	0.0
8	CHEMICALS EXCLUDING PHARMACEUTICALS	1.0	0.0	3.1	7.3	1.0	0.0
9	PHARMACEUTICALS	0.0	0.0	0.0	2.1	0.0	0.0
10	RUBBER AND PLASTICS PRODUCTS	0.0	0.0	0.0	10.4	0.0	0.0
11	OTHER NON-METALLIC MINERAL PRODUCTS	1.0	0.0	0.0	2.1	0.0	0.0
12	IRON & STEEL	0.0	1.0	0.0	7.3	0.0	0.0
13	NON-FERROUS METALS	0.0	0.0	1.0	8.3	1.0	0.0
14	FABRICATED METAL PRODUCTS, EXCEPT MACHINARY AND EQUIPMENT	0.0	0.0	0.0	7.3	0.0	0.0
15	MACHINERY AND EQUIPMENT, N.E.C.	2.1	0.0	2.1	3.1	3.1	0.0
16	OFFICE AND ELECTRICAL MACHINARY	1.0	0.0	4.2	1.0	2.1	0.0
17	RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	2.1	0.0	2.1	2.1	2.1	0.0
18	MANUFACTURING NEC AND MEDICAL INSTRUMENTS	7.3	0.0	1.0	3.1	1.0	0.0
19	MOTOR VEHICULES,SHIPS AND BOATS, AIRCRAFT AND SPACECRAFT; AND ROAILROAD EQUIPMENT	0.0	1.0	2.1	1.0	1.0	0.0
20	ELECTRICITY, GAS AND WATER SUPPLY	0.0	0.0	2.1	2.1	0.0	0.0
21	CONSTRUCTION	0.0	0.0	4.2	0.0	0.0	0.0
22	WHOLESALE AND RETAIL TRADE; REPAIRS	0.0	0.0	1.0	1.0	0.0	0.0
23	HOTELS AND RESTAURANTS	0.0	0.0	0.0	19.8	0.0	0.0
24	TRANSPORT AND STORAGE	0.0	0.0	0.0	0.0	0.0	0.0
25	POST AND TELECOMMUNICATIONS	0.0	0.0	1.0	4.2	0.0	0.0

26	FINANCE, INSURANCE	0.0	0.0	0.0	2.1	0.0	0.0
27	REAL ESTATE ACTIVITIES	0.0	0.0	0.0	2.1	0.0	0.0
28	RENTING, MACHINARY ,COMPUTER, RESEARCH, PUBLIC ADMINISTRATION PUBLIC AND PRIVATE HOUSEHOLDS	0.0	0.0	5.2	2.1	0.0	0.0
29	OTHER BUSINESS ACTIVITIES	0.0	0.0	0.0	1.0	0.0	0.0
30	EDUCATION	0.0	0.0	0.0	25.0	0.0	0.0
31	HEALTH AND SOCIAL WORK	0.0	0.0	0.0	0.0	0.0	0.0
32	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	0.0	0.0	0.0	0.0	0.0	0.0

Conclusions

In this paper we have found a North American economic network that shows the structural connections existing between sectors in Canada, the US and Mexico. Analysing that structure we conclude that the three economies are highly interdependent, because in each country intermediate imports from other North American countries are essential to carry out production in various industries. Nevertheless, sectors within each economy are primarily linked to domestic sectors, secondly to branches within North America and thirdly to industries beyond. In that sense, the North American network contains three interconnected subsystems, one for each country.

The complexity of an economic system has been defined as the amount of connections between industries relative to the maximum possible amount of interindustry liaisons. In North America, the US is the most complex subsystem; it is also less dependent upon imports from its neighbouring partners, but keeps closer trade relationships with the rest of the World. Canada and Mexico maintain scarce direct relationships and import intermediate goods mainly from the U.S. The complexity of their subsystems is also lower. Influence will expand more easily through a complex network, because industries will be connected through a larger amount of paths, involving more sectors. This paper uses density as an indicator of the complexity of the system.

Indeed, sectors in the Canadian economy show a particularly low level of integration, which means that they are poorly connected indirectly through intermediate demands; moreover, while there is a group of industries interlinked through a large number of direct connections -forming the core of the structure- there are also groups of industries connected to that core through one particular sector only (called cutpoint). The Canadian subsystem can easily be split into disconnected groups if the connections if such cutpoints demise; moreover, there are also a few sectors totally disconnected. The Mexican subsystem contains fewer cutpoints, but it shows a level of complexity comparable to that of Canada. Apparently, in both cases integration with North America has encouraged that domestic sectors cultivate connections with US industries, rather than maintaining stronger links to domestic sectors, as has been the case in the US. In Canada the structure is based upon the extractive sectors; in Mexico the manufacturing industry has turned to assemble imported components to export goods; these activities are barely related to the domestic productive sector, for which exports show low multipliers and probably that is one reason for which the economy shows low growth rates. The benefits of constructing a single economic area are not clear for Canada or Mexico.

Lastly, it is both the high and low technology sectors that define the complexity of the economic network in North America. Such a feature is observed also for the US, but that is not obvious for neither Canada or in Mexico, where high technology sectors are smaller and import larger proportions of inputs. Medium technology industries are also more important for these two countries.

Identifying IC and the actual net of connections between sectors can be helpful to decide economic policies towards economic integration and growth. IC have been used to identify key sectors, but we have extended the method to make evident the paths through which influence propagates in the system, e.g., when one sector changes its technology, it will also change its intermediate demands, changing its relationships with the rest of the sectors as well; the latter will probably be driven to modify their net of connections with other industries, until the whole system changes.

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