ECONOMIC LINKAGES AND PRODUCTIVE STRUCTURE IN BRAZILIAN STATES (2011 AND 2018): AN EMPIRICAL ANALYSIS

This paper investigates the Brazilian productive structure in 2011 and 2018 (last official available input output matrix) by applying input-output methods and econometric estimations for all 27 Brazilian states. The main findings indicate that the decline in the share of manufacturing in Brazil occurred alongside a spatial deconcentration of its activities. Additionally, services and trade sectors became relatively more prominent, while manufacturing lost value-added share even in states where it has been a key sector. The influence of Manufacturing over other sectors, such as services and trade, construction, mining and quarrying, diminished, contributing to a decline in economic complexity (ICR) over the period. At the same time, services and trade did not demonstrate stronger growth-enhancing effects (in terms of intersectoral linkages or ICR) compared to Public Utility Industrial Services (SIUP), such as electricity, gas and water supply or manufacturing in certain states. This process reflects a weakening of intersectoral linkages among key sectors across Brazilian states. The research reveals that some states appear to be trapped in low to- middle-complexity structures due to regressive productive specialization.

JEL: R11, R15, O14 and C67**.**

1. Introduction

Economic development consists of structural change, investment in new activities, and the acquisition of new productive capabilities (Rodrik, 2006). These productive capabilities and knowledge cannot be easily acquired by workers or entrepreneurs. According to Hausmann *et al.* (2011), this kind of knowledge also requires structural change, i.e., developing a new industry requires changes in the pattern of interactions inside organizations and economic sectors (by selling or buying inputs, e.g.). Moreover, the speed at which each country conducts structural transformation is a key factor that differentiates the income expansions and productivity gains (McMillan *et al*., 2014).

In the Kaldorian and Structuralist approach, manufacturing represents the most important tradable sector, though some sophisticated services (e.g., finance services, software engineering, and so on) and knowledge-intensive agricultural activities (such as seed production) also play important roles in the structural change process. Given these features, the reallocation of resources to modern tradable activities can accelerate economic growth. In other words, the labor transferring from low productivity activities to high-productivity activities is an important driver of economic development (McMillan *et al*., 2014).

According to McMillan et al. (2014, pp. 26-27) and Gabriel and Missio (2019) the great difference between Asian and both Latin American and African productivity performance is accounted for by differences in the pattern of structural change, which influences economic complexity[1]. Since 1990, structural change in Latin America, in particular, has been growth-reducing, with the labor force transferring to less productive activities, notably in services and the informal sector.

[1] Hausmann *et al.* (2011) developed a measure of economic complexity whereby diversity and ubiquity are approximations of the variety of capabilities available in an economy. While more diversified and less ubiquitous products tend to demand large quantities of capability and knowledge, such as aircraft, more ubiquitous products (e.g., cloths) or less ubiquitous products based on scarcity, such as niobium (and other natural resources), reflect the need for less capability and knowledge. Of course, low ubiquity can come from the need for large capability and knowledge. In this case, the products are more complex, such as X-ray machines and computerized tomography machines (CAT scan).

This paper provides new contributions to the literature on economic and regional development using data from Brazilian states. It aims to investigate the Brazilian productive structure in 2011 and 2018[2] by applying input-output methods and multivariate estimations for all 27 Brazilian states. Moreover, this article makes several original contributions to the field of regional economic analysis and complexity economics.

In a broad perspective, this paper innovatively integrates the concepts of economic complexity and input-output linkages, providing a robust empirical investigation of how backward and forward linkages relate to regional complexity (ICR) across Brazilian states. While complexity theory has often been applied to international trade data, this study adapts and applies it to the subnational level using input-output matrices. Secondly, the paper introduces the concept of Total Field of Influence (CIT) and Sectoral Influence Field (CIS) as a dynamic indicator of sectoral centrality within the regional productive structure. By measuring the intersectoral impacts of each industry over time, the CIT and CIS capture not only direct but also indirect linkages, offering a more comprehensive understanding of structural transformation.

This paper also employs Welsh variance decomposition to quantify the relative importance of economic variables (e.g., Backward and Forward linkages, output multipliers, intra/inter shares) in explaining the variation in economic complexity between 2011 and 2018. This statistical decomposition, rarely used in this field, enhances the analytical power of the results.

Finally, this work highlights a regional perspective often underexplored in the literature: the existence of "low and medium complexity traps" in certain Brazilian states, which are linked to regressive specialization in primary sectors. This insight contributes to policy debates on regional inequality and structural development in emerging economies.

As will be analyzed, the influence of manufacturing over other sectors, such as services and trade, construction, mining and quarrying, diminished. In other words, the intermediate purchases and sales of manufacturing reduced its influence on the intersectoral relationships on the other activities in most Brazilian states. At the same time, services and trade sectors did not demonstrate stronger growth-enhancing effects (in terms of linkages) than the Public Utility Industrial Services (SIUP), such as electricity, gas and water supply or manufacturing in certain states, as well as construction and SIUP. Furthermore, in a broader perspective, according to The Observatory of Economic Complexity (OEC), Brazil was closer to the most complex countries in 2000, in 26th position. However, it has fallen into the range of less complex countries in 2019, in the 53rd position, with a steady decrease in 2011 and 2018, which is our focus in this work.

Our main hypothesis is that this process is closely related to loss of intersectoral linkages among the key sectors in Brazilian states and in the lack of multi-level institutional and governance arrangements based on mission-led policies. Evidence based on the field of influence analysis gives support to it as well as econometric estimations. The research reveals that some states appear to be trapped in low to middle-complexity structures due to regressive productive specialization and that national industrial policies are not well suited for the enormous heterogeneity among Brazilian states. To reverse this process, it is needed an intense collaboration between public and private sectors of different states to identify and invest in economic activities that can contribute to development based on growth enhancing key sectors.

Therefore, the evidence presented in this paper provides important contributions for regional development as well as mission-led policies. More specifically, it provides robust evidence of a heterogeneously falling behind pattern across Brazilian states. This has implications for addressing (existing) regional inequalities in the country (Ribeiro et al., 2018; Cardoso et al., 2022). Local policymakers and place leaders will need to adjust place-based policies to ensure their region can take advantage of central government initiatives based on all the evidence presented.

Given the absence of officially published interregional input–output (IRIO) tables by Brazil's national statistical agencies, one of the main contributions of this paper lies in the use of two IRIO tables constructed for the years 2011 and 2018, both aligned with the most recent international

[2] Last public available official input-output matrix.

standard for the System of National Accounts (UNITED NATIONS, 2009), thereby ensuring mutual compatibility. The first table, estimated by Haddad *et al.* (2017), comprises 27 Brazilian states and 68 sectors. The second, developed by Seinfra (2022), consists of 53 regions and 68 sectors, in which the regional breakdown includes all 27 Brazilian states. Both IRIO are fully consistent with the Systems of National and Regional Accounts of Brazil (IBGE, 2015).

Given this paper's focus on the regional dynamics of the manufacturing industry, both IRIO were aggregated into seven sectors, following the methodological framework proposed by Gabriel and Ribeiro (2019), as detailed in Appendix 1. Additionally, the 2018 IRIO (SEINFRA, 2022) was further aggregated to represent all 27 Brazilian states.

This paper is divided into five sections. In section 2 is presented Hirschman-Rasmussen (HR)´s Index and Field of Influence methods. In section 3 we show our empirical analysis by Brazilian state based on IRIO. In section 4 we apply multivariate analysis considering IO methods and economic complexity. Finally, in section 5, we draw final remarks and policy implications.

2. Hirschman-Rasmussen (HR)´s Index and Field of Influence

There is a range of methods which measure intersectoral linkages (Cella, 1984; Chenery & Watanabe, 1958) to identify key sectors (Rasmussen, 1956; Hirschman, 1958), growth poles (Perroux, 1955; Myrdal, 1957), fields of influence (Sonis & Hewings, 1991) and pure linkage indexes (Guilhoto *et al*., 2005).

The relationship between manufacturing and economic growth from the input-output perspective is directly associated to the concept of intersectoral linkages. According to Silva and Perobelli (2018, p. 254), from the 1950s, studies related to economic growth began to look at the relevance of intersectoral flows of goods. In other words, the promotion of intersectoral linkages through the supply and demand of inputs has gained importance as a strategy of economic growth to be followed (Perroux, 1955; Rasmussen, 1956; Hirschman, 1958; Chenery and Watanabe, 1958).

Hirschman (1958) and Prado (1981) argued that sectors which present simultaneously high backward and forward linkages will be capable of leading the growth process. According to these definitions, the growth of an industry *i* generates the growth, respectively, of industries that purchase its goods and that provide its inputs. Following this logic, the empirical basis used by Hirschman was the input-output matrices. Thus, we have chosen the Hirschman-Rasmussen’s indexes and the Field of Influence to measure the role of manufacturing industry in terms of its linkages.

We calculate two intersectoral linkages: Hirschman-Rasmussen’s indexes (HR) and the Field of Influence. The former was suggested by Rasmussen (1956) and Hirschman (1958) and measures the dispersion power of the backward and forward linkages effects in the productive structure of a given economy. This index shows the ratio between the impacts’ average of the sector and the total average of the economy, and formally can be written as follows:

$$U_{oj} = \frac{\frac{1}{n} B_{oj}}{\frac{1}{n^2} \sum_{i=1}^{n} B_{oj}} \qquad U_{io} = \frac{\frac{1}{n} B_{io}}{\frac{1}{n^2} \sum_{j=1}^{m} B_{io}} \tag{1}$$

Where U_{oj} is the backward linkage effect (BL), and U_{io} is the forward Linkage effect (FL). Since it is a ratio between averages, the HR coefficients can be classified as those that are above the average and those that are below the total average. Therefore, it can be analyzed by means of a limit value that is usually estimated in one (Perroux, 1955; Prado, 1981). In other words, the backward linkages assess the importance of sectors as demanders of inputs from other sectors, while the forward linkages evaluate a given sector in the supply of inputs to the other sectors of the economy (Rasmussen, 1956; Hirschman, 1958).

The Field of Influence, on the other hand, was developed by Sonis and Hewings (1991). Using this method, it is possible to visualize the sectors with higher linkages in the productive structure. In other words, the purchases and sales of the sectors with a greater field have an influence on the intersectoral relationships on the other activities.

For its calculation, the Technological Coefficients matrix (A), a matrix of incremental variations in the coefficients (E) and the Leontief Inverse matrix (B) are used. A small variation is conducted[3] ε, in each isolated a_{ij}, i.e., ΔA is a Matrix $E = \left|\varepsilon_{ij}\right|$, such that:

$$\varepsilon_{ij} = \begin{cases} \varepsilon \ se \ i = i_1 \ e \ j = j_1 \\ 0 \ se \ i \neq i_1 \ e \ j \neq j_1 \end{cases} \tag{2}$$

The Leontief Inverse matrix is recalculated considering the variation ε. Thus, the Field of Influence of each coefficient is plotted in equation 3, while the total influence of each technical coefficient is calculated by equation 4.

$$F(\varepsilon_{ij}) = \frac{B^* - B}{\varepsilon_{ij}} \tag{3}$$

$$S_{ij} = \sum_{k=1}^{n} \sum_{l=1}^{n} \left[f_{kl}(\varepsilon_{ij}) \right]^2 \tag{4}$$

The larger S_{ij}, the greater the Field of Influence of the coefficient a_{ij} on the productive structure.

As mentioned earlier, it is important to highlight that 68 sectors are aggregated into 7 sectors, which are: 1) Agriculture, Hunting, Forestry and Fishing, 2) Mining and Quarrying, 3) Manufacturing Industry, 4) Electricity, Gas and Water Supply, 5) Construction, 6) Trade and 7) Services.

Manufacturing industry is classified as a key sector in most Brazilian states, in both years. In other words, backward and forward linkage effects (BL and FL) are greater than one, which means that this sector has linkages above the economy average. According to Prado (1981) and Guilhoto et al. (2005), key sectors should be considered strategic in terms of driving economic growth.

3. Empirical analysis by Brazilian state based on IO method

Considering 2011 and 2018, the Brazilian economy grew by approximately 2.63% in real terms. In terms of GDP composition between 2011 and 2018, services sector increased its share from 60% to 64.59%, trade sector from 11.39% to 11.53%, agriculture sector rose from 4.52% to 4.56%, extractive industry reduced its share from 3.87% to 2.37%, manufacturing shrank from 12.28% to 10.85%, SIUP (Industrial Services of Public Utility) increased from 2.37% to 2.52%, and construction decreased from 5.56% to 3.58%. Therefore, according to the aggregation described in Annex 1, industrial sectors (extractive, manufacturing, and construction) reduced their share of output, while services sector expanded, followed by more modest growth in trade, agriculture, and SIUP sectors.

In Table 1, key sectors in 2011 are highlighted in green, key sectors in 2018 in light red, and output multipliers above the national average plus one standard deviation in yellow. Additionally, dark red indicates a loss of sectoral participation within the state (% - State - intra) and/or in the national share (% - Brazil - inter). Conversely, blue indicates an increase in sectoral share within the state (% - State – intra) and/or in national share (% - Brazil - inter).

Services sector was key sector in the following states: Espírito Santo (ES), Rio de Janeiro (RJ), and the Federal District (DF) in 2018. However, ES and RJ lost participation in national share. Only DF increased its national share in the services sector between 2011 and 2018.

[3] We adopt $e = 0.001$.

In the North region, manufacturing was key sector in RO (2018), AC (2011 and 2018), AM (2011 and 2018), RR (2018), PA (2011 and 2018), and TO (2018). In the Northeast region, MA (2018), PI (2018), CE (2011 and 2018), RN (2011 and 2018), PB (2011 and 2018), PE (2011), AL (2011 and 2018), SE (2011 and 2018), and BA (2011 and 2018). In the Southeast, in MG (2011 and 2018), ES (2011 and 2018), RJ (2011 and 2018), SP (2011 and 2018), and PR (2011 and 2018). In the South, the manufacturing industry was key in SC (2011) and RS (2011 and 2018). Finally, in the Midwest region, in MS (2011 and 2018), MT (2018), and GO (2011 and 2018).

Therefore, manufacturing holds the most important backward linkages — that is, in terms of the magnitude and importance of sectors as demanders of inputs from other sectors — while simultaneously maintaining relevance in forward linkages, i.e., its magnitude in supplying inputs to other sectors of the economy. This means it is more connected to other sectors in terms of both demand and supply of inputs.

In terms of its importance for the output multiplier - OM (above the national average plus one standard deviation), it is evident that manufacturing was most relevant in RO (2011 and 2018), AC (2011 and 2018), AM (2011 and 2018), RR (2018), PA (2011 and 2018), TO (2011 and 2018), CE (2011), RN (2011 and 2018), PE (2011), BA (2011 and 2018), MG (2011 and 2018), RJ (2011), SP (2011 and 2018), PR (2018), RS (2011 and 2018), MS (2011), and MT (2011 and 2018).

Moreover, when analyzing only its intra-state importance, its relevance increases, as it is consistently among the top three positions in terms of OM, alongside SIUP and construction sectors. In gray are marked the highest OMs, considering the sector's relevance only within each state (excluding those already highlighted above). In this case, manufacturing is the most relevant in MA (2011 and 2018), PB (2011), SE (2011 and 2018), ES (2018), PR (2011), MS (2018), GO (2011 and 2018), and DF (2018). Construction was the most relevant in terms of OM in CE (2018), MG (2018), and DF (2011). Lastly, SIUP sector was the most relevant in PA (2018), AP (2018), PI (2011 and 2018), PB (2018), RJ (2018), SC (2011), GO (2018), and DF (2011 and 2018).

Although it is the key sector in the states mentioned above, manufacturing has been losing its share at both state and national levels. In the first case, in the following states: RO, AM, PA, TO, PI, CE, PB, SE, MG, RJ, SP, PR, SC, RS, MT, and GO. In the second case, in AM, PA, PI, PB, SE, RJ, SP, and SC. The increases in national share occurred only slightly in the states of RO, TO (from the third decimal place onward), MA (with the largest relative increase), CE, RN, PE, BA, MG, ES, PR, RS, MS, MT, and GO (with only marginal national increases). Therefore, an important process of structural transformation is observed here.

This overview reveals key aspects of Brazil's productive transformation. The decreasing share of manufacturing in Brazil's economy occurred alongside a spatial deconcentration of this sector during the analyzed period, especially from SP and RJ (see Table 1). Furthermore, manufacturing lost participation in states where it is considered a key sector, with only marginal gains in its share of productive structure in certain states — gains that did not compensate for the aggregate loss of this economic activity at the national level. At the same time, services and trade sectors did not demonstrate stronger growth-enhancing effects (in terms of linkages, i.e., FL > 1 and BL > 1) than the SIUP and manufacturing sectors.

Table 1 – ICR, IO indexes and sectoral share by Brazilian states.

UF	ICR 2011	ICR 2018	Var	Sectors	BL 2011	BL 2018	FL 2011	FL 2018	MP 2011	MP 2018	% intra state 2011	% intra state 2018	% inter 2011	% inter 2018
RO	-0.87	-0.46	0.41	Agriculture, H.F.F.	0.88	0.85	0.96	1.04	1.14	1.17	8.98	12.56	1.32	1.85
				M. and Quarrying	0.98	0.93	0.81	0.81	1.26	1.29	0.72	0.25	0.12	0.07
				Manufacturing	1.15	1.19	0.93	1.01	1.48	1.65	5.16	4.86	0.28	0.30
				SIUP	1.15	1.19	1.16	1.33	1.57	1.58	0.76	7.40	0.21	1.97
				Construction	1.22	1.14	0.90	0.82	1.29	1.51	14.55	2.97	1.74	0.56
				Trade	1.00	1.09	1.06	0.90	1.17	1.33	13.46	11.76	0.79	0.69
				Services	0.91	0.96	1.18	1.10	1.11	1.19	56.38	60.20	0.63	0.63
AC	-1.28	-0.96	0.32	Agriculture, H.F.F.	0.88	0.83	0.99	1.06	1.09	1.13	9.22	7.86	0.45	0.39
				M. and Quarrying	0.92	1.05	0.83	0.77	1.13	1.44	0.14	0.03	0.01	0.00
				Manufacturing	1.14	1.18	0.91	0.93	1.41	1.61	2.41	1.95	0.04	0.04
				SIUP	1.14	1.18	1.09	1.25	1.46	1.66	0.79	1.74	0.07	0.16
				Construction	1.18	1.22	0.94	0.79	1.29	1.31	6.73	3.37	0.27	0.21
				Trade	1.04	0.96	1.05	0.97	1.14	1.24	12.75	11.58	0.25	0.23
				Services	0.92	0.91	1.18	1.25	1.13	1.16	67.96	73.46	0.25	0.26
AM	0.88	0.72	-0.16	Agriculture, H.F.F.	0.83	0.80	0.80	0.72	1.09	1.16	6.62	5.89	2.27	1.78
				M. and Quarrying	0.90	0.98	0.86	0.79	1.19	1.42	3.79	1.48	1.52	0.86
				Manufacturing	1.11	1.11	1.32	1.60	1.46	1.62	27.16	23.21	3.43	2.95
				SIUP	1.11	1.11	1.16	1.20	1.76	1.84	2.29	3.18	1.50	1.74
				Construction	1.33	1.26	0.83	0.73	1.36	1.42	5.23	3.01	1.46	1.16
				Trade	1.03	0.98	0.90	0.84	1.18	1.43	9.31	9.96	1.27	1.19
				Services	0.90	0.98	1.13	1.13	1.20	1.29	45.59	53.27	1.18	1.14
RR	-1.07	-0.70	0.38	Agriculture, H.F.F.	0.93	0.88	0.94	1.02	1.12	1.18	2.30	4.60	0.09	0.21
				M. and Quarrying	0.92	1.02	0.86	0.81	1.11	1.36	0.75	0.07	0.04	0.01
				Manufacturing	1.00	1.21	0.87	0.87	1.20	1.62	1.50	1.02	0.02	0.02
				SIUP	1.00	1.21	1.20	1.31	1.52	1.61	1.58	3.80	0.12	0.31
				Construction	1.27	1.20	0.96	0.77	1.24	1.16	6.83	4.82	0.22	0.28
				Trade	1.03	0.87	1.03	0.95	1.10	1.29	12.05	12.04	0.19	0.21
				Services	0.91	0.96	1.13	1.25	1.12	1.14	74.98	73.65	0.23	0.23
PA	-0.88	-1.07	-0.19	Agriculture, H.F.F.	0.87	0.87	0.92	0.93	1.09	1.16	8.98	9.23	4.72	4.83
				M. and Quarrying	0.87	0.87	0.84	0.83	1.09	1.17	21.27	12.23	13.07	12.32
				Manufacturing	1.17	1.26	1.01	1.13	1.46	1.69	4.54	3.50	0.88	0.77
				SIUP	1.17	1.26	1.14	1.18	1.45	1.41	2.60	7.98	2.61	7.56
				Construction	1.16	1.05	0.91	0.84	1.33	1.36	6.26	4.34	2.68	2.90
				Trade	1.06	1.01	1.00	0.92	1.18	1.32	9.36	9.45	1.95	1.96
				Services	0.94	0.99	1.18	1.16	1.16	1.27	46.99	53.27	1.86	1.97
AP	-1.16	-1.15	0.01	Agriculture, H.F.F.	0.86	0.88	0.87	0.85	1.11	1.15	2.23	1.67	0.12	0.09
				M. and Quarrying	1.04	1.00	0.80	0.81	1.34	1.30	2.08	0.12	0.13	0.01
				Manufacturing	0.99	1.13	0.86	0.98	1.27	1.48	1.59	2.24	0.03	0.05
				SIUP	0.99	1.13	1.27	1.35	1.81	1.51	0.83	4.45	0.08	0.46
				Construction	1.41	1.16	0.93	0.85	1.25	1.32	5.22	3.56	0.22	0.26
				Trade	0.97	1.01	1.03	0.98	1.12	1.26	12.19	11.08	0.25	0.25
				Services	0.87	0.96	1.24	1.17	1.10	1.11	77.53	76.88	0.31	0.31
TO	-0.99	-1.01	-0.02	Agriculture, H.F.F.	0.96	0.84	1.01	1.04	1.17	1.22	11.30	11.15	1.10	1.35
				M. and Quarrying	0.95	1.06	0.83	0.75	1.17	1.53	0.49	0.47	0.06	0.11
				Manufacturing	1.20	1.19	0.96	1.00	1.46	1.72	2.96	2.14	0.11	0.11
				SIUP	1.20	1.19	1.01	1.11	1.17	1.59	7.19	3.42	1.34	0.75
				Construction	0.96	1.11	0.93	0.78	1.29	1.56	6.65	4.46	0.53	0.69
				Trade	1.05	1.08	1.08	1.09	1.19	1.25	10.70	14.57	0.41	0.70
				Services	0.97	0.87	1.18	1.23	1.11	1.22	60.71	63.79	0.45	0.55
MA	-0.82	-0.98	-0.16	Agriculture, H.F.F.	0.90	0.96	0.88	0.93	1.11	1.21	9.73	7.90	2.71	2.51
				M. and Quarrying	0.94	0.87	0.83	0.83	1.17	1.10	2.16	0.56	0.70	0.34
				Manufacturing	1.12	1.15	0.97	1.17	1.39	1.45	3.63	7.01	0.37	0.94
				SIUP	1.12	1.15	1.08	1.08	1.34	1.29	2.10	4.82	1.11	2.77
				Construction	1.08	1.02	0.93	0.87	1.30	1.37	7.83	3.96	1.77	1.60
				Trade	1.05	1.08	1.04	0.92	1.18	1.20	13.14	11.62	1.45	1.46
				Services	0.95	0.95	1.27	1.20	1.19	1.21	61.41	64.12	1.29	1.44
PI	-0.78	-1.01	-0.23	Agriculture, H.F.F.	0.93	0.87	0.90	0.92	1.15	1.12	7.03	8.73	1.02	1.43
				M. and Quarrying	0.93	0.90	0.83	0.82	1.15	1.16	0.54	0.22	0.09	0.07
				Manufacturing	1.10	1.17	0.96	1.05	1.37	1.51	4.03	2.74	0.22	0.19
				SIUP	1.10	1.17	1.09	1.20	1.41	1.52	4.03	2.74	1.11	0.81
				Construction	1.13	1.18	0.93	0.86	1.30	1.33	7.05	4.85	0.83	1.01
				Trade	1.04	1.04	1.05	0.97	1.17	1.19	14.02	12.51	0.81	0.81
				Services	0.94	0.92	1.25	1.18	1.16	1.19	63.29	68.22	0.69	0.79

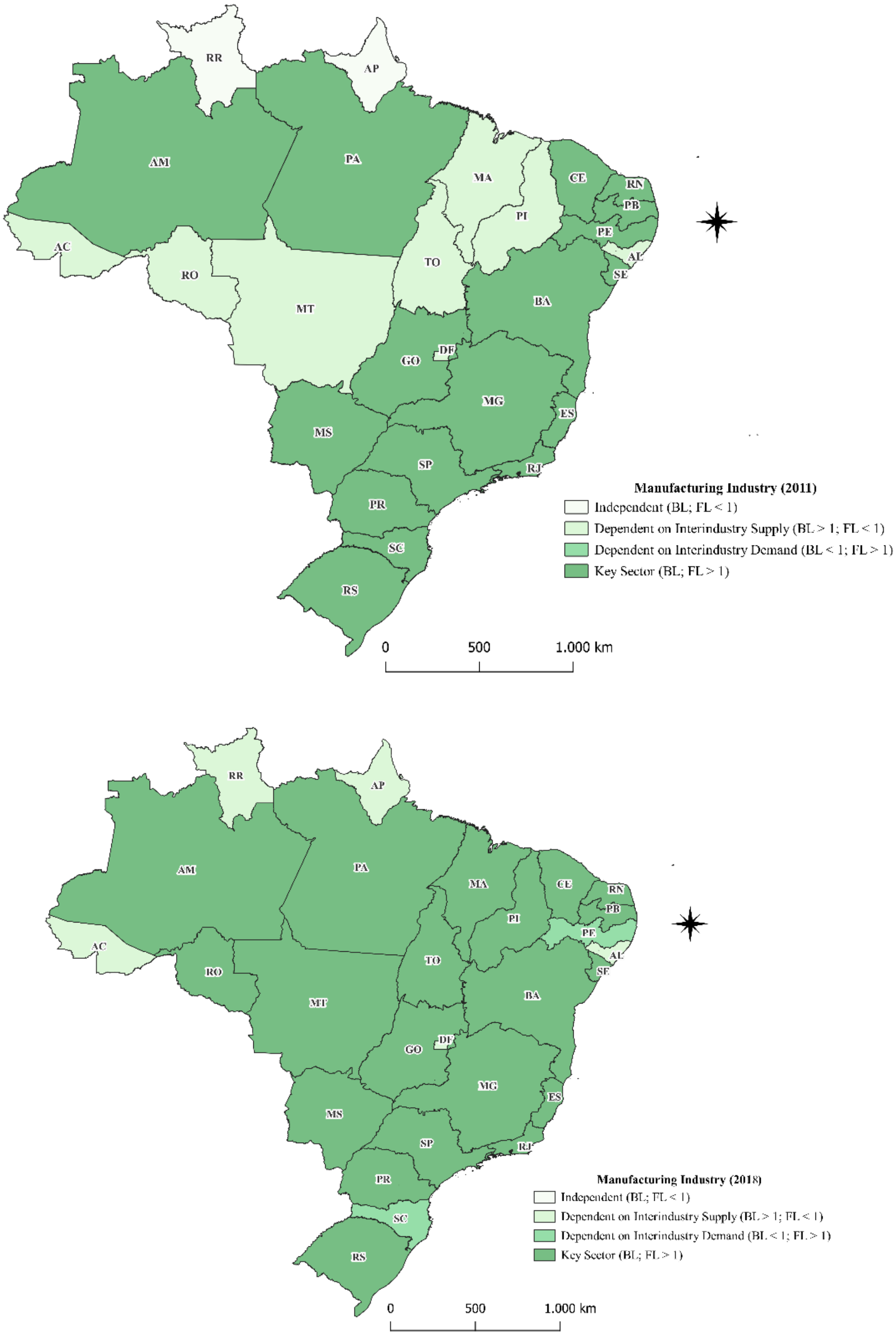
				Agriculture, H.F.F.	0.88	0.90	0.85	0.83	1.14	1.17	5.62	4.52	2.68	2.29
				M. and Quarrying	0.97	0.83	0.80	0.80	1.26	1.08	0.46	0.27	0.26	0.26
				Manufacturing	1.10	1.06	1.06	1.20	1.42	1.38	8.95	8.09	1.58	1.72
CE	0.18	-0.05	-0.22	SIUP	1.10	1.06	1.04	1.09	1.45	1.45	2.72	3.21	2.47	2.94
				Construction	1.12	1.11	0.89	0.84	1.36	1.48	6.24	4.22	2.42	2.72
				Trade	1.05	1.14	1.02	0.97	1.21	1.29	13.67	12.70	2.59	2.55
				Services	0.93	0.99	1.35	1.28	1.23	1.28	62.35	67.00	2.25	2.40
				Agriculture, H.F.F.	0.90	0.88	0.82	0.81	1.18	1.16	3.22	3.83	0.70	0.84
				M. and Quarrying	0.92	0.97	0.94	0.97	1.21	1.28	7.97	2.58	2.03	1.09
				Manufacturing	1.13	1.19	1.06	1.15	1.49	1.57	5.39	5.60	0.43	0.51
RN	-0.36	-0.56	-0.20	SIUP	1.13	1.19	1.09	1.07	1.60	1.36	1.40	4.65	0.58	1.84
				Construction	1.22	1.03	0.89	0.88	1.35	1.43	6.90	3.94	1.22	1.10
				Trade	1.03	1.08	0.99	0.94	1.18	1.23	11.93	12.09	1.03	1.05
				Services	0.90	0.93	1.21	1.17	1.17	1.20	63.18	67.30	1.04	1.04
				Agriculture, H.F.F.	0.91	0.92	0.88	0.87	1.11	1.14	4.77	3.49	0.94	0.73
				M. and Quarrying	0.99	0.83	0.84	0.81	1.21	1.03	0.45	0.25	0.10	0.10
				Manufacturing	1.08	1.07	1.00	1.09	1.32	1.34	7.77	5.76	0.57	0.51
PB	-0.16	-0.66	-0.50	SIUP	1.08	1.07	1.03	1.21	1.30	1.50	2.78	3.26	1.05	1.23
				Construction	1.07	1.20	0.95	0.89	1.29	1.34	5.43	4.38	0.87	1.17
				Trade	1.06	1.07	1.07	0.99	1.17	1.21	12.12	11.74	0.95	0.97
				Services	0.96	0.97	1.23	1.14	1.13	1.17	66.68	71.12	0.99	1.05
				Agriculture, H.F.F.	0.88	0.81	0.82	0.71	1.17	1.22	3.86	3.69	2.18	2.16
				M. and Quarrying	1.01	1.35	0.77	0.72	1.34	2.02	0.13	0.04	0.09	0.05
				Manufacturing	1.08	0.95	1.08	1.52	1.42	1.43	7.87	11.21	1.64	2.76
PE	0.28	0.19	-0.09	SIUP	1.08	0.95	1.07	1.05	1.50	1.64	2.36	3.03	2.54	3.21
				Construction	1.14	1.09	0.87	0.75	1.37	1.64	8.45	3.57	3.89	2.66
				Trade	1.03	1.09	1.01	0.89	1.23	1.31	12.80	11.96	2.87	2.77
				Services	0.93	0.87	1.38	1.35	1.23	1.25	64.53	66.48	2.75	2.75
				Agriculture, H.F.F.	0.96	0.80	0.97	1.00	1.21	1.07	9.27	15.02	1.59	2.62
				M. and Quarrying	0.94	1.15	0.84	0.83	1.19	1.56	1.76	0.37	0.35	0.13
				Manufacturing	1.09	1.14	0.95	0.98	1.38	1.54	9.88	4.32	0.63	0.32
AL	-0.51	-0.59	-0.08	SIUP	1.09	1.14	1.11	1.14	1.49	1.57	1.78	2.46	0.58	0.78
				Construction	1.18	1.16	0.91	0.84	1.27	1.26	6.49	3.71	0.91	0.82
				Trade	1.01	0.94	0.99	0.89	1.14	1.25	12.76	9.60	0.87	0.66
				Services	0.90	0.93	1.23	1.33	1.17	1.19	58.07	64.53	0.75	0.80
				Agriculture, H.F.F.	0.93	0.94	0.87	0.84	1.15	1.22	4.70	3.39	0.72	0.46
				M. and Quarrying	0.97	0.99	0.84	0.88	1.20	1.28	6.77	1.85	1.21	0.48
				Manufacturing	1.10	1.14	1.00	1.14	1.36	1.48	6.03	5.04	0.34	0.29
SE	-0.41	-0.59	-0.18	SIUP	1.10	1.14	1.06	1.09	1.33	1.29	6.83	6.52	1.98	1.59
				Construction	1.07	0.99	0.91	0.87	1.27	1.35	7.09	4.40	0.88	0.76
				Trade	1.03	1.04	1.02	0.94	1.17	1.25	10.02	10.94	0.61	0.58
				Services	0.94	0.96	1.29	1.24	1.18	1.21	58.56	67.85	0.67	0.65
				Agriculture, H.F.F.	0.95	0.89	0.81	0.76	1.26	1.31	7.19	6.74	6.26	6.17
				M. and Quarrying	0.96	1.01	0.81	0.75	1.27	1.49	2.64	1.16	2.68	2.04
				Manufacturing	1.10	1.14	1.17	1.50	1.46	1.67	7.82	10.12	2.51	3.89
BA	-0.15	-0.39	-0.24	SIUP	1.10	1.14	1.07	0.99	1.50	1.59	3.13	3.34	5.18	5.52
				Construction	1.13	1.08	0.86	0.79	1.34	1.63	7.36	4.44	5.21	5.17
				Trade	1.01	1.10	0.96	0.91	1.23	1.30	11.88	11.51	4.11	4.16
				Services	0.93	0.88	1.32	1.30	1.23	1.31	59.99	62.69	3.94	4.04
				Agriculture, H.F.F.	0.95	1.03	0.83	0.82	1.24	1.49	6.09	4.65	12.52	9.06
				M. and Quarrying	0.96	0.77	0.80	0.76	1.26	1.12	6.67	4.50	16.04	16.85
				Manufacturing	1.09	1.13	1.14	1.41	1.43	1.62	13.45	12.54	10.19	10.26
MG	0.21	0.29	0.08	SIUP	1.09	1.13	1.02	1.00	1.37	1.66	3.41	2.60	13.37	9.16
				Construction	1.05	1.15	0.88	0.78	1.37	1.56	6.13	4.03	10.26	9.99
				Trade	1.05	1.08	0.98	0.90	1.26	1.36	10.56	10.72	8.63	8.26
				Services	0.96	0.94	1.35	1.33	1.23	1.28	53.69	60.97	8.33	8.38
				Agriculture, H.F.F.	0.91	1.10	0.83	0.85	1.17	1.39	3.09	3.29	1.57	1.42
				M. and Quarrying	0.95	1.01	0.83	0.94	1.22	1.28	23.22	13.00	13.81	10.74
				Manufacturing	1.06	1.14	1.03	1.20	1.36	1.44	8.48	9.94	1.59	1.79
ES	0.35	0.35	0.00	SIUP	1.06	1.14	1.09	0.90	1.44	1.03	1.80	2.11	1.74	1.64
				Construction	1.12	0.82	0.88	0.82	1.34	1.10	4.95	3.22	2.05	1.76
				Trade	1.05	0.87	1.02	1.00	1.25	1.30	10.89	12.62	2.20	2.14
				Services	0.97	1.03	1.32	1.29	1.19	1.29	47.57	55.82	1.82	1.69

RJ	1.77	1.44	-0.34	Agriculture, H.F.F.	0.86	0.84	0.76	0.74	1.14	1.14	0.45	0.43	1.12	0.96
				M. and Quarrying	0.96	0.89	0.86	0.91	1.27	1.21	14.65	10.11	43.11	43.61
				Manufacturing	1.08	1.13	1.02	1.16	1.42	1.54	6.32	5.85	5.86	5.51
				SIUP	1.08	1.13	1.01	0.99	1.47	1.56	2.40	2.28	11.52	9.26
				Construction	1.11	1.14	0.86	0.85	1.33	1.40	4.96	3.34	10.16	9.55
				Trade	1.00	1.02	0.96	0.91	1.32	1.39	8.80	9.29	8.81	8.25
				Services	1.00	1.02	1.54	1.44	1.32	1.31	62.42	68.71	11.85	10.88
SP	2.63	2.43	-0.20	Agriculture, H.F.F.	0.93	0.97	0.74	0.72	1.32	1.46	1.74	1.50	12.30	10.21
				M. and Quarrying	0.99	0.75	0.72	0.71	1.40	1.13	0.29	0.65	2.38	8.53
				Manufacturing	1.07	1.14	1.29	1.47	1.51	1.72	16.00	13.20	41.60	37.75
				SIUP	1.07	1.14	0.90	0.96	1.47	1.73	1.62	1.44	21.74	17.76
				Construction	1.04	1.15	0.80	0.78	1.45	1.67	4.87	3.27	27.95	28.30
				Trade	1.02	1.11	0.97	0.91	1.38	1.45	11.64	12.14	32.63	32.71
				Services	0.97	0.96	1.59	1.45	1.38	1.38	63.85	67.80	33.98	32.58
PR	1.36	1.51	0.15	Agriculture, H.F.F.	0.93	0.95	0.82	0.82	1.20	1.37	8.22	8.30	10.91	11.75
				M. and Quarrying	1.03	1.00	0.78	0.71	1.34	1.45	0.14	0.11	0.22	0.29
				Manufacturing	1.05	1.09	1.12	1.47	1.36	1.58	15.19	13.39	7.42	7.95
				SIUP	1.05	1.09	1.02	0.96	1.33	1.52	3.89	4.16	9.82	10.64
				Construction	1.02	1.05	0.85	0.77	1.32	1.55	5.38	3.73	5.80	6.72
				Trade	1.01	1.07	1.03	0.94	1.29	1.36	13.20	12.69	6.96	7.10
				Services	0.99	0.94	1.38	1.34	1.24	1.31	53.98	57.63	5.40	5.75
SC	1.45	1.73	0.29	Agriculture, H.F.F.	0.92	0.92	0.83	0.80	1.20	1.32	5.28	4.75	4.70	4.42
				M. and Quarrying	0.99	1.05	0.78	0.72	1.29	1.50	0.38	0.24	0.39	0.43
				Manufacturing	1.06	0.99	1.14	1.39	1.38	1.41	20.49	16.96	6.73	6.62
				SIUP	1.06	0.99	1.04	1.08	1.40	1.70	2.52	1.72	4.28	2.89
				Construction	1.08	1.19	0.87	0.76	1.39	1.46	5.87	4.12	4.26	4.87
				Trade	1.07	1.02	1.02	0.94	1.24	1.34	13.28	13.86	4.71	5.09
				Services	0.95	0.94	1.32	1.32	1.21	1.26	52.19	58.36	3.51	3.83
RS	1.29	1.60	0.31	Agriculture, H.F.F.	0.93	0.88	0.82	0.79	1.27	1.41	7.29	7.84	9.93	11.50
				M. and Quarrying	1.01	1.10	0.74	0.64	1.38	1.76	0.16	0.09	0.25	0.25
				Manufacturing	1.09	1.07	1.26	1.55	1.50	1.71	16.79	14.13	8.42	8.70
				SIUP	1.09	1.07	0.97	0.97	1.45	1.74	2.12	2.05	5.49	5.43
				Construction	1.06	1.08	0.82	0.73	1.41	1.76	4.68	3.34	5.19	6.22
				Trade	1.03	1.09	0.99	0.91	1.30	1.47	12.52	12.63	6.78	7.32
				Services	0.95	0.91	1.40	1.39	1.28	1.38	56.44	59.92	5.80	6.20
MS	-0.36	-0.11	0.24	Agriculture, H.F.F.	0.94	0.84	0.93	0.99	1.18	1.15	15.47	17.05	4.46	5.91
				M. and Quarrying	1.00	1.06	0.81	0.76	1.26	1.46	0.77	0.38	0.26	0.25
				Manufacturing	1.13	1.09	1.01	1.10	1.42	1.49	8.55	11.27	0.91	1.64
				SIUP	1.13	1.09	1.02	1.01	1.24	1.38	4.95	4.61	2.72	2.89
				Construction	0.99	1.01	0.91	0.84	1.32	1.47	5.71	3.69	1.34	1.63
				Trade	1.05	1.08	1.05	0.96	1.19	1.35	11.78	10.37	1.35	1.42
				Services	0.95	0.99	1.27	1.34	1.18	1.28	52.78	52.64	1.15	1.29
MT	-0.65	-0.51	0.14	Agriculture, H.F.F.	0.95	0.82	0.94	0.89	1.27	1.26	18.85	17.68	7.16	8.30
				M. and Quarrying	0.99	0.95	0.78	0.71	1.31	1.46	0.34	0.31	0.15	0.28
				Manufacturing	1.17	1.09	0.98	1.18	1.56	1.67	8.10	6.98	1.13	1.37
				SIUP	1.17	1.09	1.07	1.09	1.44	1.89	1.80	2.44	1.30	2.07
				Construction	1.08	1.23	0.86	0.72	1.34	1.69	5.00	3.63	1.54	2.16
				Trade	1.00	1.10	1.05	1.03	1.23	1.42	14.68	15.53	2.22	2.88
				Services	0.92	0.92	1.32	1.39	1.18	1.39	51.24	53.43	1.47	1.77
GO	-0.30	-0.16	0.14	Agriculture, H.F.F.	0.96	0.90	0.91	0.94	1.19	1.24	9.61	10.09	6.11	6.43
				M. and Quarrying	0.98	0.86	0.82	0.78	1.23	1.18	1.23	0.67	0.92	0.82
				Manufacturing	1.11	1.13	1.01	1.21	1.39	1.54	11.26	9.95	2.64	2.66
				SIUP	1.11	1.13	1.05	1.01	1.30	1.54	3.73	3.09	4.52	3.55
				Construction	1.04	1.12	0.91	0.84	1.27	1.49	7.21	4.59	3.73	3.72
				Trade	1.01	1.09	1.03	0.93	1.18	1.32	13.04	11.82	3.30	2.98
				Services	0.95	0.96	1.27	1.28	1.18	1.28	53.92	59.79	2.59	2.69
DF	0.35	0.70	0.35	Agriculture, H.F.F.	0.92	0.87	0.83	0.81	1.13	1.16	0.44	0.43	0.32	0.33
				M. and Quarrying	0.98	0.99	0.83	0.76	1.21	1.32	0.02	0.01	0.01	0.01
				Manufacturing	1.00	1.09	0.90	0.94	1.23	1.45	1.56	1.19	0.43	0.38
				SIUP	1.00	1.09	0.90	1.05	1.27	1.45	0.79	0.76	1.12	1.06
				Construction	1.03	1.08	0.97	0.95	1.27	1.39	4.27	2.04	2.58	2.00
				Trade	1.03	1.04	1.05	1.00	1.20	1.37	6.80	5.29	2.01	1.61
				Services	0.98	1.03	1.53	1.48	1.28	1.21	86.13	90.28	4.83	4.91

Source: Authors´own.

Figure 1 illustrates the spatial pattern of the classification of linkage indices for the manufacturing sector across Brazilian territory in 2011 and 2018. As illustrated in Figure 1, except for Mato Grosso (MT), all states in which the manufacturing sector was not classified as a key sector in 2011 are located in the country's less developed regions, namely the North and Northeast. By 2018, the pattern became more consolidated; however, a weakening of production linkages is observed in Santa Catarina (SC) and Pernambuco (PE).

Figure 1: Spatial pattern of manufacturing's linkage indexes



Source: Author's own.

To deepen the investigation of sectorial´s interdependence, Fig. 2 presents the Fields of Influence for 2011 and 2018 for all 27 Brazilian states. With this it should be possible to compare the importance of each sector in the above-mentioned period. According to Guilhoto *et al.* (2005), this method should be used in a complementary way to the Hirschman-Rasmussen´indexes. To facilitate interpretation, the results for each productive linkage were highlighted in color scales indicating above-average fields of influence, i.e., they are the most important linkages for the economy. The reading is similar to input-output matrices, i.e., the rows are the sectors that sell inputs, while the columns are the purchase sectors.

The Field of Influence (hereafter FI) was developed by Sonis and Hewings (1991). Using this method, it is possible to visualize the sectors with higher linkages in the productive structure. In other words, the purchases and sales of the sectors with a greater field have an influence on the intersectoral relationships on the other activities.

From Figure 2, it is possible to identify some patterns. In general, services and trade sectors became relatively more important for most Brazilian states in 2018. More importantly, Electricity, gas, and water supply (4) became relatively more significant in terms of forward linkage (FL). As a matter of fact, for Brazil as a whole, between 2011 and 2018, services sector (7) grew by 10.5% and the trade sector (6) by 3.9%, at constant prices (2010), in terms of value added. In contrast, manufacturing (3) shrank by 9.3%, construction (5) by 33.9%, and the extractive industry (2) by 37.15%. However, between the two periods, there was an 8.9% increase in sector 4 at constant prices and a 3.35% increase in sector 1.

In next section, we analyze the field of influence for each Brazilian state according to its macro-regional classification.

3.1. Northeast region

For Maranhão, sector (4) is the main purchaser and seller of inputs in both 2011 and 2018, with stronger intersectoral relationships with sectors (1), (2), and (6). However, in terms of sales, the strongest linkages (above average +1 standard deviation - SD) increased toward sectors (1), (2), (5), and (6). The main change in intersectoral analysis between the two periods is the loss of importance in purchases from sector (5), relative to sectors (5) and (7), which are no longer relevant in the FI, along with the loss of linkage intensity with sector (4). In Piauí, sector (4) is also the main purchaser and seller of inputs in both 2011 and 2018, with the strongest intersectoral connections with sectors (1), (2), and (6), all above average +1 SD. The most significant change between the two periods is the loss of relevant intersectoral linkages (above average +1 SD) with sectors (5) and (7).

Ceará exhibits more relevant linkages in sectors (3), (4), and (7) for both input purchases and sales during the two periods. However, it loses intersectoral connections with sector (5), while sector (7) gained greater relevance in purchasing inputs from sectors (3), (5), and (7) and in selling inputs to those same sectors. In Rio Grande do Norte, sector (4) is the most relevant in terms of input purchases and sales in both 2011 and 2018. However, in the latter year, sectors (2), (3), and (5) start to show more intersectoral connections in supply side. Sector (2) has significant linkages with sectors (3) and (4), sector (3) with sectors (2), (5), and (7), and sector (5) with sectors (3), (5), and (7), all above average +1 SD.

In Paraíba, sector (4) is the most relevant in terms of input purchases and sales in both 2011 and 2018. This state loses important intersectoral linkages in sectors (3), (5), and (7) in both input purchases and sales. Pernambuco has sectors (3), (4), and (7) as the main purchasers and sellers of inputs during both analyzed periods. There are a few losses in linkages, such as in sectors (3) and (7) for input sales.

In Alagoas, sector (4) is the main buyer and seller of inputs in both 2011 and 2018. A relevant change for this state is the loss of interconnection between sectors (5) and (7) with sector (7) itself. However, this loss is offset by the increased importance of sectors (2) and (3) relative to sector (7). In addition, there are losses in the linkages of sectors (5) and (7) in input sales to sector (5). Sergipe presents sector (4) as the main purchaser and seller of inputs in both 2011 and 2018. Additionally, sectors (3), (5), and (7) are the main purchasers and sellers of inputs in both years, with sector (2) becoming more relevant in 2018 for purchasing inputs from sectors (3) and (4).

Bahia underwent the most significant transformation in terms of the field of influence. In 2011, the state has sector (4) as the main purchaser and seller of inputs. By 2018, sector (3) has become more important in terms of both input purchases and sales. Sector (4) becomes secondary in these interconnections. Sector (3) has strong input purchases from sectors (1), (2), and (6), and sold inputs mainly to sectors (1), (2), (5), and (6).

3.2. North region

In Rondônia (RO), SIUP sector (4) exhibits the strongest intersectoral relationships in 2011 (above average), with higher input purchases (above average +1 S.D.) from sectors (1), (2), and (6), and stronger sales (above average +1 S.D.) to sector (2). In 2018, the above-average intensity remains only for purchases from sectors (1) and (6), while stronger intersectoral sales are recorded toward sectors (2) and (6). Manufacturing (3) shows linkages above average +1 S.D., despite a -2.4% decline in the sector's value added between the two years. In Acre (AC), as in RO, SIUP sector (4) has the strongest intersectoral relationships in 2011 (above average), with greater input purchases (above average +1 S.D.) from sectors (1), (2), and (6), and stronger intersectoral sales (above average +1 S.D.) to sectors (2) and — unlike RO — also to sector (6). Between the two years, there is a loss of linkages for input sales to sectors (3), (5), and (7), and for input purchases from sectors (5) and (7). This pattern is consistent with broad deindustrialization — that is, in manufacturing, construction, and extractive sectors — which declines of 15.6%, 47.7%, and 78.5% respectively between 2011 and 2018 (in value added at 2010 prices).

Amazonas (AM) presents a distinct pattern compared to other states in the North of Brazil. It is the only state that maintained intersectoral linkages in activities (3) and (4) and even expanded them in 2018 (above average +1 S.D.). This expansion mainly occurs in the input purchases and sales of sector (3) in relation to sectors (1), (2), and (6). Thus, an increase in intersectoral relations outside manufacturing is observed, while the industry itself maintains above-average linkages in sectors (3) and (4), with intensified connections to agriculture, extractive, and trade sectors. Roraima (RR) shows a pattern like AC and RO, where sector (4) is the most relevant in terms of input purchases and sales. However, in 2011, there is a strong linkage from the construction (5), which disappears by 2018. Moreover, input purchases of sector (4) intensifies in 2018 with sectors (5) and (6), as does input sales to these same sectors. Therefore, a decline in the importance of sectors (2) and (3) is observed in terms of input sales from sector (4), and in input purchases from sector (2) by sector (4) in 2011.

Pará (PA) also shows a distinct pattern of linkage distribution, similar to AM. Linkages expand for both purchases and sales of inputs in sectors (3) and (4). Furthermore, the services sector (7) presents intersectoral indicators in 2018 that are not present in 2011, particularly in relation to sectors (3) and (7) itself. This fact aligns with the leap in the services sector's share of the state GDP, which increases by approximately 6.28 percentage points. Amapá (AP) presents more relevant intersectoral connections (above average) in sector (4). This pattern remained virtually constant in 2018, with the only change being a greater volume of input sales from sector (4) to sector (6).

Tocantins (TO) is the state in the North region that loses the most linkages over the analyzed period. These losses are particularly notable in sectors (3) and (5), for both input purchases and sales. This state experiences the greatest intra-state variation in trade and services sectors between 2011 and 2018. It is important to highlight that, based on the modularity analysis conducted by Ribeiro et al. (2023), these states exhibit a certain degree of productive isolation. These authors mainly attribute this outcome to the presence of the Amazon Rainforest.

3.3. Southeast region

In Minas Gerais (MG), the number of relevant linkages in 2018 remains the same as in 2011. However, their distribution changes, with a greater concentration of input purchases and sales in sector (3) and a loss of relevant linkages in sector (7). In sector (3), this increased concentration of input purchases (relative to 2011) occurs in sectors (1), (2), and (6). Still within sector (3), the increased concentration of input sales occurs in sector (1). There are losses in input purchases from sector (5) linked to sectors (5) and (7). Regarding sector (7), there are losses in input purchases from sectors (1) and (6). In Espírito Santo (ES), important changes occur over the analyzed period regarding the loss of linkages in sector (4), both in input purchases and sales. Furthermore, sector (7) became the main purchaser and seller of inputs from all other sectors. Moreover, sectors (2), (3), (5), and (6) become more relevant as sellers of inputs.

In Rio de Janeiro (RJ), a significant reorganization of sectoral linkages takes place. Between 2011 and 2018, there are notable losses in linkages in sector (7), both in terms of purchasing and selling inputs to other sectors. Moreover, sector (3) becomes more important in terms of intersectoral connections — purchasing from sectors (3), (4), (5), (6), and (7), and selling to sectors (3), (4), (5), and (7). In São Paulo (SP), a significant change in linkage patterns occurs. While the total number of interconnections remains constant, the number of linkages in sector (7) declines in both input purchases and sales. The sectors with higher intensity (above average + 1 S.D.) gain greater relevance in sectors (3) and (4), especially in purchasing inputs from sectors (1), (5), and (6) simultaneously. Additionally, the sales of inputs from sectors (5) and (7) to sector (7) gain greater relevance.

3.4 South region

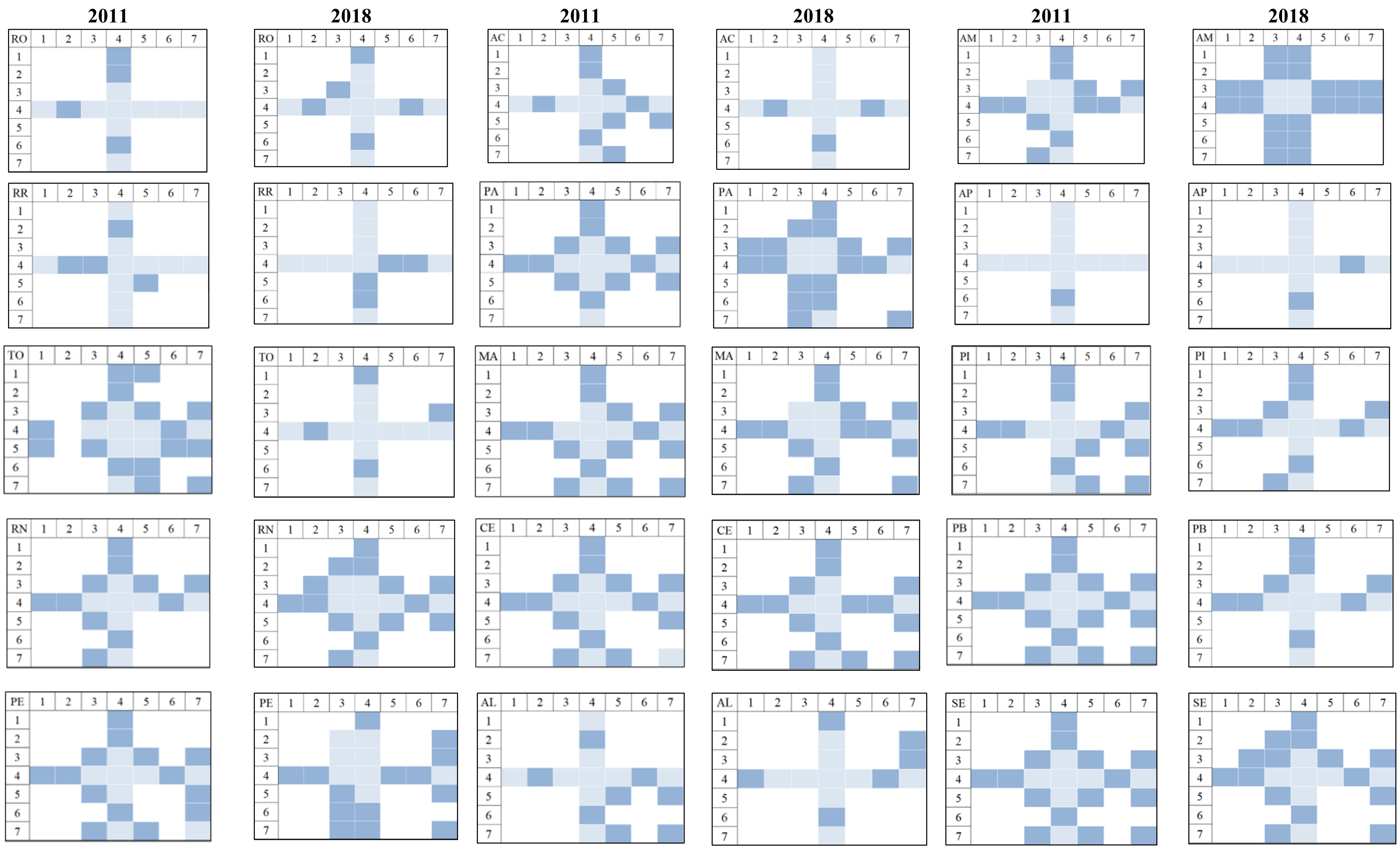
In Paraná (PR), sectors (3) and (4) become more important input buyers, to the detriment of sector (7), which loses linkages in both input purchases and sales. Sectors (3) and (5) become more important input sellers in 2018. In Santa Catarina (SC), sector (4) gains greater importance in input sales, while maintaining the same level of importance in input purchases. There are losses in linkages for sector (5) in terms of input purchases from sectors (3), (5), and (7). In Rio Grande do Sul (RS), significant losses in linkages are observed in 2018 for input purchases by sector (7) from sectors (1), (2), and (6). Additionally, sector (2) develops relevant linkages with sectors (3) and (4), replacing its 2011 linkages with sector (7). According to Ribeiro et al. (2023), these states exhibit the highest degree of sectoral interconnectedness with the rest of the country.

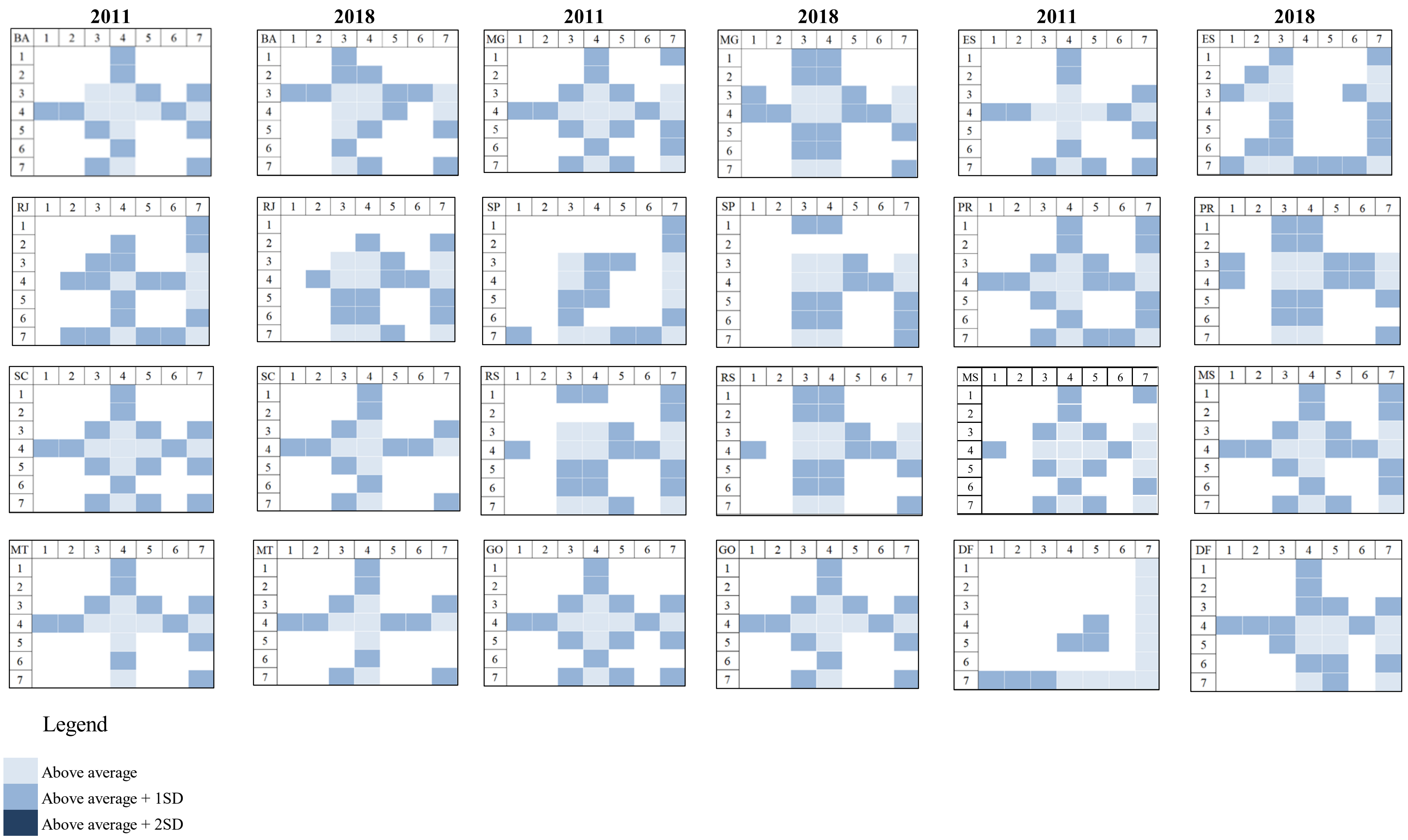
3.5 Midwest region

Important changes can be observed in Federal District (DF). In 2011, the main input buyers and sellers are concentrated in sector (7), with few relevant linkages, limited mainly to sectors (3) and (4). However, in 2018, sector (4) intensifies its interdependence with other sectors. Additionally, sector (5) becomes an important supplier of inputs to sectors (3), (4), (5), and (7). This same sector also becomes a significant buyer of inputs from sectors (3), (4), (5), (6), and (7). Goiás (GO) maintains an almost constant distribution of importance among its sectors. The main change is the loss of linkages in input sales from sectors (5) and (7) to sector (5). Mato Grosso (MT), the importance of sector (4) maintains across both periods. There is a decrease in the importance of input sales from sector (5) to sector (7) and a gain in the relevance of input sales from sector (7) to sector (5).

Finally, Mato Grosso do Sul (MS) exhibits a pattern that contrasts with those of GO and MT, as it increases the interconnections of sectors (4) and (7), with the only observed loss being the linkage of sector (5) with itself.

Figure 2 – Field of influence for Brazilian states – 2011 and 2018





Source: Author’s own based on IOM.

5. Multivariate analysis from IO results.

Expression (5) presents the calculation of the Total Field of Influence (CIT) of sector i:

$$CIT_i = \sum_{j=1}^{7} M[i,j] + \sum_{j=1}^{7} M[j,i] \quad (5)$$

Using expression (5), we can better analyze the systemic centrality of sector i in Brazilian productive structure, that is, by how much it affects (first part of (5)) and is affected (second part of (5)) by all other sectors. Therefore, the row of the matrix ($\sum_{j=1}^{7} M[i,j]$) shows how much the sector influences other sectors, and the column ($\sum_{j=1}^{7} M[j,i]$) of the matrix shows how much the sector is influenced by others. In this way, the fields of influence are recalculated with this corrected definition (sum of the row + sum of the column) for all 27 states in 2011 and 2018, and then we perform a correlation analysis with the ICR, as shown in Table 2.

Table 2 - Correlation between Total Field of Influence (CIT) and Economic Complexity (ICR)

Setor	Corr. with ICR 2011	p-valor	Corr. with ICR 2018	p-valor
Agriculture	–0.16	0.438	+0.27	0.174
Mining	~0.00	0.999	+0.05	0.823
Manufacturing	+0.78	0.035	+0.52	0.024
Utilities	+0.12	0.565	+0.35	0.074
Construction	–0.19	0.347	+0.08	0.680
Trade	+0.17	0.387	+0.47	0.013
Services	+0.41	<0.001	+0.43	0.002

Source: Authors ‘own.
Note: n=1,350 (in 2011 and 2018).

These results suggest that manufacturing remains the sector most correlated with regional economic complexity (at aggregate level), with statistical significance in both years. The correlation of other sectors has either declined or become statistically insignificant, showing that mutual influence (row + column) reinforces the centrality of manufacturing within the productive structure. SIUP sector gains strength in 2018 but remains at the threshold of significance ($p \approx 0.07$).

These findings suggest that the greater the manufacturing sector’s capacity to productively link to other sectors, the higher the economic complexity of a state tends to be. Manufacturing is historically associated with goods of high technological content and knowledge — therefore, its articulated presence signals productive sophistication (Gabriel *et al*., 2020).

SIUP sector (electricity, gas, and water) shows a moderate positive correlation with the ICR in 2018 (+0.35), with a marginally significant p-value. This suggests that a well-integrated energy infrastructure, when connected to productive sectors, can support economic complexity, even if indirectly. In 2011, this effect was weaker.

Construction has a negative correlation in 2011, which turned positive (though weak) in 2018. This result indicates that this sector — traditionally viewed as labor-intensive and low in technological content (in Brazil) — has gained a more strategic role, supporting more complex sectors in recent years. This may reflect public investments made under the Growth Acceleration Program (*Programa de Aceleração do Crescimento* – PAC) between 2007 and 2014 (Ribeiro and Leite, 2014).

The Extractive sector shows an almost null or very weak correlation in both years. Although it is an important sector in several states (mainly in MG and PA), it tends to have limited productive linkages, focused on exports with low local value-added. This is consistent with the idea that extractive sectors, in isolation, do not increase economic complexity (Gabriel and Missio, 2019).

Agriculture evolved from a negative correlation in 2011 to a positive one in 2018. This likely reflects the process of modernization and vertical integration of agriculture in several states, with the incorporation of agro-industries, logistics, and technologies that enhance productive linkages and local sophistication, especially in those states located in the Midwest.

The most robust finding concerns manufacturing: in regions where it holds greater influence— both as a supplier and a demander of inputs — economic complexity tends to be higher. Sectors such as SIUP and construction, although traditionally not considered sophisticated, begin to correlate with complexity when they function as structural support platforms. In contrast, primary sectors such as traditional agriculture and mining contribute to complexity only when they are integrated into more elaborate value chains.

Statistical analysis revealed the following correlations between the ICR and economic multipliers: i) ICR and MP: Moderate positive correlation (~0.52). This suggests that states with greater economic complexity tend to have higher output multipliers, indicating that increases in final demand in these states result in significant increases in total output; ii) ICR and BL: Moderate negative correlation (~-0.47). This may indicate that states with greater economic complexity depend less on inputs from other industries, possibly due to a more diversified and self-sufficient production base; and iii) ICR and FL: Slightly negative correlation (~-0.27). This suggests that states with greater economic complexity do not necessarily provide inputs and outputs that are widely used by other industries, which may indicate a specialization in certain products.

Equation (6) of the Sectoral Influence Field (CIS) measures the impact of variations in the technological matrix. The formulation is given by:

$$FI_{ij} = \frac{\partial L}{\partial a_{ij}} = L\ E^{ij}\ L \qquad (6)$$

Where, $L = (I - A)^{-1}$ is the Leontief Inverse matrix; $A = [a_{ij}]$ is the Technological matrix, with a_{ij} indicating the quantity of the output of sector i to produce a unit of sector j; E^{ij} is a matrix with 1 in position (i, j) and zeros in the others and, finally, $L\ E^{ij}\ L$ represents the total impact of a variation in a_{ij} on the entire matrix L. Table 3 presents the correlation between CIS and ICR considering all Brazilian States.

Table 3 - Pearson Correlation (PC) between CIS and ICR (2011 and 2018)

Sector	PC (2011)	p-value (2011)	PC (2018)	p-value (2018)
Agriculture	0.077	0.701	0.177	0.377
Mining	0.153	0.447	0.048	0.814
Manufacturing	**0.611**	**0.001**	**0.618**	**0.001**
Utilities	-0.190	0.341	-0.027	0.892
Construction	0.017	0.934	**0.441**	**0.021**
Trade	0.072	0.720	0.091	0.651
Services	0.140	0.489	0.119	0.559

Source: Author´own.

The manufacturing industry maintained the highest positive and significant correlation with the ICR in 2011 and 2018, reinforcing its role as a pillar of regional complexity. Construction became significant in 2018, which may indicate its role in supporting economic complexity. Trade and Services, despite being relevant in terms of employment and GDP, did not show significant correlations with the ICR, suggesting low articulation with more sophisticated production chains, through the SIF linkages. The other sectors (Agriculture, Mining and SIUP) also did not show significant correlations, which is consistent with their more basic production profiles or those focused on commodity exports.

The variance decomposition (Welsh) of ICR for all Brazilian states, in Table 4, shows how the variation in economic complexity (VAR) can be explained by variations in intra-state and inter-state %, BL and FL and Output Multiplier:

Table 4 – Welsh variance decomposition considering ICR (var)

Variável	F	p-valor
% intra (2011 – 2018)	0.53	0.47
% inter (2011 - 2018)	0.10	0.76
BL (2011 – 2018)	5.16	0.034
FL (2011 – 2018)	8.53	0.008
Output multiplier (2011 – 2018)	5.26	0.032

Source: Author´own.

Production chains (BL and FL) and the output multiplier (OM) significantly explain the variation in complexity between 2011 and 2018, considering all Brazilian states over the analyzed years. Therefore, the productive structure (intra/inter) alone does not explain the change in complexity, when considered BL, FL, and OM. Considering a simple panel data model with fixed effects, such as:

$$\Delta eci_{it} = \beta_{1it} + \beta_{2it}\Delta \text{intra}_{it} + \beta_{3it}\Delta \text{inter}_{it} + \beta_{4it}\Delta \text{BL}_{it} + \beta_{5it}\Delta \text{FL}_{it} + \beta_{6it}\Delta \text{OM}_{it} + \mu_{it} + \eta_{it} \quad (7)$$

Based on this specification (7, the following results are found (*n*=1,917):

Table 5 – Equation (7) estimation model for (ΔECI)

Var	Coef	S.D.	t-value	p-value
Intercept	-0.238253	0.069561	-3.425068	0.002544
Delta_Intra	0.020625	0.029345	0.702847	0.489870
Delta_Inter	0.061653	0.047237	1.305175	0.205954
Delta_BL	-2.554790	0.868769	-2.940701	0.007809
Delta_FL	1.947583	0.901464	2.160467	0.042444
Delta_OM	3.018962	0.756153	3.992530	0.000661

The Breusch-Pagan test presented a LM Statistic: 2.28; LM-Test p-value: 0.8087; F-Statistic: 0.39 and F-Test p-value: 0.8514. The JB Statistic: 0.10; JB p-value: 0.9502; Skewness: 0.10 and Kurtosis: 3.23. The average VIF was under 3.0.
Source: Author´own.

Table 5´s estimation indicates that the Backward Linkage (BL), Forward Linkage (FL) and Output Multiplier (OM) have statistically significant effects on the variation in regional economic complexity (Var) in 2018. The intrastate (Intra) and interstate (Inter) shares did not present statistical significance, suggesting a limited influence in this context.

The Breusch-Pagan test indicates the absence of heteroscedasticity, which supports the reliability of the standard errors. The Jarque-Bera test confirms the normality of the residuals, validating the statistical tests. The VIF values indicate moderate multicollinearity, with OM being the variable with the highest VIF.

These results suggest that the structural change in the Brazilian economy plays a relevant role in explaining regional variation in the ICR between 2011 and 2018 (as seen in the CIT vs. ICR comparison, e.g.). However, when the variation in the ICR is analyzed in terms of backward and forward linkages (BL and FL), and considering each state's sectoral composition, these linkages prove to be statistically significant determinants of ICR variation, unlike the isolated variation within or across s states (i.e., Δintra_{it} and Δinter_{it}). In other words, structural change matters, but its effect on Δeci_{it} is conditional on the influence of BL and FL.

5. Final remarks and policy implication

Our empirical results showed that regional economic complexity in Brazil, as measured by the Index of Regional Economic Complexity (ICR), is strongly associated to the productive structure and intersectoral linkages of their states. Between 2011 and 2018, significant structural change was observed: while the services sector increased its share in GDP, manufacturing lost centrality, both in value added and, in its capacity to influence other economic sectors.

Statistical analyses indicate that the Output Multiplier (OM) has a moderate positive correlation to ICR, suggesting that more complex states also tend to generate greater economic impacts in response to demand shocks. On the other hand, the backward (BL) and forward linkages (FL) indexes show negative correlations to ICR, which may reflect greater self-sufficiency and specialization in niche goods in more complex regions.

The Welsh variance decomposition confirms that the evolution of the ICR over time is mainly explained by linkages and output multipliers (BL, FL, and OM), and not by simple intra- or interstate sectoral redistribution. In other words, structural change matters, but its effects on regional complexity depend on how sectors are articulated through their productive linkages.

Sectoral analysis reinforces the central role of manufacturing, which maintains the highest correlation to the ICR, even in the face of its relative decline. In contrast, sectors such as agriculture and mining only contribute to complexity when integrated into more sophisticated production chains.

Our empirical evidence indicated that states such as Acre (AC), Rondônia (RO), Tocantins (TO), Paraíba (PB), and Roraima (RR), located in the Brazilian poorer regions, are caught in a structural trap of low to medium economic complexity. This condition stems from a pattern of regressive productive specialization, characterized by persistent concentration in primary or low-value-added sectors with limited intersectoral linkages. Despite modest increases in their Index of Regional Economic Complexity (ICR) between 2011 and 2018, these states continue to exhibit the lowest complexity scores in the country. This suggests that structural change has either been insufficient or has occurred in directions that do not foster technological upgrading or diversification.

The relatively high values of BL and FL indexes observed in these regions do not reflect dense or sophisticated productive ecosystems. Rather, they are indicative of a dependence on inputs from and sales to a narrow range of low-complexity sectors, frequently associated with natural resource extraction or basic agricultural production. The analysis of economic multipliers reinforced this diagnosis: although some states register high OM values, these gains are not coupled with significant shifts in industrial integration or complexity-enhancing trajectories.

This regressive specialization implies that productive expansion occurred predominantly in sectors with limited potential for technological diffusion or innovation spillovers. Consequently, these states remain vulnerable to commodity cycles, suffer from low productivity growth, and struggle to ascend in the complexity hierarchy. Breaking out of this trap will require targeted industrial policies that strengthen regional value chains, promote diversification toward more complex activities, and build institutional capacity to support structural transformation.

In the absence of official interregional input-output (IRIO) tables, one of the main limitations of this study is that the results were based on estimated IRIO matrices, which may not accurately reflect the actual regional productive structures. For this reason, efforts by statistical agencies to produce official input–output matrices at the regional level would directly enhance the quality of information and, consequently, support more accurate and effective public policy design.

In summary, this study showed that regional development policies should consider not only sectoral diversification but also the intensity and direction of productive connections between sectors. Promoting sectors with a strong capacity to generate and absorb inputs — such as the manufacturing and SIUP sectors — is essential to increase economic complexity and reduce regional heterogeneity in Brazil.

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Appendix 1 – Sectoral aggregation

Original Classification	Aggregation	
1 Agriculture, including support activities and post-harvest services 2 Livestock, including support activities 3 Forestry, fishing, and aquaculture	(1+2+3) Agriculture, Hunting, Forestry and Fishing	1
4 Mining of coal and non-metallic minerals 5 Extraction of petroleum and natural gas, including support activities 6 Iron ore mining, including beneficiation and agglomeration 7 Non-ferrous metal ore mining, including beneficiation	(4+5+6+7) Mining and Quarrying	2
8 Slaughtering and meat products, including dairy and fish products 9 Sugar manufacturing and refining 10 Other food products 11 Beverage manufacturing 12 Tobacco products manufacturing 13 Textile manufacturing 14 Apparel and accessories manufacturing 15 Footwear and leather products manufacturing 16 Wood products manufacturing 17 Pulp, paper, and paper products manufacturing 18 Printing and reproduction of recordings 19 Petroleum refining and coke manufacturing 20 Biofuel manufacturing 21 Manufacture of organic and inorganic chemicals, resins, and elastomers 22 Manufacture of pesticides, disinfectants, paints, and other chemicals 23 Manufacture of cleaning products, cosmetics/perfumes, and personal hygiene products 24 Pharmaceutical and pharmaceutical chemical manufacturing 25 Rubber and plastic products manufacturing 26 Non-metallic mineral products manufacturing 27 Pig iron/ferroalloy production, steelmaking, and seamless steel tubes 28 Non-ferrous metal metallurgy and metal casting 29 Fabricated metal products manufacturing, except machinery and equipment 30 Manufacture of computer equipment, electronic, and optical products 31 Electrical machinery and equipment manufacturing 32 Machinery and mechanical equipment manufacturing 33 Manufacture of automobiles, trucks, and buses, except parts 34 Manufacture of parts and accessories for motor vehicles 35 Manufacture of other transport equipment, except motor vehicles 36 Furniture and miscellaneous manufacturing 37 Maintenance, repair, and installation of machinery and equipment	(8+9+10+...+35+36+37) Mafacturing Industry	3
38 Electricity, natural gas, and other utilities 39 Water supply, sewage, and waste management	(38+39) Electricity, Gas and Water Supply	4
40 Construction	(40) Construction	5
41 Trade and repair of motor vehicles and motorcycles 42 Wholesale and retail trade, except motor vehicles	(41 + 42) Trade	6
43 Land transport 44 Water transport 45 Air transport 46 Storage, transport support activities, and postal services 47 Accommodation 48 Food services 49 Publishing and integrated printing 50 Television, radio, cinema, and sound/image recording/editing activities 51 Telecommunications 52 Software development and other information services 53 Financial intermediation, insurance, and supplementary pensions 54 Real estate activities 55 Legal, accounting, consulting, and head office activities 56 Architectural, engineering, technical testing/analysis, and R&D services 57 Other professional, scientific, and technical activities 58 Non-real estate rentals and intellectual property asset management 59 Other administrative and support services 60 Security, surveillance, and investigation activities 61 Public administration, defense, and social security 62 Public education 63 Private education 64 Public health 65 Private health 66 Artistic, creative, and performance activities 67 Associative organizations and other personal services 68 Domestic services	(43+44+45+...+65+66+67+68) Services	7

Source: Author's own.