AN INTER-REGIONAL NETWORK PERSPECTIVE TO EVALUATE THE BRAZILIAN ECONOMY

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**Abstract:** This paper aims to deepen the discussion about the productive interdependence among the Brazilian states through an input-output network in order to identify emergent patterns or properties within the Brazilian states. We use an inter-regional IO matrix, base year 2011, for the 27 Brazilian states and 68 sectors. The main results show that the out-degree of most important sectors was greater than the in-degree, which reveals, for this group of sectors, a greater relative importance on the supply side of the economy. The modularity analysis suggests that some states are isolated in the Brazilian productive structure. Thus, the use of seven indicators gave us a kaleidoscopic vision of the Brazilian internal trade performance and enables us to deal with points like complementarity, hierarchy and integration in spatial terms. We can affirm that this diagnosis plays an important role for the development process as it disaggregates the interdependence in different aspects.

Keywords: Brazilian economy; regional development; network; input-output.

**Resumo:** Este artigo objetiva aprofundar a discussão sobre interdependência produtiva entre os estados brasileiros por meio de uma rede de insumo-produto no sentido de identificar padrões emergentes ou propriedades inerentes aos estados. Utilizamos uma matriz inter-regional de insumo-produto, ano base 2011, para os 27 estados brasileiros e 68 setores. Os principais resultados mostram que o grau de saída da maioria dos setores mais importantes foi maior do que o grau de entrada, o que revela, para este grupo de setores, uma maior importância relativa pelo lado da oferta da economia. A análise de modularidade sugere que alguns estados estão isolados na estrutura produtiva brasileira. Portanto, o uso de sete indicadores nos deu uma visão caleidoscópica do desempenho do comércio interno brasileiro e nos permitiu lidar com questões de complementariedade, hierarquia e integração em termos espaciais. Podemos afirmar que este diagnóstico desempenha um importante papel no processo de desenvolvimento na medida em que desagrega a interdependência em diferentes aspectos.

Palavras-chave: Economia brasileira; desenvolvimento regional; rede; insumo-produto.

JEL: C67; R15; R58.

**Área 10 - Economia Regional e Urbana**

**1 Introduction**

To propose new ways of assessing sectorial interdependencies, models’ integration has been extensively explored in the specialized literature. We highlight the integration between input-output (IO) models and complex networks. Network analysis provides powerful tools for formally describing and testing theories of complex interaction systems (Smith and White, 1992).

The increasing use of complex networks has provided important analytical tools in several areas such as sociology, biology and economics, allowing analyzing various interactions in a given system. The different methods and techniques of networks can be found in classical studies such as Barabasi and Albert (1999), Albert and Barabasi (2003), Newman (2003) and Boccaletti et al. (2003).

In economics, for example, we can highlight the use of networks in topics such as game theory (Jackson, 2010), microfinance (Banerjee et al., 2013) and financial markets (Mantegna, 1999; Acemoglu et al., 2015). We observe a number of applications of network analysis in the field of international trade, i.e., involving several countries at the same time (Tsekeris, 2017a; Río-Chanona et al., 2017; Xing et al., 2017; Xiao et al., 2017; Cerina et al., 2015) and also for a single country assessment (Ribeiro et al., 2018; He et al., 2017; Tsekeris, 2017b; Acemoglu et al., 2016; Carvalho and Gabaix, 2013; Atalay et al., 2011; Xu et al., 2011). All these previous studies have used IO database associated to network properties.

IO networks have been provided the identification of new properties such as centralities or re-reading already known problems as aggregate fluctuations. Acemoglu et al. (2012), using the beta centrality measure, have demonstrated that microeconomic shocks in supply sectors that are strongly connected can spread throughout the network. These authors have shown the relevance of the "cascade effect" by identifying that productivity shocks in one central sector could affect the entire network. Gabaix (2011), considering the 100 largest companies in the United States, has found that the companies’ size has a distribution of heavy-tailed, which means that the microeconomic shocks in these companies could affect the US economy by interfering with per capita GDP and explaining up to one-third of the aggregate volatility.

Centrality measures, therefore, identify the most central sectors in IO networks in that a disturbance in these sectors can lead to a propagation effect across the network. Blochl et al. (2010) evaluated several economies from two measures (random walks and betweenness) for the years 1995 and 2000. For the US, these authors identified that the Public administration and defense, social security sector is the most central and, in the case of China, the construction and textile sectors, considering the random walks and the betweenness, respectively. Cerina et al. (2015) analyzed the World Input-Output Network using the pagerank and community coreness centralities and Tsekeris (2017b) identified sectorial clusters, and which activities were more central in Greece according to the betweenness, closeness and eigenvector centralities.

However, there is a shortage of studies involving IO networks in a subnational perspective. Within the same country there may be sectorial and regional heterogeneity that can be identified by centrality measures. This could provide subsidies to a regional development policy, since in identifying these properties local authorities can carry out planning according to those sectors that are more central and not only considering characteristics related to the size, for instance. There are sectors that, despite having a high value added, have few purchasing and selling relationships with the rest of the economy and there are sectors that have a lower value added, however they are central from the network point of view. Sun, An and Liu (2018), for instance, have used Chinese inter-regional IO matrices to develop 30 subnational IO networks and one inter-regional IO network, in order to identify key sectors and assess economic structure similarity.

This paper aims to deepen the discussion about the productive interdependence among the Brazilian states through integration between an IO model and complex network theory in order to identify emergent patterns or properties within the Brazilian states. Thus, we use seven centrality measures to assessing sectorial interdependencies. 1) ***Average degree*** – it is a global measure of sectorial interdependence because it compares each sector with the average. There is no upper or lower bound. It is important to observe the global picture of sectorial interdependence, built a first rank, and better understand the centrality of regions and sectors in the intra-industry trade; 2) ***Weighted degree*** – is a local measure of the sectorial interdependence since a group of connections weights a given sector. Thus, it is possible to build a ranking of connections classifying them in the most important links and least important links. This measure is closely connected with the idea of Key-sector; 3) ***In-degree*** – is a measure of forward linkages, which enables us to implement an analysis by the supply side. In other words, we can ranking regions and sectors in terms of its importance in the interdependence by the supply side; 4) ***Out-degree*** - is a measure of backward linkages, which enables us to implement an analysis by the demand side. In other words, we can rank regions and sectors in terms of its importance in the interdependence by the demand side; 5) ***PageRank*** – this measure qualifies the sectorial interdependency analysis, since it is based on the idea of “important links”. This last measure has a relation with the idea of field of influence; 6) ***Communities* –** this measure creates communities that reveals sectors which tend to interact more with each other; and 7) ***Betweenness*** – this measure identifies sectors that have strategic position in terms of information control.

In other words, we apply the network framework to better understand the interdependence among Brazilian states. To do so, we use an inter-regional IO matrix estimated by Haddad et al. (2017), base year 2011, covering up all the 27 Brazilian states and 68 sectors. As far of our knowledge, there are only the studies of Abreu (2014) and Ribeiro et al. (2018) that have used IO networks to assess the Brazilian economy, but both in a national perspective.

**2 Spatial dynamics and productive interdependence**

The spatial dynamics of the productive distribution in Brazil and, therefore, regional economic growth are very heterogeneous. This heterogeneity can be measured by aspects such as the qualification of the workforce; physical and financial capital stock; availability of transport infrastructure, energy and logistics; productive integration, among others.

All these factors affect regional economic growth. In this article, we deal with a specific aspect that is the productive integration, i.e. sectorial and spatial interdependence. It is important to emphasize that the question of inter-regional interdependence, that is, inter-regional purchasing and selling flows are a relevant topic for issues related to the regional planning process. The literature shows that there are gains from trade and/or interdependence between nations and between regions belonging to the same country.

The interdependence between regions has an important impact on the evolution of regional inequalities. The way a local economy is connected to others determines the impact of that territory upon other regions as well as the impact of those other regions on the region considered. The trade patterns between the dynamic and lagging regions will thus affect the regional convergence process. Examination of these trade linkages could assist in the development of policies that might enhance the prospects for convergence (Perobelli et al., 2010).

The idea of sectorial dependence, sector linkages and regional interdependence is studied in the input-output literature in several ways, since the seminal work of Hirschman (1958). The author analyzes the sectorial relation on the demand side – backward links. Within this aspect, Hirschman (1958) sought to understand how growth could be transmitted from one region to another. He proposes the hypothesis of unbalanced growth and is concerned with the analysis of the interrelationships between the various sectors, as well as with the promotion of the backward and forward linkages. According to this author, contrary to the orthodox view, growth must be unbalanced, as this creates tensions and creates opportunity for capital investment in other sectors. Therefore, growth starts in the key sectors and moves to the next in an unbalanced way.

We also have the contributions from; a) Cella (1984), who studies the sectorial dependence on the supply side (forward effects); b) Chenery and Watanabe (1958) that deal with backward effects using the Technical Coefficient matrix – A; c) Rasmussen (1958) and Hirschman (1958) that introduce the idea of key sector analysis; d) Sonis et al. (2000) that bring the concept of the field of influence and enables us to better understand and visualize the main links within an economy; e) Guilhoto et al. (1994) and Sonis et al. (1995) that proposed an improvement at Cella and Clements measure of linkages and create the pure linkage index; and f) Strassert (1968) improved by Dietzenbacher et al. (1993), through the hypothetical extraction method.

Thus, since the 1950s, the studies that deal with economic growth starts to focus into the relevance of intersectorial flows of goods. The development of linkages among the sectors thorough the supply of inputs, which means the intermediary consumption relation, has been highlighted as a strategy of economic growth to be followed by the regions. This notion is due to the idea that some sectors could foster the production of other sectors, through the increase of its production (Perroux, 1955; Rasmussen, 1958; Hirschman, 1958 and Chenery and Watanabe, 1958). The common point of these four studies is that the key sectors are seen as preference alternatives for investment in development policies.

**3 Model and Data**

3.1 The IO model

The IO model describes the relationships between economic sectors and final demand in a given economy. The solution of the standard model, proposed by Leontief (1941), can be specified as:

(1)

Where x is the total output; L = is the Leontief inverse matrix; and y is the final demand.

The IO model can be constructed for several regions, that is, inter-regional models. Following the matrix notation of Miller and Blair (2009), we can specify a model for two regions as:

(2)

The main diagonal of this matrix shows intraregional trade relations, while the rest of the elements reveal inter-regional trade relations. It is worth mentioning that the mathematical specification of the inter-regional model’s solution is the same as the standard model (equation 1). Haddad et al. (2013) point out that the main advantage of this model is to consider the whole system (states and sectors) in an integrated way through trade relations.

For the network construction, as well as its metrics that will support the topological analysis (described in the next section), we use the Leontief Inverse elements (lij), in order to capture the direct and indirect effects between the sectors and regions. Nevertheless, in order to have the net effects of the main diagonal we subtracted from L the identity matrix (I). According to Perobelli et al. (2007: 117), the subtraction of the identity matrix has the role of extracting from the matrix L the initial requirements produced by the final demand of each sector.

3.2 Concept of IO network and properties

An IO network is a directed graph on *n* vertices. In our case, , because we have 68 economic sectors. According to Carvalho and Salehi (2018, p. 3), “each vertex in this graph corresponds to an industry, with a directed edge with weight present from vertex *j* to vertex *i* if industry *j* is an input-supplier of industry *i*". Several properties support the topological analysis of the network (Newman, 2010). In this paper we use the following measures of centrality: i) average degree; (ii) weighted degree; iii) in-degree; iv) out-degree; v) pagerank; vi) communities; and vi) betweenness.

The average degree of a directed network is given by , in which is the degree of vertex *i* and represents the amount of edges incidents on vertex *i.* The definition of weighted average degree is given by . Considering the sum of all weights of all in-or-out arcs connected to vertex *i*.

The out-degree of vertex *i* is given by the sum of all out arcs connected to vertex *i*. Economically speaking, it can be represented as the sum of the total sales from a sector j. On the other hand, the in-degree of vertex *i* is given by the sum of all in arcs connected to vertex *i*. In other words, it can be represented as the sum of the total sales of a sector *j*.

The PageRank measures the importance of a node (sector) by counting the number and quality of arcs (if the network is addressed) by pointing to it. PageRank is a measure of quantity and quality because it captures both the number of arcs a node can have and the importance of the node in the network; a node (sector) can be important if it receives an arc from an important node. According to Page et al. (1998):

At , an initial probability distribution is assumed, usually where n is the total number of nodes; at each time step, the PageRank of node i is computed as:

Where are the in-neighbors of , is the weight of the link between the nodes i and j, S is the sum of the weights of the outgoing arcs from j, and the damping factor d is set to its default value, 0.85.

The analysis of communities and modularity are important issues in complex networks (Girvan and Newman, 2002; Newman, 2006). These concepts have several applications such as in human cell differentiation (Galvão et al., 2010) and social networks (Traud et al., 2012). In this paper, to analyze communities, we use modularity by the algorithm proposed by Blondel et al. (2008). In our IO network, communities can represent sectors that most transact each other. The algorithm proposed by Blondel et al. (2008) defines, based on the modularity optimization, a high modularity partition by recursive agglomeration of groups of connected nodes or modules until a high modularity is achieved.

In order to identify the sectors that have strategic position in terms of information control, we use the metric betweenness. This metric identifies the individual position in the network and is given by:

Where is the number of links of the geodesic path of the individuals *i* and *j* which passing through the node *k*, and is the number of links of the geodesic path of the agents *i* and *j*.

3.3 Data

The database used for the construction of the network refers to an inter-regional IO system estimated for the year 2011 by Haddad et al. (2017). This system is made up of the 27 Brazilian states and takes into account 128 commodities and 68 sectors, according to the latest revision of the System of National Accounts – SNA 2008 (UNITED NATIONS, 2008). It is important to highlight that Brazilian statistics offices do not publish any inter-regional matrices. Furthermore, this is the latest available inter-regional matrix. Roughly speaking our idea is use the topological analysis of network applied to an IO database.

**4 Results and discussions**

For this article, as commented earlier, we use the following measures of centrality: i) average degree; (ii) weighted degree; iii) in-degree; iv) out-degree; v) pagerank; vi) communities; and vii) betweenness. The use of these different measures gives complementary and important information about the network topology. When applying network centrality measures in a Brazilian inter-regional IO matrix, it is sought to capture the interaction between sectors and better understand the functioning of their productive structure. Therefore, we provide a novel method to evaluate the productive interdependence among the Brazilian states.

The average degree measures the average amount of connections between the network’s vertices. In our case, this metric indicates the average number of trade relations of the sectors. In 2011, the average degree of the Brazilian inter-regional IO network was approximately 174, that is, each sector, on average, is related (demand or supply) to another 174 sectors. Figure 1 shows an overview of the inter-regional IO network for Brazil in 2011. Each color indicates a specific Brazilian state (see Appendix 1) and the numbers indicate the economic sectors (see Appendix 2).

Figure 1 suggests the most important sectors are in São Paulo (SP) and Rio de Janeiro (RJ), which we will comment further. The network diameter was 6 and the average agglomeration coefficient was 0.434. In comparative terms, the network diameter calculated by Abreu (2014) for the Brazilian economy in 2007 was 2. However, it should be noted that this author has used a national IO matrix with 42 sectors, which justifies a smaller diameter. Roughly, an increase of this indicator over two periods of time, for instance, would indicate increased network connectivity.

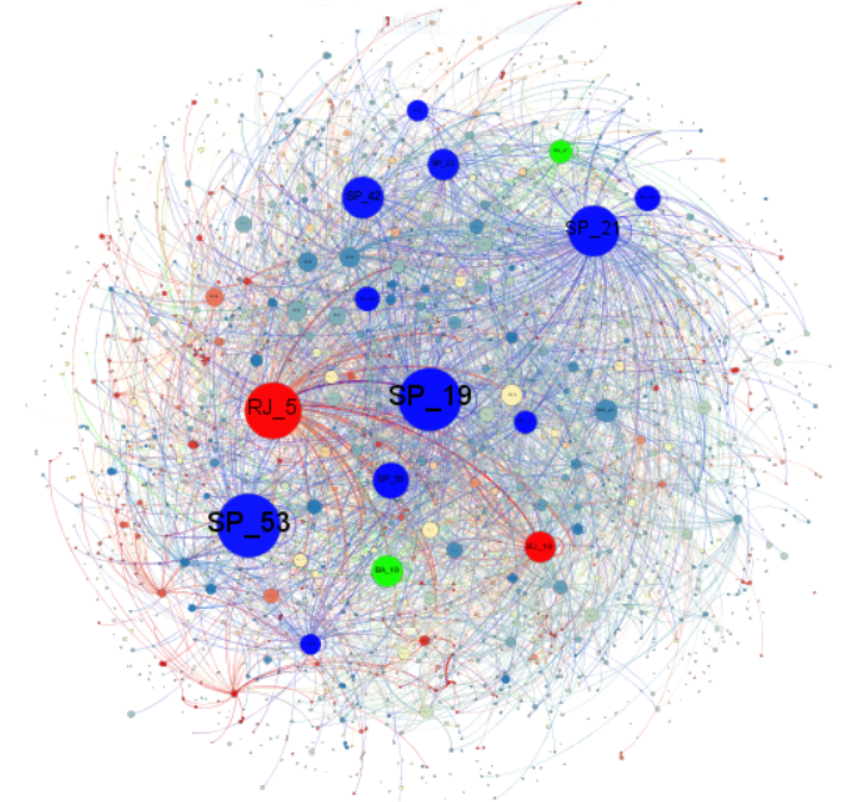


Figure 1: Brazilian inter-regional IO network, 2011

Source: Authors’own elaboration.

The average behavior of the network is not enough to understand the peculiarities of trade relations between sectors and regions. In this way, the network properties were calculated for each of the 68 sectors of the 27 Brazilian states. That is, this regional and sectorial structure provides 1,836 units of analysis. Figure 2 shows the number of connections per Brazilian state according to the weighted degree. The spatial distribution of the weighted degree enables us to divide the Brazilian economy in two corridors. The one formed from Bahia (BA) to Rio Grande do Sul (RS) states that present the most important links and the other with the rest of the Brazilian states.

This is even more evident if we correlate the weighted degree (Figure 2) with the per capita GDP of the Brazilian states for the year 2011 (see Appendix 3). We can see a hierarchy well known in the Brazilian economy, from the formation of four groups in which few states stand out from the majority. This correlation analysis serves as a robustness test, because it shows the method’s adherence in capturing an important characteristic of the Brazilian economy.



Figure 2: Weighted degree per Brazilian state, 2011

Source: Authors’own elaboration.

Table 1 shows the ten sectors of each Brazilian state with higher and lower average degree in 2011. Economically speaking, this metric reveals the most important and least important sectors in terms of relations in the economy. In other words, we can use this metric to identify key sectors.

Eight of the ten sectors with the highest number of connections are in São Paulo state, one in Bahia and one in Rio de Janeiro, which means nine connections in the Southeast region. In general, all these sectors are related to industrial activities. On the contrary, nine of the ten sectors with the weakest linkages are in the poorest regions of the country, North (RR, RO, AP, TO) and Northeast (SE, RN and PB)[[1]](#footnote-1). Most of these activities are associated with services, with emphasis on public education. The data presented at Table 1 and 2 show an interesting pattern. For the ten highest measures, all of them are manufacturing sectors and for the ten smallest measures are linked to the supply of public services, which is a non-tradable sector and shows the weakness of the links at the regions and the dependence of public service in its interdependence structure.

This reveals an important issue nowadays, since the Brazilian government have approved a new fiscal regime (EC 95/2016) that establishes a zero real growth of the federal primary expenditures in the period 2017-2037. This kind of regime tends to increase regional inequalities and affects relatively more the poorest regions and households because, according to Tupy and Toyoshima (2013), they are more dependent of the public expenditures. These effects were already pointed out for Greece (Caraveli and Tsionas, 2012), Guatemala (Cabrera et al., 2015) and the United Kingdom (Green and Lavery, 2015).

Table 1: Average degree – selected sectors, 2011.

|  |  |  |
| --- | --- | --- |
| **State** | **Sector** | **Degree** |
| SP | Manufacture of pulp, paper and paper products | 1,993 |
| SP | Manufacture of pesticides, disinfectants, paints and various chemicals | 1,983 |
| SP | Manufacture of other organic and inorganic chemicals, resins and elastomers | 1,972 |
| BA | Oil refining and coke plants | 1,965 |
| SP | Oil refining and coke plants | 1,963 |
| SP | Manufacture of rubber and plastic products | 1,949 |
| SP | Manufacture of electrical machinery and equipment | 1,944 |
| RJ | Oil refining and coke plants | 1,939 |
| SP | Manufacture of metal products, except machinery and equipment | 1,937 |
| SP | Other professional, scientific and technical activities | 1,927 |
| RR | Public education | 61 |
| SE | Public education | 60 |
| RN | Public education | 57 |
| PB | Public education | 54 |
| RO | Public education | 51 |
| RR | Surveillance, security and research activities | 39 |
| AP | Public education | 32 |
| TO | Extraction of iron ore, including processing and agglomeration | 15 |
| RR | Manufacture of cars, trucks and buses, except parts | 12 |
| DF | Extraction of iron ore, including processing and agglomeration | 7 |

Source: Authors’own elaboration.

Although the average degree takes into account the number of connections of each sector, it can be considered flawed because it also considers weak connections. Because of that, we also present the results of the weighted degree at sectorial level, which considers the links’ weight of each sector in the entire productive structure. Thus, this centrality weights the average degree by a coefficient (see Table 2).

Table 2: Weighted degree – selected sectors, 2011.

|  |  |  |
| --- | --- | --- |
| **State** | **Sector** | **Degree** |
| SP | Financial intermediation, insurance and supplementary pension plans | 36,117 |
| SP | Oil refining and coke plants | 35,657 |
| RJ | Extraction of oil and gas, including support activities | 31,922 |
| SP | Manufacture of other organic and inorganic chemicals, resins and elastomers | 28,811 |
| SP | Wholesale and retail trade, except motor vehicles | 23,529 |
| SP | Legal, accounting, consulting and corporate headquarters activities | 20,277 |
| BA | Oil refining and coke plants | 17,583 |
| SP | Manufacture of pesticides, disinfectants, paints and various chemicals | 17,573 |
| RJ | Oil refining and coke plants | 17,335 |
| SP | Manufacture of rubber and plastic products | 14,279 |
| TO | Public education | 109 |
| RN | Public education | 109 |
| PB | Public education | 94 |
| RO | Public education | 86 |
| RR | Surveillance, security and research activities | 62 |
| AP | Public education | 52 |
| MA | Public education | 22 |
| RR | Manufacture of cars, trucks and buses, except parts | 19 |
| TO | Extraction of iron ore, including processing and agglomeration | 18 |
| DF | Extraction of iron ore, including processing and agglomeration | 7 |

Source: Authors’own elaboration.

Even if the results in terms of states have been maintained in Table 2, we can see important changes for the sectors with the highest number of connections. The Financial intermediation, insurance and supplementary pension plans sector of São Paulo presents the highest weighted degree, which may be justified by the state being the financial center of the country (sector SP\_53 in Figure 1). In addition, two other service segments, also from São Paulo, emerge as important sectors when considering their connections, they are: Wholesale and retail trade, except motor vehicles and Legal, accounting, consulting and corporate headquarters activities.

The ranking changes in sectorial terms when we use the weighted degree instead of the average degree. However, from the regional point of view, the Southeast’s states continue to present the greatest number of connections in the Brazilian inter-regional structure.

Another possibility of analysis is to relate the weighted degree sectors’ ranking to the measures of in-degree and out-degree. As the IO network is a directed graph, it is important to analyze the in-degree and out-degree instead assess only the average degree or weighted degree. In general, the out-degree is much higher than the in-degree of the sectors located in the richest regions of the country, Southeast and South, which indicates important relations of these sectors on the supply side of the economy. These results can be a proxy of the integration degree of the regional productive structure. On the other hand, most of the sectors located in North, Northeast and Midwest regions, have the in-degree greater than the out-degree, indicating a relative importance of the demand side.

Among the 50 largest out-degree indicators, the only sectors in Northeast region that appear are Oil refining and coke plants and Manufacture of other organic and inorganic chemicals, resins and elastomers of Bahia’s state. This can be justified by the presence of the Petrochemical Complex of Camaçari, which places Bahia as an important supplier of petroleum refining products in both regional and national terms, as already pointed out by Ribeiro and Rocha (2013) and Ribeiro et al. (2010).

According to Cerina et al. (2015: 15) the use of PageRank improves our analysis once this metric “considers that an industry is important if it is connected with other important industries”. In this regard, Table 3 shows the highest and lowest PageRank for the Brazilian inter-regional IO network.

Table 3: PageRank – selected sectors, 2011.

|  |  |  |
| --- | --- | --- |
| **State** | **Sector** | **Degree** |
| PE | Food services | 0.001200 |
| DF | Associations and other personal services | 0.001181 |
| PR | Food services | 0.001155 |
| CE | Food services | 0.001123 |
| BA | Oil refining and coke plants | 0.001033 |
| MA | Associations and other personal services | 0.001025 |
| RJ | Manufacture of metal products, except machinery and equipment | 0.001018 |
| SC | Manufacture of cars, trucks and buses, except parts | 0.001011 |
| RS | Manufacture of metal products, except machinery and equipment | 0.000978 |
| PE | Manufacture of beverages | 0.000923 |
| DF | Real estate activities | 0.000361 |
| RJ | Real estate activities | 0.000361 |
| SC | Real estate activities | 0.000361 |
| MS | Real estate activities | 0.000361 |
| MT | Real estate activities | 0.000361 |
| PR | Legal, accounting, consulting and corporate headquarters activities | 0.000361 |
| PR | Real estate activities | 0.000361 |
| PR | Public education | 0.000361 |
| RS | Real estate activities | 0.000361 |
| DF | Extraction of iron ore, including processing and agglomeration | 0.000361 |

Source: Authors’own elaboration.

Unlike Tables 1 and 2, Table 3 reveals different states which have the highest PageRank. In other words, the use of this metric changes the rank completely. States such as Pernambuco (PE), Ceará (CE), Maranhão (MA) and Bahia (BA), even located in a peripheral region (Northeast), present sectors with high PageRank, which means that they are related to important sectors, not necessary in their region, reflecting a complementarity relation. On the other hand, it is worth mentioning that Real estate activities appear in several Brazilian states with the lowest PageRank. Moreover, none of the poorest regions’ states (North and Northeast) appears in the top ten lowest indicators.

The emergence of Northeastern sectors suggests that they, besides having a high degree, are related to other important sectors of the national economy. Thus, in Brazil, although the location of some sectors is in poor regions, they may play a relevant regional role, especially the food and beverage sectors that require agricultural inputs, forming a food complex in the Brazilian economy, as identified by Ribeiro et al. (2018).

The modularity result created 16 communities in our Brazilian IO network, as we can observe in Table 4. Each column shows which state belongs to a specific community and the number in parenthesis represents the amount of sectors that appears in each state. In order to facilitate our analysis, each state has a different color and the states of the same region have the same color tonality (blue, green, orange, yellow and gray).

Table 4: Communities of the Brazilian IO network, 2011



Source: Author’s own elaboration.

Table 4 shows interesting patterns. In communities 0, 2, 4, 5 and 11, for instance, we have only one state in each of them, they are: Acre (AC), Pará (PA), Maranhão (MA), Ceará (CE) and Rio Grande do Sul (RS), respectively. It means that in these communities these states tends to interact more with itself, which could indicate a kind of isolation in terms of productive interdependence. On the other hand, sectors of São Paulo appear in 7 communities, indicating that São Paulo has trade relations with all Brazilian states.

We can highlight also in Table 4 an economic approximation between Paraíba (PB), Pernambuco (PE) and Rio Grande do Norte - RN (community 6), Bahia (BA) and Sergipe - SE (community 8), Distrito Federal (DF), Goiás (GO) and Minas Gerais – MG (community 13) and Espírito Santo (ES) and Rio de Janeiro - RN (community 15). In these communities, almost all state sectors tends to interact with each other.

Modularity enabled to identify regional clusters of trade relations and, at the same time, relatively isolated states from the productive integration’s point of view. Modularity, in this sense, can be a tool for assessing the integration degree of the regional economy, since the smaller the amount of communities, the more interconnected would be the inter-regional IO network, which would allow for an increase in inter-regional trade.

The last metric we use is betweenness, which identifies economic sectors in strategic positions in terms of information control. Brazilian sectors with highest and lowest betweenness are in Table 5.

Table 5: Betweenness – selected sectors, 2011.

|  |  |  |
| --- | --- | --- |
| **State** | **Sector** | **Degree** |
| SP | Other professional, scientific and technical activities | 0.020948 |
| BA | Oil refining and coke plants | 0.013505 |
| AM | Oil refining and coke plants | 0.012219 |
| AM | Manufacture of computer, electronic and optical products | 0.010667 |
| SP | Metallurgy of nonferrous metals and metal smelting | 0.009750 |
| SP | Manufacture of pulp, paper and paper products | 0.009397 |
| SE | Manufacture of other organic and inorganic chemicals, resins and elastomers | 0.008415 |
| AC | Wholesale and retail trade, except motor vehicles | 0.008413 |
| RN | Extraction of oil and gas, including support activities | 0.008340 |
| MA | Ground transportation | 0.007649 |
| PI | Legal, accounting, consulting and corporate headquarters activities | 0.000000 |
| AL | Manufacture of wearing apparel and accessories | 0.000000 |
| SE | Manufacture of pharmaceutical and pharmacokinetic products | 0.000000 |
| RN | Surveillance, security and research activities | 0.000000 |
| ES | Manufacture of pharmaceutical and pharmacokinetic products | 0.000000 |
| SE | Surveillance, security and research activities | 0.000000 |
| MG | Public health | 0.000000 |
| PR | Public health | 0.000000 |
| SC | Public health | 0.000000 |
| DF | Extraction of iron ore, including processing and agglomeration | 0.000000 |

Source: Authors’own elaboration.

The most important observation about Table 5 is that sectors from North and Northeast regions appear in the top ten, such as: Oil refining and coke plants (BA and AM), Manufacture of computer, electronic and optical products (AM), Manufacture of other organic and inorganic chemicals, resins and elastomers (SE), Wholesale and retail trade, except motor vehicles (AC), Extraction of oil and gas, including support activities (RN) and Ground transportation (AM). The results for Amazonas state (AM) could be justified because of the oil refinery named Isaac Sabbá (Reman) and the “Zona Franca de Manaus” which has an important pole of electronics products. Furthermore, Rio Grande do Norte (RN) is one the greatest producer of oil in the country.

The betweenness centrality allowed identifying the importance of sectors located in the poorest regions of Brazil, North and Northeast, which would not be a trivial task from the use of common indicators used in the IO analysis. In general, our results show that is important to use different measures of centralities, because the structural pattern of results could change significantly.

**5 Final remarks**

This paper aimed to deepen the discussion about the productive interdependence among the Brazilian states through integration between an IO model and complex network theory in order to identify emergent patterns or properties within the Brazilian states. To do so, we use an inter-regional IO matrix, base year 2011, for the 27 Brazilian states and 68 sectors.

From the centrality measures, it was possible to identify which Brazilian sectors are more central in our inter-regional IO network. According to Acemoglu et al. (2012), shocks in these sectors can be diffused to the entire network because these sectors are related to a significant part of other sectors that constitute the network. In other words, there is a set of key sectors that may be targets of sectorial policies.

The main results indicate that sectors of Southeast’ states, mainly São Paulo, Rio de Janeiro and Minas Gerais, have presented the highest indicators in terms of average degree and weighted degree. However, it was possible to see a change in the ranking when we used different metrics, such as PageRank and Betweenness.

Therefore, it is important highlight the use of these metrics in a complementary way. More than this, the use of these seven indicators gave us a kaleidoscopic vision of the Brazilian internal trade performance and enables us to deal with points like complementarity, hierarchy and integration in spatial terms. We can affirm that this diagnosis plays an important role for the development process as it disaggregates the interdependence in different aspects.

As a step further, as our input-output matrix is estimated, it would be interesting to verify how sensitive our results are related to the estimated trade flows, especially the inter-regional ones.

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Appendix 1: Brazilian states and regions

|  |  |  |  |
| --- | --- | --- | --- |
| **Code** | **State** | | **Region** |
| 11 | RO | Rondônia | North |
| 12 | AC | Acre |
| 13 | AM | Amazonas |
| 14 | RR | Roraima |
| 15 | PA | Pará |
| 16 | AP | Amapá |
| 17 | TO | Tocantins |
| 21 | MA | Maranhão | Northeast |
| 22 | PI | Piauí |
| 23 | CE | Ceará |
| 24 | RN | Rio Grande do Norte |
| 25 | PB | Paraíba |
| 26 | PE | Pernambuco |
| 27 | AL | Alagoas |
| 28 | SE | Sergipe |
| 29 | BA | Bahia |
| 31 | MG | Minas Gerais | Southeast |
| 32 | ES | Espírito Santo |
| 33 | RJ | Rio de Janeiro |
| 35 | SP | São Paulo |
| 41 | PR | Paraná | South |
| 42 | SC | Santa Catarina |
| 43 | RS | Rio Grande do Sul |
| 50 | MS | Mato Grosso do Sul | Midwest |
| 51 | MT | Mato Grosso |
| 52 | GO | Goiás |
| 53 | DF | Distrito Federal |

Source: Authors’own elaboration.

Appendix 2: Economic sectors



Source: Authors’own elaboration.

Appendix 3: Correlation between weighted degree and per capita GDP of the Brazilian states, 2011

Source: Author’s own elaboration based on IPEADATA and research findings.

1. Appendix 1 shows the names of the Brazilian states and regions. [↑](#footnote-ref-1)