PRODUCTIVE INTERDEPENDENCE AND STRUCTURAL CHANGE IN BRAZIL: AN EMPIRICAL ANALYSIS

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RESUMO:

Este artigo tem como objetivo analisar a interdependência produtiva em termos multissetorial e a mudança estrutural do Brasil aplicando métodos de insumo-produto (IO), como, multiplicadores, índices de encadeamento e Análise de Decomposição Estrutural (SDA). Além disso, as estimativas de dados em painel são aplicadas para esclarecer como os setores afetam a complexidade econômica. Os principais resultados sugerem um reduzido processo de convergência intersetorial em termos de crescentes vínculos serviços-indústria e um processo de desadensamento na indústria. A manufatura está perdendo a intensidade e a importância do multiplicador em relação aos serviços, apesar do menor impacto deste último setor sobre a complexidade econômica. Além disso, verificou-se que a grande maioria da variação total da produção no Brasil se deve à variação da demanda final, e não à variação tecnológica. Finalmente, a mudança estrutural com maior interdependência entre serviços e manufatura sugerem um padrão de aumento do crescimento, mas isso não foi verificado no Brasil.

Palavras – Chave: Mudança estrutural; método Insumo-Produto; Interdependência produtiva; Crescimento econômico.

ABSTRACT:

This paper aims to analyze Brazil's multisectoral productive interdependence and structural change by applying input-output (IO) methods, such as multipliers, linkages indexes and Structural Decomposition Analysis (SDA). Furthermore, panel data estimations are applied to shed light on how sectors affect economic complexity. The main findings suggest a reduced inter-sectoral convergence process in terms of growing service-manufacturing linkages and a de-densification process in the industry. Manufacturing is losing the multiplier's intensity and importance compared to services, albeit the less impact of this last sector over economic complexity. Furthermore, we verified that the vast majority of the total output change in Brazil is due to final demand change, not technological change. Finally, structural change and interdependence between service and manufacturing suggest a growth-enhancing pattern, but this was not verified in Brazil.

Keyword: Structural change; Input-Output method; Productive interdependence; Economic growth

JEL: C23; C67; L16.

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1. INTRODUCTION

According to the Brazilian Institute of Geography and Statistics (IBGE), service sector accounted for 70% of the Brazilian GDP in 2021[4]. It is a very heterogeneous sector with a low concentration of economic activities. There are a few activities whose market structure registered a high degree of concentration, such as air transport, pipeline transport, rail and subway transport mail and other delivery activities. In 2019 (last available data), wholesale and retail trade (except motor vehicles), real estate activities, public administration, defense, and social security had the greatest share in terms of constant gross value added within this sector (IBGE, 2019).

Services in general and some categories of producer services (such as business services, financial services, and communication services, among others) and trade have been among the fastest growing segments of the economy in the last decades (Ouwsu *et al.*, 2020). However, Guerrieri and Meliciani (2005, p. 489) explain that a country's capability to develop an internationally competitive and modern service economy depends on the structure of its manufacturing sector as some manufacturing industries are more intensive users of these services. These authors argue that there is a virtuous cycle as the same service producers are also intensive users of these producer services. Therefore, there are important interdependences between manufacturing industries and the service sector as well as within the producer services sectors, mainly through knowledge and information-intensive sectors.

Structural change toward knowledge and information-intensive economic activities produces higher capabilities in different economies through linkages effects, spillovers, research and development (R&D), more efficient resource reallocation, higher skilled jobs with better human capital, and international trade**.** This process boosts economic complexity and economic growth (Hausmann *et al.*, 2011). However, structural change effects are not homogeneous within sectors, i.e., service and manufacturing differ concerning its impacts on income, employment, production and the degree of influence on purchases and sales of inputs among different sectors (i.e., in terms of the interdependence degree among sectors) as well as linkages.

The main objective of this paper is to analyze the multisectoral productive interdependence and structural change in Brazil by applying input-output (IO) methods, such as linkages indexes, income, employment and production multipliers and Structural Decomposition Analysis (SDA) considering two different periods (2000 and 2018). Furthermore, panel data estimations are applied[5], considering the previous sectors in aggregated terms, presenting the dynamics effects over developing (including Brazil) as well as developed countries.

The above-mentioned investigation is conducted using constant prices input–output (IO) matrices considering 42 sectors and panel data estimations for 51 countries, that is, 38 developing countries (Brazil included) and 13 developed countries from 1960 to 2019. The econometric analysis for different samples of countries will shed more light on the Brazilian economy (our main focus). Furthermore, the greater time span and chosen econometric method, as will be explained, avoid potential econometric problems.

It is important to highlight that one of the main contributions of this paper is to use input-output (IO) analysis and econometric estimations in a complementary way to offer results that contemplate different characteristics concerning productive interdependence and structural change in Brazil from a multisectoral perspective. The production structure of emerging economies is an important field of research because it enables the assessment of sectoral policies and advises policymakers in order to support sustained economic growth in the long-term.

2. PRODUCTIVE INTERDEPENDENCE AND STRUCTURAL CHANGE

There is a growing literature presenting the increasing importance of the service sector in the world as a source of economic dynamism and development (Maroto-Sanchez and Cuadrado-Roura, 2009; Szirmai and Verspagen, 2015; Perobelli *et al.*, 2016). Service sectors account, on average, for over 60% of GDP in

[4] In sharp contrast, in Brazil manufacturing industries accounted for 11,3% of national GDP, according to National Industrial Confederation (CNI) in the same period.

[5] As will be explained in section 5 time series analysis just for Brazil is not the best econometric method that would assure statistical robustness, given the article´s objectives and econometric issues.

advanced economies, and some activities such as software development, financial services, and tourism, among others, play important roles as leading economic activities that boost economic growth (Dasgupta and Singh, 2005). Timmer and Vries (2008) also highlight the increasing importance of the service sector in a sample of countries in Asia and Latin America. Moreover, the rise of global value chains (GVC) and its growing geographical fragmentation of production have increased the service contents of many manufactured goods (Duggan *et al.* 2013).

In order to understand the growing importance of services in economic development, it is necessary to understand the role played by each sector in different stages of development and the importance of knowledge-intensive services in the recent period. There is a great variety of explanations for the fact that services have become relatively more important in developed countries. In general, in the later stages of development, i.e., when countries achieve higher levels of *per capita* income, there is a greater driving for the demand of services given the high-income elasticity of demand for services (Rowthorn and Ramaswamy, 1997).

Differently, in the early stage of development, as *per capita* income grows in dual developing economies, the sector with the highest relative share becomes the industrial sector. Rowthorn and Ramaswamy (1997) highlight two factors that explain this change: i) the effect of Engel´s Law, that is, the proportion of income spent on goods in the agricultural sector declines while *per capita* output increases, causing a change in the pattern of demand from agricultural products to industrial products and services and ii) on the supply side, the rapid growth of labor productivity in agriculture means that fewer workers are needed, shifting them to the service sector, but mainly for the industrial sector in the early stages of the industrialization process.

This pattern of interaction between demand and supply in the economy as *per capita* income rises drives more demand for the service sector. Foster-McGregor and Verspagen (2016), Diao, McMillan and Rodrik (2017), Owusu, Szirmai and Foster-McGregor (2020), among others, explain that this trend generates further increase for intermediate service inputs by other economic sectors (as in manufacturing). Meanwhile the demand for services, in general, is also rising. This means that manufacturing productivity depends on the performance of firms within its sectors themselves but also on upstream services as intermediate inputs and downstream services linking producers and consumers (Beverelli *et al.*, 2017).

The above-mentioned process means an inter-sectorial convergence as manufacturing activities are more service-oriented or service-dependent, and the service sector is a more intensive user of manufacturing producer services. In aggregated terms, Rowthorn and Ramaswamy (1997) formalized the economic growth process, in which there is an increase in the industrial sector share and linkages in the early stages of economic development and subsequently de-industrialization and transition to an economy where the services sector is dominant in the later stages, with higher income. Rowthorn and Wells (1987) also explain that this process may be related to a higher stage of development where the level of *per capita* income is, as a rule, higher.

Rowthorn and Ramaswamy (1997) and Szirmai (2012) explain that the greater importance of services and the decreasing share of manufacturing in the developed economies was observed mainly in the late 1960s and throughout the 1970s. Notwithstanding, as the authors observed, it was not just linked to a change in the aggregate consumption pattern of the industrial sector to the services sector or the pattern of North-South international trade. Instead, it mainly reflected the impact of differential productivity growth (and technological progress) between manufacturing and services. This productivity increased consistently faster in manufacturing. Then, the services sector absorbed a greater proportion of employment to keep its output rising (Rowthorn and Ramaswamy, 1997, p.12; Rodrik, 2016, p.3).

Rowthorn and Ramaswamy´s (1997 and 1999) emphasis on the productivity differential as the leading cause of the structural change process is different from the causes pointed out by Clark (1957), Sachs and Schatz (1994), Wood (1994 and 1995) and Saeger (1996). According to Clark (1957) the main causal factor of change in the productive structure is related to the change in the composition of demand. In this case, this author extrapolates Engel´s Law to the greater demand for manufactured goods so that higher income levels imply a greater demand for manufactured goods and services. At higher income levels, spending on manufactured goods may stabilize or decline when relative employment in the manufacturing industry falls.

Sachs and Schatz (1994), Wood (1994 and 1995), and Saeger (1996) emphasize "North"-"South" (i.e., developed and developing, respectively) international trade as having a significant role in the decreasing importance of manufacturing. In this case, a service-oriented economy with a decreasing manufacturing share in advanced countries would occur because of the importation of more labor-intensive (and less qualified) products from the South, reducing the participation of similar, less competitive manufacturing sectors in the North. In this scenario, productivity, and employment gains in the more capital-intensive manufacturing industry in the North would not offset this loss. However, to Rowthorn and Ramaswamy (1999), this pattern of exchanges between developed and developing economies explains less than 20% of the deindustrialization (and a growing service share) process in advanced economies.

Another reason for the growing importance of services in developed countries is related to the servicification of the manufacturing industries and its growing interdependence. In this process, these industries demand more services for production[6], trade, distribution, and fiscalization, as well as legal problem resolution (Chang, 2014; Silva and Perobelli, 2018). In other words, services would be more integrated into manufacturing (Cuadrado-Roura, 2013; Pilat and Wölfl, 2005; Chang, 2014). Therefore, this suggests that manufacturing is using more intermediate services and employing a rising number of service-related companies and workers[7].

For Owusu, Szirmai and Foster-McGregor (2020), Guerrieri and Meliciani (2005), and Antonelli (1998), communication, business services, and financial services have been considered as knowledge and information-intensive economic activities. They have been recognized as providers of strategic inputs. Several studies have shown that the depth, share, liquidity, and quality of financial services is critical to raise aggregated investment and economic growth (Levine e Zervos, 1998, King e Levine, 2003 and Levine, 2004).

Knowledge-Intensity Business Services (KIBS) are central in advanced economies because they have producers of information and services capable of spreading knowledge to other companies and sectors. As knowledge-intensive activities, they are often linked to new technologies acting in the design of innovation processes in different networks[8]. Therefore, they contribute to increasing the overall productivity of economies (Miles, 2000). Moreover, increasing the firms' capabilities related to their innovative activities and productive knowledge promotes the diversification and sophistication of the goods and services, increasing economic complexity (Hausman *et al.*, 2011). This increase allows better performance in international trade and economic growth.[9]

Besides servicification of the economies, there is the possibility of the fragmentation of production to other countries because of different advantages related to the production and distribution costs (such as those related to transport and imports) and multilateral agreements[10]. In general, this means greater international labor division, where developed countries transfer less technologically advanced economic activities and more standardized inputs or intermediate steps of production to developing countries (Silva and Perobelli, 2018). For developed countries, this process resulted in a decrease in vertical integration.

This fragmentation process can also occur within economies, generating a productive interdependence due to a process of specialization that increases the technical and social division of labor in different sectors (and firms). About this process, Guerrieri and Meliciani (2005) tested whether a particular manufacturing sector structure, with a competitive advantage in those industries that intensively

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[6] Such as design, Research and Development (R&D), branding, logistics, consultancy, finance, accounting, telecommunication and so on.

[7] For an analysis of this process for European countries, see Pilat and Wölfl (2005).

[8] According to Freire (2006), taking into account IBGE classification in Brazil, are KIBS activities: telecommunications, computer activities, consulting in computer systems, development of computer programs, data processing, database activities, maintenance and repair of office and computer machines, technical services to firms, legal activities, accounting and auditing, market and public opinion research, shareholding management, business management consultancy, architectural and engineering services and specialized technical advice, material and product testing and advertising. These activities are in sectors 34, 35, and 37 in the following sections.

[9] In section 5, this point is treated econometrically and will help to understand how different sectors impact economic complexity in Brazil.

[10] The relocation of the value chain to developing countries has fragmented international production in coordinated networks. The latter is also known as global value chains. For further discussion on this topic, we recommend Unctad (2013).

use producer services, is an important source of international competitiveness in financial, communication, and business services. According to the authors, this could occur because of the stimulus coming from a higher level of intermediate demand and the knowledge flows associated with forwarding linkages or spillovers (ibidem, p. 495).

Moreover, Guerrieri and Meliciani (2005) estimated the determinants of international specialization and competitiveness in producer services (such as communication and business services). They found that for specialization, labor costs over production were not relevant. However, the services use of services (i.e., intermediate demand from other services), information and communication technologies (ICTs), and manufacturing use of services (i.e., intermediate demand from the manufacturing sector), were relevant (in this order of importance). Moreover, when considering the exports share, the most important variables were ICT, manufacturing use of services, and labor costs overproduction. [11]

Specifically, about the manufacturing use of services, the third most important in the above-mentioned work, Bryson and Daniel (2010) define them as intermediate inputs (production-related services, such as insurance, legal consulting, insurance, finance, and business services, ICT services) and services developed to support new products (such as training and maintenance support for new goods).

Di Berardino and Onesti (2018), considering the six main member countries in the Organization for Economic Cooperation and Development (OECD), found evidence of a trend toward greater integration between manufacturing industries and services, given its importance on the supply of intermediate inputs. Moreover, the density of inter-industry integration (linkages) between manufacturing and services has continued to increase, considering countries with different levels of development in different periods (Owusu *et al*., 2020).

In general, Guerrieri and Meliciani (2005) argue that the manufacturing industries of each country affect performance in producer services and have important implications because the ability to develop an efficient and dynamic service economy is linked to the structure of its manufacturing sector. More specifically, they found that knowledge-intensive industries (such as office and computing machinery, professional goods, electrical apparatus and radio, TV and communication equipment, industrial chemicals, and drugs) are the main users of producer services.

Based on this analysis, the authors observed that it becomes challenging to develop a competitive service economy independent of the national manufacturing structure. Therefore, the specialization of the services developed within a country will impact international competitiveness and economic performance in producer services, which, in turn, depends on how intensely service industries use their producer services. In other words, producer services are the main users of other producer services, that is, there are complementarities and self-enforcing mechanisms in the development of these economic activities. In this sense, measuring the production, employment, income, field of influence (in terms of links and intensity), structural decomposition analysis and the effects of each sector on economic complexity is essential. The following sections apply input-output (IO) methods and econometric analysis from a multisectoral perspective to evaluate these questions.

3. HIRSCHMAN-RASMUSSEN (HR)´S INDEX, PRODUCTION, EMPLOYMENT, AND INCOME MULTIPLIERS

There is a range of methods that measure intersectoral linkages (Cella, 1984; Chenery & Watanabe, 1958) in order 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).

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

[11] Specialisation is the share of exports in a given sector over total country exports. At the same time, competitiveness is the share of a given country´s exports over total exports (of all countries) in the same sector (the absolute advantage index). In order to measure inter-sectoral linkages, the authors used the OECD input–output database. The OECD international trade in services database. Data on labor costs, production, and value-added were taken from the OECD STAN database. The author´s research took into consideration 11 countries and 8 years.

linkages through the supply and demand of inputs has gained importance as a strategy for economic growth to be followed (Perroux, 1955; Rasmussen, 1956; Hirschman, 1958; Chenery and Watanabe, 1958).

Hirschman (1958) and Prado (1981) have argued that sectors with simultaneously high backward and forward linkages will be capable of leading the growth process. According to these definitions, the growth of industry *i* generates the growth of industries that purchase its goods and provide inputs. Following this logic, the empirical basis used by Hirschman was the input-output matrices. Thus, we have chosen Hirschman-Rasmussen's indexes and the Field of Influence to measure the role of 42 Brazilian sectors in terms of their linkages.

Therefore, in this section, we calculate two intersectoral linkages: Hirschman-Rasmussen's indexes (HR) and the Field of Influence in section 4. The former was suggested by Rasmussen (1956) and Hirschman (1958) and measures the dispersion power of the backward and forward linkage's effects on 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:

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

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 above the average and those below the total average. Therefore, it can be analyzed through a limit value usually estimated in 1 (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).

Furthermore, two ways are mentioned in the literature to identify key sectors more precisely: the restricted and the unrestricted. The restricted concept is adopted, that is, if both values are greater than 1, the industry is considered a key sector since it causes a backward and forward linkage effect above the economy average (McGilvray, 1977).

The Field of Influence, on the other hand, was developed by Sonis and Hewings (1991). With 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 in 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[12] ε , in each isolated a_{ij}, i.e., ΔA is a Matrix $E = |\varepsilon_{ij}|$, 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 variationε. Thus, the Field of Influence of each coefficient is plotted in equation 3, while the total influence of each technical coefficient of the input-output matrix 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.

In order to calculate the HR linkage indexes, the Fields of Influence, the multipliers and the SDA analysis we use the input-output matrices of 42 sectors estimated by Alves-Passoni and Freitas (2020) at constant prices for the years 2000 and 2018.

Table 1 presents the results of Hirschman and Rasmussen's indexes for 42 sectors in 2000 and 2018 in Brazil.

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[12] We adopt $e = 0.001$.

It is noteworthy that in 2000 Brazil had six key sectors (i.e., 5, 11, 13, 15, 19, and 32), five of them from the manufacturing industry. The same happened in 2018; that is, Brazil also had six key sectors (i.e, 5, 13, 15, 21, 29, and 32), five of them in the manufacturing industry, albeit the rise of importance of sector 29. Sectors 11 and 19 lost their importance, mainly through the decrease in their forward linkage. Otherwise, sectors 21 and 29 increased their importance mainly through forward and backward linkages, respectively.

According to Prado (1981) and Guilhoto *et al.* (2005), key sectors should be considered strategic in terms of driving economic growth.

Table 1 - Hirschman-Rasmussen´s Index – 2000 and 2018 – 42 sectors for Brazil

	Sectors	BL		FL	
		2000	**2018**	**2000**	**2018**
1	Agriculture, forestry, forestry, livestock and fisheries	0,85	0,93	1,64	1,69
2	Oil and gas extraction, including support activities	0,93	0,91	1,03	1,11
3	Iron ore extraction, including beneficiation and agglomeration	1,04	0,94	0,59	0,64
4	Others from the extractive industry	1,13	1,02	0,73	0,70
5	Food and Beverages	1,29	1,28	1,15	1,16
6	Manufacture of tobacco products	1,21	1,22	0,59	0,56
7	Manufacture of textile products	1,11	1,08	0,98	0,88
8	Manufacture of garments and accessories	1,00	0,98	0,57	0,58
9	Manufacture of footwear and leather goods	1,22	1,08	0,63	0,63
10	Manufacture of wood products	1,03	1,08	0,66	0,65
11	Manufacture of pulp, paper and paper products	1,08	1,12	1,00	0,91
12	Printing and playing back recordings	0,91	0,94	0,69	0,61
13	Oil refining and coke plants	1,27	1,29	1,76	1,97
14	Manufacture of biofuels	1,13	1,28	0,62	0,67
15	Manufacture of organic and inorganic chemicals, resins and elastomers	1,13	1,06	1,78	1,58
16	Pharmaceuticals	0,88	0,91	0,60	0,60
17	Perfumery hygiene and cleaning	1,12	1,16	0,61	0,60
18	Manufacture of pesticides, disinfectants, paints and miscellaneous chemicals	1,20	1,09	0,96	0,92
19	Rubber and plastic articles	1,16	1,09	1,04	0,99
20	Cement and other non-metallic mineral products	1,15	1,14	0,76	0,74
21	Manufacture of steel and derivatives	1,24	1,14	0,95	1,04
22	Metallurgy of non-ferrous metals	1,16	1,13	0,78	0,85
23	Metal products - excluding machinery and equipment	1,03	1,11	0,89	0,87
24	Machinery and equipment and furniture and products from various industries	0,96	0,97	1,36	1,19
25	Household appliances and electronics	1,10	1,10	0,67	0,70
26	Cars vans trucks and buses	1,09	1,22	0,65	0,66
27	Parts and accessories for motor vehicles	1,20	1,11	0,71	0,77
28	Other transport equipment	0,83	0,94	0,58	0,59
29	Production and distribution of electricity gas water sewage and urban cleaning	0,90	1,01	1,61	1,69
30	Civil construction	0,94	0,99	0,77	0,77
31	Trade	0,88	0,84	2,01	2,75
32	Transport warehousing and mail	1,02	1,02	2,03	2,29
33	Accommodation and food services	0,93	0,99	0,67	0,67
34	Information services	0,89	0,87	1,42	1,10
35	Financial intermediation insurance and supplementary pension and related services	0,78	0,78	1,94	1,52
36	Real estate activities and rentals	0,58	0,59	0,80	0,77
37	Services provided to businesses and families and maintenance services	0,82	0,79	2,83	2,62
38	Public administration, defense and social security	0,75	0,75	0,64	0,66
39	Public education	0,68	0,66	0,60	0,57
40	Private education	0,76	0,73	0,57	0,58
41	Public health	0,79	0,79	0,53	0,54

42	Private health	0,85	0,85	0,60	0,61

Source: Authors' own calculations from Brazilian IO data estimated by Alves-Passoni and Freitas (2020).

In this section we calculate IO production, employment, and income multipliers of 42 sector countries for the years 2000 and 2018.

The IO production multiplier measures the total production value in all sectors of the economy needed to attend an additional currency unit of the final demand for the production of the 42 sectors in Table 2. On average, the production multipliers decreased by 2,14%, considering all sectors. However, 75% of the greatest fall (greater than two standard deviation) was concentrated in industry, such as in the sectors, 2, 3, 4, 7, 8, 9, 15, 18, 19, 21, 22, 27 and 25% in the service sector, such as in the sector 31, 34, 39, 40.

The employment multiplier indicates how much is generated, directly and indirectly, of employment for each unit directly generated from a job. For each US $1,000,000 final demand variation in the economy, on average, the whole economy created, direct and indirect, 26 new jobs in 2000, but 24 jobs in 2018. This multiplier can be seen for each sector in Table 2.

Among the 42 sectors in Table 2, just around 35,71% presented increased employment multiplier: sectors 7, 8, 12, 23, 24, 26, 28, 29, 30, 34, 36, 37, 40, 41 and 42. The other sectors presented a sharp decrease (greater than 10%), except sectors 9, 12, 16, 19, 20, 25, and 35, which also registered a negative decrease, but in a more moderate magnitude (less than 10%).

The income multiplier shows the relationship between direct income and total income for each sector. It is worth mentioning that they did not change much between the two analyzed years. Furthermore, the service sector, in general, presents a greater income multiplier, mainly in sectors 35, 36, 38, 39, 40, and 41. For these sectors, income multipliers are greater or equal to 0,40 in both years.

Table 2 – Production, Employment, and Income multipliers – 2000 and 2018 – 42 sectors for Brazil

	Sectors	Production		Employment		Income	
		2000	2018	2000	2018	2000	2018
1	Agriculture, forestry, forestry, livestock and fisheries	1,62	1,74	93	48	0,39	0,36
2	Oil and gas extraction, including support activities	1,77	1,69	12	10	0,34	0,34
3	Iron ore extraction, including beneficiation and agglomeration	1,98	1,76	14	10	0,32	0,36
4	Others from the extractive industry	2,16	1,90	24	17	0,31	0,34
5	Food and Beverages	2,47	2,39	52	32	0,35	0,35
6	Manufacture of tobacco products	2,31	2,28	45	32	0,36	0,37
7	Manufacture of textile products	2,13	2,02	34	37	0,33	0,32
8	Manufacture of garments and accessories	1,92	1,83	45	60	0,36	0,35
9	Manufacture of footwear and leather goods	2,33	2,02	37	35	0,34	0,35
10	Manufacture of wood products	1,98	2,02	44	36	0,36	0,35
11	Manufacture of pulp, paper and paper products	2,07	2,09	18	17	0,34	0,33
12	Printing and playing back recordings	1,75	1,76	18	24	0,37	0,36
13	Oil refining and coke plants	2,43	2,41	11	9	0,27	0,25
14	Manufacture of biofuels	2,16	2,38	46	31	0,38	0,36
15	Manufacture of organic and inorganic chemicals, resins and elastomers	2,15	1,99	12	10	0,27	0,22
16	Pharmaceuticals	1,68	1,69	14	14	0,36	0,35
17	Perfumery hygiene and cleaning	2,14	2,16	23	20	0,32	0,30
18	Manufacture of pesticides, disinfectants, paints and miscellaneous chemicals	2,29	2,03	18	14	0,28	0,25
19	Rubber and plastic articles	2,22	2,04	19	17	0,30	0,28
20	Cement and other non-metallic mineral products	2,20	2,12	25	25	0,34	0,34
21	Manufacture of steel and derivatives	2,37	2,13	17	13	0,29	0,31
22	Metallurgy of non-ferrous metals	2,23	2,12	18	15	0,31	0,30
23	Metal products - excluding machinery and equipment	1,98	2,08	22	23	0,35	0,33
24	Machinery and equipment and furniture and products from various industries	1,83	1,81	18	19	0,28	0,29
25	Household appliances and electronics	2,11	2,05	18	17	0,31	0,30
26	Cars vans trucks and buses	2,08	2,27	15	16	0,31	0,28

27	Parts and accessories for motor vehicles	2,30	2,08	19	17	0,30	0,31
28	Other transport equipment	1,58	1,76	10	12	0,28	0,25
29	Production and distribution of electricity gas water sewage and urban cleaning	1,72	1,89	11	11	0,37	0,36
30	Civil construction	1,80	1,85	28	36	0,36	0,35
31	Trade	1,68	1,57	49	34	0,39	0,39
32	Transport warehousing and mail	1,95	1,91	28	24	0,35	0,35
33	Accommodation and food services	1,79	1,85	55	47	0,37	0,37
34	Information services	1,70	1,62	14	16	0,39	0,38
35	Financial intermediation insurance and supplementary pension and related services	1,49	1,46	10	10	0,40	0,41
36	Real estate activities and rentals	1,11	1,10	2	2	0,43	0,44
37	Services provided to businesses and families and maintenance services	1,57	1,48	42	42	0,39	0,40
38	Public administration, defense and social security	1,43	1,41	18	16	0,41	0,42
39	Public education	1,30	1,23	31	25	0,42	0,43
40	Private education	1,46	1,36	30	41	0,41	0,41
41	Public health	1,52	1,48	27	28	0,40	0,40
42	Private health	1,62	1,58	26	29	0,38	0,38

Source: Authors' own calculations from Brazilian IO data estimated by Alves-Passoni and Freitas (2020).

4. FIELD OF INFLUENCE ANALYSIS

In order to deepen the investigation of the multisectoral interdependence, Figures 1 and 2 present the fields of influence of Brazil for the years 2000 and 2018. Thus, it is possible to compare the importance of different sectors in the above-mentioned period. According to Guilhoto *et al.* (2005), this method should be complementary to the Hirschman-Rasmussen indexes. To better comprehension, the results for each productive linkage were highlighted in color scales[13], indicating above-average fields of influence, i.e., they are the most important linkages for the economy as a whole. The reading is similar to input-output matrices, i.e., the rows are the sectors that sell inputs (i.e., suppliers), while the columns are the purchase sectors (i.e., the demand).

With Figures 1 and 2, it is possible to evaluate the relative importance of each sector in terms of links and degree of integration, i.e., the most critical inter-sectoral relations in terms of the purchase (columns) and sale of inputs (rows) in two different years. Our analysis here focuses on the two major sectors in Brazil, i.e., services and manufacturing.

According to Figure 1, in 2000, oil refining and coke plants (sector 13) was the sector with the greatest productive linkage in intensity and links with different sectors (both demand and supply). Followed by this sector, the manufacture of organic and inorganic chemicals, resins, and elastomers (sector 15) was the sector with the second greatest synergy. The same sectors kept their importance in 2018 but with less intense links.

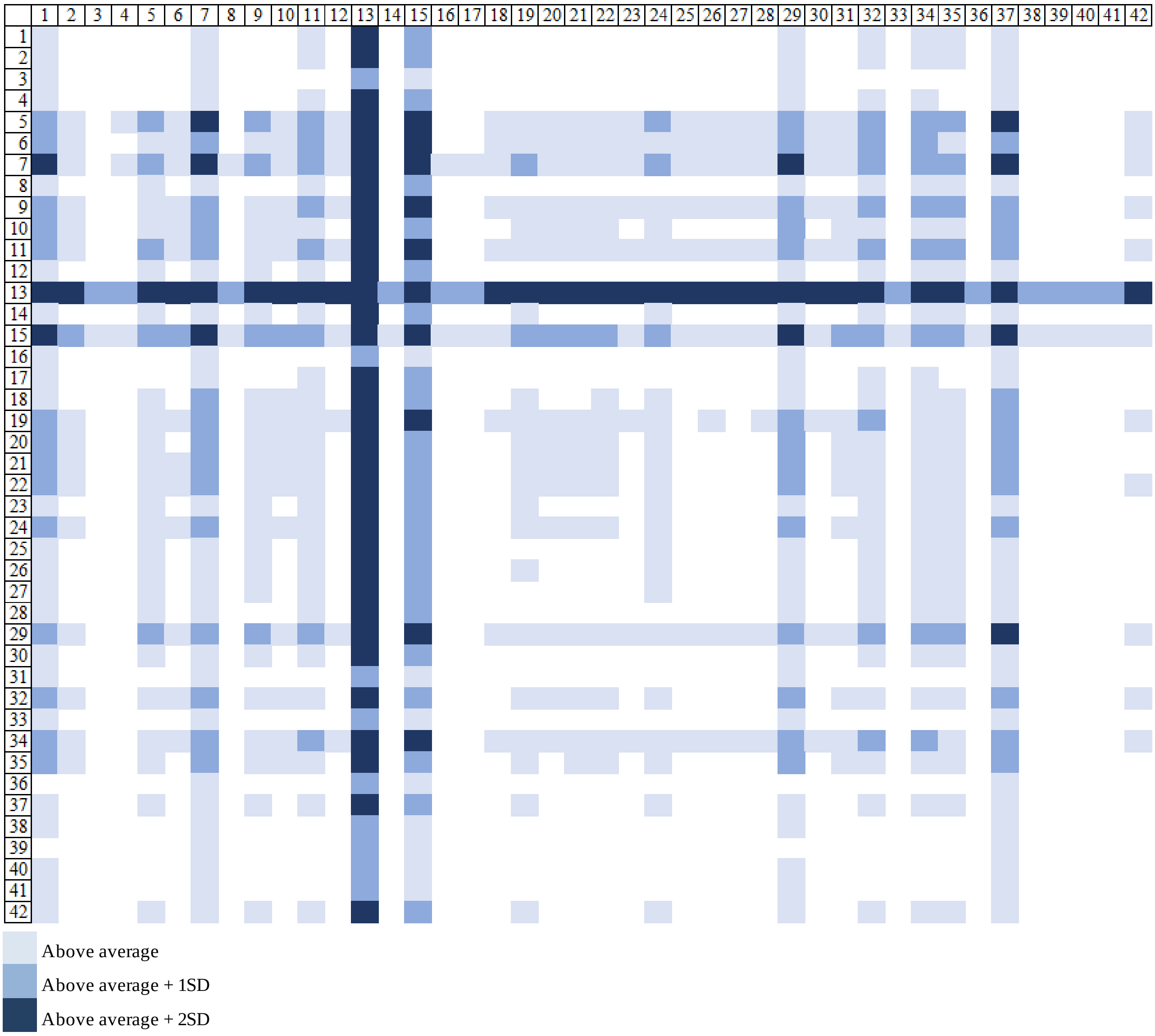
Sectors 31-42 (i.e., trade and services) presented greater interdependence (important suppliers), with sectors 13 and 15 with greater relevance (both of them in terms of the input demand). Concerning sector 13, the stronger links were with sectors 33, 35, 36, 37, and 42 (above average plus two SD), but also relevant in sectors 31, 33, 36, 38, 39, 40, and 41 (above average plus one SD) and without any weaker link (just above average). Conversely, concerning sector 15, the stronger links were just with sector 34 and relevant in sectors 32, 35, 37, and 42, but weaker with sectors 31, 33, 36, 38, 39, 40, and 41.

In general, the sectors 32, 34, 35, 37, and 42 are important suppliers (weaker but still above average) to sectors 5, 6, 7, 9, 10, 11, and 18-28[14].

When analyzing manufacturing industries (as suppliers) and trade and services (on the demand side), sectors 13 and 15 still keep the most important links. Sector 13 presents 6 strong links (above average plus two SD), i.e., with sectors 31, 32, 34, 35, 37, and 42. Sector 15 presents just one strong link with sector 37. Most of the links within all 3 categories in Figure 1 are connected with sector 37.

[13] The lighter color represents the coefficients above the mean, the intermediate color refers to the above-average coefficients plus a standard deviation (SD), and the darker color refers to the above-average coefficients plus two standard deviations.
[14] Just three of them above average plus one SD, as presented in figure 1.

Figure 1 - Fields of influence for Brazil in 2000 – 42 sectors *per* 42 sectors



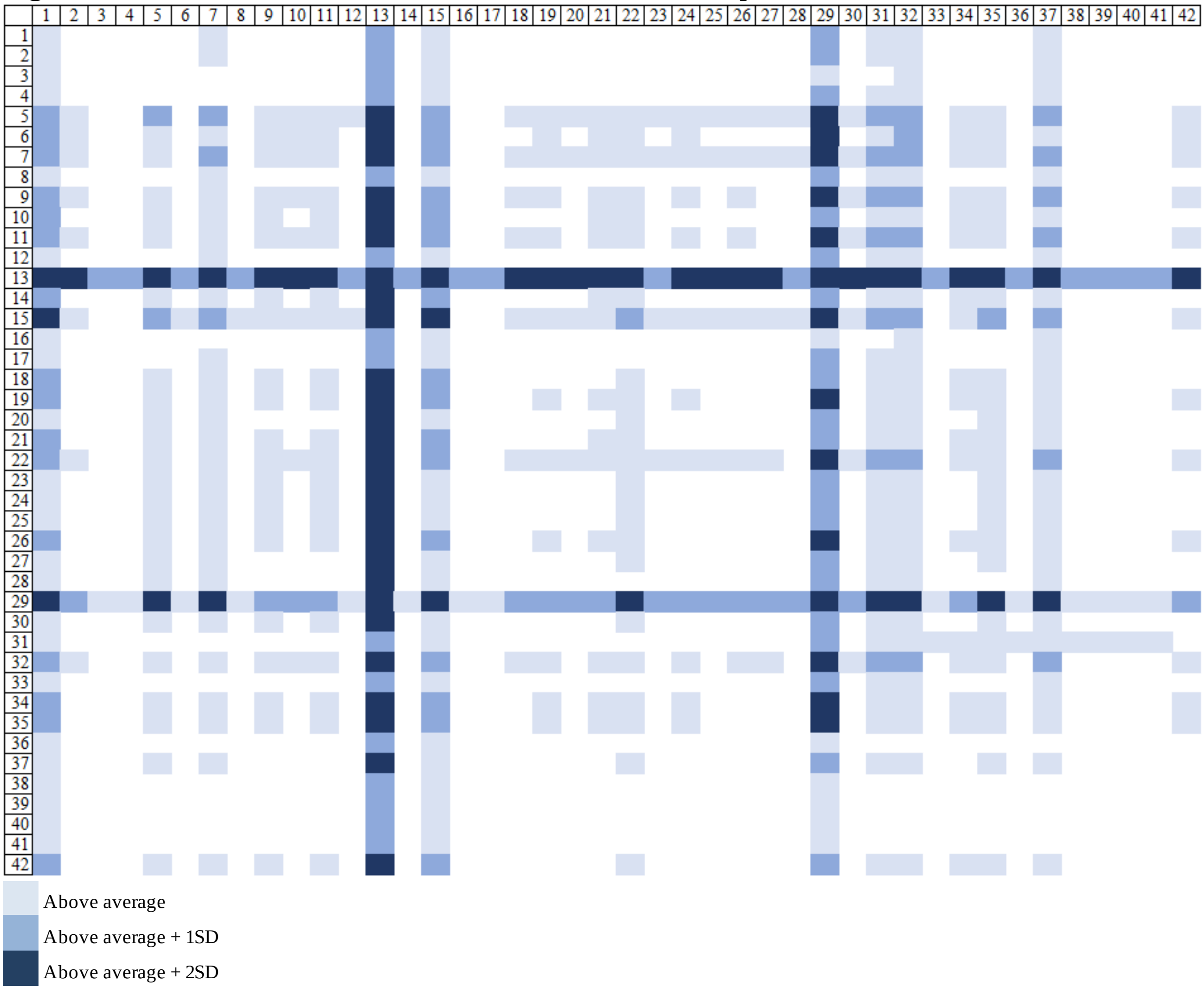
Source: Authors' own calculations from Brazilian IO data.

According to Figure 2, it can be seen that the general feature concerning the manufacturing industry and services did not change much at first glance, i.e., in 2000, the relative interdependence remained similar. Notwithstanding, there are de-densifications (loss of links) among several sectors. It can be noted with the decrease in the links of sectors 32, 34, and 35 related to the sector 7 demand as well as the decrease in the link of sector 34 related to sector 11. Furthermore, sectors 34 and 35 lost the links with sector 10, the sectors 32 and 34 lost the links with sector 6. In general, it is shown that sectors 34, 35, 37, and 42 lost links (above average) among sectors 18-28 and increased links with sector 32 among these sectors.

When analyzing manufacturing industries (as suppliers) and trade and services (on the demand side), just sector 13 kept the same synergy as in 2000. Sector 15 lost links and intensity with different sectors, such as 34 and 56. More importantly, sectors 34, 35, and 37 lost several links and intensity with 5-28.

Some important conclusions can be drawn from the above analysis. Manufacturing industries presented the most important links in different sectors, both in intensity and in the relative number of sectors. However, the stronger links are very concentrated in a few sectors. Moreover, the service sector was more integrated in 2018. However, in terms of intra-sectoral relations, there is a relatively remarkable lack of links with manufacturing and other sectors compared to 2000. Manufacturing industries were less interconnected in 2018 because occurred the loss of links and intensity among different sectors. Notwithstanding, these sectors still were the most interdependent.

Figure 2 - Fields of Influence for Brazil in 2018 – 42 sectors *per* 42 sectors



Source: Source: Authors' own calculations from Brazilian IO data.

Therefore, given all structural changes observed between the two periods in terms of links in the field of influence analysis, the Brazilian economy is more service-oriented, mainly on the demand side, with a few greater intersectoral number of connections in services as a whole in 2018 and, at the same time, with less intensity among itself and the economy at large. In other words, a broad inter-sectoral convergence process was not verified in terms of growing service-manufacturing links. Furthermore, the loss of links and intensity in manufacturing means a more de-intensified sector with itself and the rest of the economy.

4. STRUCTURAL DECOMPOSITION ANALYSIS (SDA)

Following Miller and Blair (2022), this section is explored the Brazilian gross output changes between 2000 and 2018. Therefore, we are interested in trying to disaggregate the total amount of change in some aspects of that economy into contributions made by its various components, such as one part associated with changes in technology and another related to changes in final demand over the period.

Using superscripts 0 and 1 for the two different years (i.e., 2000 and 2018), the structural decomposition in an input–output model focuses on the differences in the gross output vectors in these two periods. So, gross outputs in year t, $x^t (t = 0,1)$, are in an Input-Output system as:

$x^1 = L^1 f^1$ and $x^0 = L^0 f^0$ (5)

where f^t represents the vector of final demands in year *t*, and $L^t = (I - A^t)^{-1}$. Then the observed change in gross outputs over the period is:

$$\Delta x = x^1 - x^0 = L^1 f^1 - L^0 f^0 \qquad (6)$$

In order decompose the total change in outputs into changes in the various components it is needed the separation into changes in $L(\Delta L = L^1 - L^0)$ and changes in $f(\Delta f = f^1 - f^0)$.

According to Miller and Blair (2022), a number of alternative expansions and rearrangements of the terms in (6) can be derived. For example, using only year-1 values for L and only year-0 values for f:

$$\Delta x = L^1(f^0 + \Delta f) - (L^1 - \Delta L)f^0 = (\Delta L)f^0 + L^1(\Delta f) \qquad (7)$$

Equation (7) produces a decomposition of the total change in gross outputs into a) a part that is due to changes in technology, ΔL, in this case, weighted by year-0 final demands (f^0) and b) another part that reflects final-demand changes, Δf, which are weighted by year-1 technology (L^1).

Using only year-0 values for L and on lyn year-1 values for f, (6) becomes:

$$\Delta x = (L^0 + \Delta L)f^1 - L^0(f^1 - \Delta f) = (\Delta L)f^1 + L^0(\Delta f) \qquad (8)$$

The decomposition in (7) and (8) are equally valid, in mathematical terms, according to Miller and Blair (2009). However, the measures in (7) concerning changed technology and changed final demands will be different from those in (8), except in the totally uninteresting and implausible case where $L^1 = L^0$ and/or $f^1 = f^0$ with no change in technology or no change in demand (or no change in either) over the period.

Other expressions emerge if only year-0 or only year-1 values are used for weights on both changes terms. If it is used year-0 weights exclusively, so that L^1 and f^1 are replaced by $(L^0 + \Delta L)$ and $f^0 + \Delta f$. Therefore, (6) becomes:

$$\Delta x = (L^0 + \Delta L)(f^0 + \Delta f) - L^0 f^0 = (\Delta L)f^0 + L^0(\Delta f) + \Delta L \Delta f \qquad (9)$$

Miller and Blair (2022) explains that unlike the first two terms in (9), this new interaction term does not have an intuitively appealing interpretation. Then, using year-1 weights means putting $L^0 = L^1 - \Delta L$ and $f^0 = f^1 - \Delta f$ into (6):

$$\Delta x = L^1 f^1 - (L^1 - \Delta L)(f^1 - \Delta f) = (\Delta L)f^1 + L^1(\Delta f) - (\Delta L)(\Delta f) \qquad (10)$$

Therefore, the difference between (10) and (9) is the sign of the interaction term.

According to Miller and Blair (2022) different researchers have worked with one or more of these four alternatives, such as Skolka (1989), Rose and Chen (1991), Miller and Shao (1994) among others. Especifically, Dietzenbacher and Los (1998) conclude that using an average of results from (7) and (8) is an accptable and relevant approach. Therefore, adding (7) and (8) gives:

$$2\Delta x = (\Delta L)f^0 + L^1(\Delta f) + (\Delta L)f^1 + L^0(\Delta f) \qquad (11)$$

Then, output change can be decomposed for each sector as:

$$\underbrace{\Delta x}_{\text{Output change}} = \left(\frac{1}{2}\right) \underbrace{(\Delta L)(f^0 + f^1)}_{\text{Technology change}} + \left(\frac{1}{2}\right) \underbrace{(\Delta f)(L^0 + L^1)}_{\text{F. Demand change}} \qquad (12)$$

In order to aggregate the final effects of the aggregate sectors in a single single result, a total result for each n-element of the change vector (Δx) must be decomposed into two or more elements:

$$i'(\Delta x) = \underbrace{i'\left[(\tfrac{1}{2})(\Delta L)((f^0 + f^1)\right]}_{\text{Economy−wide technology change affect}} + \underbrace{i'\left[(\tfrac{1}{2})(L^0 + L^1)(\Delta f)\right]}_{\text{Economy−wide final−demand change effect}} \quad (13)$$

Table 3 presents the Structural Decomposition Analysis (SDA) for Brazil, considering 2000 and 2018, in a forty-two-sector model, where each element in the n-element vector changes (Δx) is decomposed into two constituent elements, i.e., technology change, and final demand change.

According to Table 3´s results, 99,19% of the total output change is due to the final demand change. Regarding sectors, just civil construction presented a negative final demand change. Most importantly, sectors 33, 16, 8, 26, 2, 36, 17, 1, 28, 35, 9, 11, 6, 25, 30, and 34 presented negative technology change (in descending order of impact, in absolute terms).

This result is closely linked to the field of influence analysis. The weak interaction between knowledge-intensive services and the economy at large as well as the loss of links among producer services and manufacturing results in an output change where the technological component is negative or less intense, as shown in Table 3. Furthermore, the verified negative technological change in Table 3 results from the loss of service-industry interconnectedness. It is associated with a closed economy, where there are low investments in R&D, human capital, and infrastructure, producing a low complexity economy and creating low-skilled and value-added jobs in the recent period (Lima, Gabriel and Jayme Jr, 2020).

It is important to highlight that while productivity growth in advanced economies typically involves technological innovation and technical progress, in developing countries, productivity growth tends to rely more on structural change towards activities with higher levels of R&D and productivity, as in manufacturing.

	Sector	**Output Change**	**%**	**Technology Change**	**%**	**Final-Demand Change**	**%**
1	Agriculture, forestry, forestry, livestock and fisheries	167468	6,64	-33932	-20,26	201400	120,26
2	Oil and gas extraction, including support activities	66590	2,64	-3490	-5,24	70079	105,24
3	Iron ore extraction, including beneficiation and agglomeration	41679	1,65	5024	12,05	36656	87,95
4	Others from the extractive industry	16995	0,67	4969	29,24	12026	70,76
5	Food and Beverages	266067	10,54	572	0,22	265495	99,78
6	Manufacture of tobacco products	1604	0,06	-1080	-67,35	2684	167,35
7	Manufacture of textile products	-1721	-0,07	-12338	717,03	10617	-617,03
8	Manufacture of garments and accessories	14431	0,57	-477	-3,31	14908	103,31
9	Manufacture of footwear and leather goods	5248	0,21	-2500	-47,63	7748	147,63
10	Manufacture of wood products	1780	0,07	537	30,20	1242	69,80
11	Manufacture of pulp, paper and paper products	21436	0,85	-12292	-57,34	33729	157,34
12	Printing and playing back recordings	-4360	-0,17	-10554	242,05	6194	-142,05
13	Oil refining and coke plants	141191	5,59	53605	37,97	87586	62,03
14	Manufacture of biofuels	70818	2,81	12913	18,23	57905	81,77
15	Manufacture of organic and inorganic chemicals, resins and elastomers	60405	2,39	4587	7,59	55818	92,41
16	Pharmaceuticals	41433	1,64	-1313	-3,17	42746	103,17
17	Perfumery hygiene and cleaning	24076	0,95	-3324	-13,81	27400	113,81
18	Manufacture of pesticides, disinfectants, paints and miscellaneous chemicals	31965	1,27	9892	30,95	22074	69,05
19	Rubber and plastic articles	23918	0,95	1436	6,00	22482	94,00
20	Cement and other non-metallic mineral products	16030	0,64	7648	47,71	8383	52,29
21	Manufacture of steel and derivatives	41508	1,64	12515	30,15	28993	69,85
22	Metallurgy of non-ferrous metals	21309	0,84	8487	39,83	12823	60,17
23	Metal products - excluding machinery and equipment	23680	0,94	2341	9,89	21339	90,11
24	Machinery and equipment and furniture and products from various industries	87109	3,45	26108	29,97	61001	70,03
25	Household appliances and electronics	18936	0,75	-12830	-67,76	31766	167,76
26	Cars vans trucks and buses	45928	1,82	-2201	-4,79	48129	104,79
27	Parts and accessories for motor vehicles	52514	2,08	23971	45,65	28543	54,35
28	Other transport equipment	27613	1,09	-6646	-24,07	34259	124,07

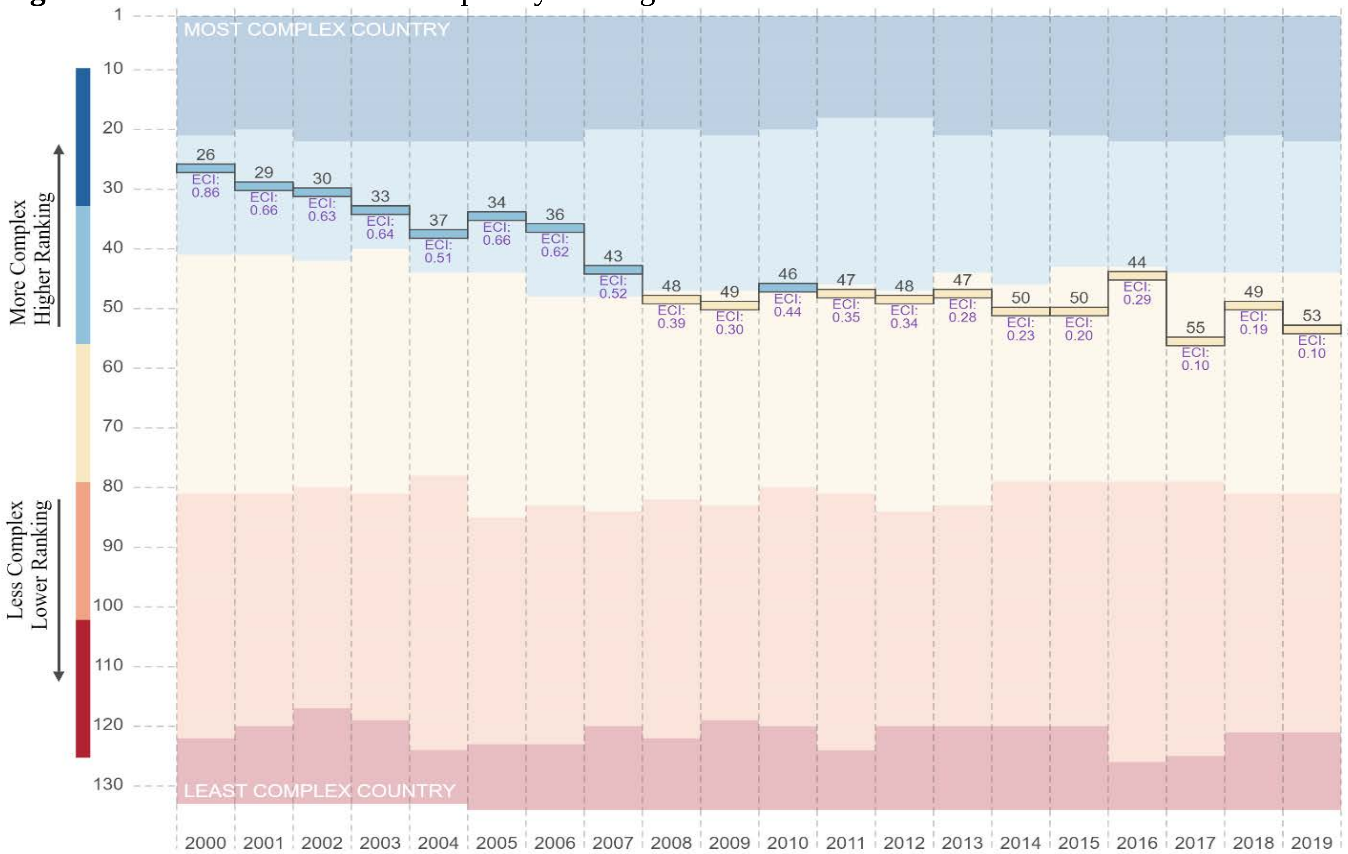
29	Production and distribution of electricity gas water sewage and urban cleaning	100022	3,96	19592	19,59	80430	80,41
30	Civil construction	-9436	-0,37	6408	-67,91	-15845	167,91
31	Trade	16724	0,66	5977	35,74	10746	64,26
32	Transport warehousing and mail	117258	4,65	20001	17,06	97257	82,94
33	Accommodation and food services	93193	3,69	-2777	-2,98	95970	102,98
34	Information services	41691	1,65	-47932	-114,97	89624	214,97
35	Financial intermediation insurance and supplementary pension and related services	152918	6,06	-56884	-37,20	209802	137,20
36	Real estate activities and rentals	60754	2,41	-7123	-11,72	67877	111,72
37	Services provided to businesses and families and maintenance services	222687	8,82	10133	4,55	212554	95,45
38	Public administration, defense and social security	142813	5,66		0,00	142813	100,00
39	Public education	93010	3,69		0,00	93010	100,00
40	Private education	30372	1,20	454	1,49	29919	98,51
41	Public health	56233	2,23		0,00	56233	100,00
42	Private health	79882	3,17	1085	1,36	78797	98,64
	Total	**2523774**	100,00	**20563**	0,81	**2503211**	99,19

Table 3 - Structural decomposition analysis (SDA) for Brazil 2000 and 2018.
Source: Authors' own calculations from Brazilian IO data estimated by Alves-Passoni and Freitas (2020).

5. ECONOMETRIC ANALYSIS

The increase of the firms' and sectors´ capabilities related to their innovative activities, productive knowledge and greater links promotes the diversification and sophistication of the goods produced. Hausman *et al*. (2011) developed a measure of economic complexity in which 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 capabilities 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 of less capabilities and knowledge.

Figure 3 – Brazilian economic complexity ranking and level – 2000 - 2019



Source: The Observatory of Economic Complexity (2022).

According to figure 3, Brazil was in the second range group of countries in terms of complexity (light blue area) at the beginning of the series. It was close to the most complex countries in 2000 (dark blue area), in the 26th position. Notwithstanding, it fell to less complex countries range (light yellow), in the 53rd position.

When analyzing Figure 3, the income gap data compared to USA real income in constant prices in 2019 is very close to that verified in 2000, i.e., though it slowly decreased between 2006 and 2014, it constantly fell until 2019.

Time series analysis just for Brazil does not provide robust results due to small sample problems and bias, for example, when considering equation (1). Notwithstanding, panel data has several advantages over the traditional methodology of time series and cross-country estimations, respectively: i) the panel data allows exploring the temporal and transversal variations of the data with heterogeneous countries, and ii) the panel avoids the biases associated with cross-country regression. In the latter, the unobserved country-specific effect is part of the forecast error so the correlation between it and the explanatory variables results in biased estimates for the regression coefficients.

Therefore, panel data models were estimated for a sample of 38 developing countries (Brazil included) and for 13 developed countries from 1960 to 2019, considering the following econometric specification:

$$eci_{it} = \beta_0 + \beta_1 mshare_{it} + \beta_2 sshare_{it} + \beta_j \sum_{J=5}^{K} \beta_j Z_{i,tj} + +\mu_t + \eta_i + u_{it} \quad (14)$$

In equation (14) eci_{it} represents the economic complexity index, $mshare_{it}$ is the share of the manufacturing industries in terms of its value added in GDP, $sshare_{it}$ is the share of the service sector in terms of its value added in each country. $Z_{i,tj}$ are the *K* control variables to each country *i*, over time *t*. The β_j´s are the parameters to be estimated, μ_t is the time-specific effect, η_i captures the non-observed effects of each country *i* that are invariant over time and u_{it} is the idiosyncratic error term.

The control variables used to estimate equation (1) follow the literature on economic growth and structural change (Bhalla, 2012, Szirmai and Verspagen, 2011, Rodrik, 2008, among others) and can be classified according to the following variables (i) government liabilities: the share of government expenditure regarding GDP (*govexps*) is used as a proxy; (ii) stabilization policies: the average inflation rate (*infla*); the technological gap (*gaptech*) is defined following the methodology used by Verspagen (1993). In this case, the technological leader is the United States, and its *per capita* GDP is a proxy for productivity; iv) gross fixed capital formation as a proportion of annual GDP (*gcfshare*) as a proxy for aggregated investment; v) terms of trade (*ttrade*), which negatively affects economic growth through its impact on real exchange rate (RER) and balance of payments and vi) degree of the economy openness (*openness*) in terms of GDP share, which explains how open is an economy in terms of exports and imports.

Table 4 briefly describes all the variables used in the estimations. We performed three-panel unit root tests: Im, Pesaran and Shin (1997) and ADF Fisher and PP Fisher developed by Maddala and Wu (1999) and Choi (2001), respectively. All variables are I (0). Furthermore, the Collin test (Ender, 2015) was applied, and the problem of multicollinearity was not detected (the VIF, i.e., the variance inflation factor average, was as low as 1,17).

Table 4 – Description of the variables used in the models, its measures and sources

Abbreviations	Brief variable description	Source
eci	Hausmann and Hidalgo *et al.* (2011) complexity indicator	MIT
mshare	Manufacturing sector share to GDP (value added, in %) - 15-37 divisions from the *International Standard Industrial Classification* (ISIC)*.	WDI- GGDC
sshare	Services sector share to GDP (value added, in %) - 50-99 divisions from	WDI- GGDC

	International Standard Industrial Classification (ISIC)*.	
govexps	Government consumption in terms of goods and services in relation to GDP in real terms.	World Bank
inflation	Annual inflation rate (from the *Consumer Price Index* – CPI, for each country)	WDI
ttrade	Terms of trade adjustment (in constant prices)	World Bank
openness	International trade (% of GDP)	WDI
gcfshare	Gross fixed capital formation as a proportion of annual GDP.	WDI
gaptech	Technological gap between countries from Verspargen (1993) methodology.	Author´s own elaboration based on PWT 8.0

Source: Author´s own elaboration.
Note: * Revision 3.0 of the *International Standard Industrial Classification* for economic activities of the United Nations Statistics Division (UNSD); Relative participation (%) calculated at constant prices in terms of 2005 dollars. IMF - *International Monetary Fund*; WDI - *World Development Indicators*; PWT - *Penn World Tables* 8.0 (see Feenstra *et al*., 2015) and MIT - *Massachusetts Institute of Technology*. GGDC - *Groningen Growth and Development Center*.

Fixed effects models were the most adequate for both samples, according to the Hausman test (at 1% statistical significance level). The estimations of these different samples faced the same problems concerning heteroskedasticity and serial autocorrelation when we applied the modified Wald test for heteroskedasticity in regression models with fixed effects and the Wooldridge test for serial correlation in the panel model, respectively. Thus, in order to correct the detected problems, we applied the Cochrane-Orcutt method with the Prais-Winsten transformation to correct for serial correlation and heteroskedasticity problems. Moreover, panels corrected standard errors were used.

As Cameron and Trivedi (2005) present, the Prais–Winsten transformation removes the heteroskedasticity and autocorrelation, and the results are unbiased coefficients and consistent panel-corrected standard errors. Furthermore, when calculating the standard errors and the variance-covariance matrix, it is assumed that the errors are heteroskedastic and contemporaneously correlated between panels.

According to Table 5´s results, manufacturing influences almost 3,4 more economic complexity when compared to the service sector in the analyzed period for the developing countries sample (column 3). Furthermore, manufacturing influences almost 2,16 more economic complexity when compared to the service sector in the analyzed period for the developed countries sample (column 6). In both cases, different control variables were taken into consideration.

The technological gap proxy, gross capital formation, and openness were statistically significant for developing countries. Although, the latter is without the expected sign. The technological gap proxy, government expenditure, and terms of trade were statistically significant for developed countries, and all of them had the expected sign.

Table 5 – Panel Prais-Winsten estimations with heteroskedastic panels corrected standard errors -1960 – 2019

Model	Developing			Developed		
	(1)	(2)	(3)	(4)	(5)	(6)
eci	Eci	eci	eci	eci	eci	eci
mshare	0.0161***	0.0169***	0.0229***	0.0159**	0.0284***	0.0570***
	(7.29)	(7.52)	(7.11)	(2.75)	(4.32)	(8.94)
sshare		0.00800***	0.00674***		0.0163***	0.0264***
		(6.02)	(3.77)		(3.69)	(6.63)
gcfshare			0.00340*			0.00689

			(2.11)			(1.96)
govexps			0.00641			0.0169^{**}
			(1.75)			(2.62)
inflation			0.0000151			-0.00281
			(1.54)			(-0.87)
openness			0.00128^{*}			-0.000499
			(2.07)			(-1.18)
ttrade			2.96e-17			$4.92e\text{-}13^{*}$
			(0.34)			(2.45)
gaptech			-0.00767^{***}			-0.352^{***}
			(-5.84)			(-6.62)
_cons	-0.759^{***}	-1.137^{***}	-1.056^{***}	1.044^{***}	-0.161	-0.945^{**}
	(-17.16)	(-14.69)	(-8.45)	(9.01)	(-0.48)	(-2.67)
N	2607	2389	1947	640	640	628

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We can highlight here some important results taking into consideration the 2 last sections. Considering the value added of each sector as the net product of the economic sector after adding the gross value of the entire product and subtracting the intermediate goods (intra or inter-sectorial) involved in the production process. For different country samples, manufacturing value added share affects more economic complexity, mainly in developing countries, like Brazil. According to IBGE (2022) and CNI (2022)´s data manufacturing is decreasing its share, i.e., gross value and the demand for intermediate goods from this sector are reducing compared to services. It means less impact of this sector on the Brazilian economic complexity and, consequently, economic growth.

Although the increased importance of services in Brazil, the strongest linkages are concentrated in a few manufacturing sectors, which is decreasing in terms of the density of inter-industry linkages between manufacturing and services. Moreover, it was verified that the service sector was more integrated in 2018. However, mainly in intra-sectoral relations, there is a relative lack of links with manufacturing and other sectors. On the other hand, Silva and Perobelli (2018) analyzed a group of 40 countries between 1995 and 2011. Their results suggest a drop in linkages between industrial sectors and an increase in the integration of services with other activities. As verified in the last section, manufacturing industries were less interconnected in 2018 because of the loss of links and intensity among different sectors (in both inter and intra-sectorial terms). On average, this loss of links means less purchase and sale of inputs, which represents a de-densification in a lower sectorial GDP share.

6. CONCLUDING REMARKS

The main objective of this paper was to analyze the multisectoral productive interdependence and structural change in Brazil by applying input-output (IO) methods, such as Hirschman Rasmussen´s index, income, employment, and production multipliers, and Structural Decomposition Analysis (SDA). Furthermore, panel data estimations were applied, considering the previous sectors in aggregated terms, presenting the dynamics effects over developing (including Brazil) as well as developed countries, in an effort to make inferences about the Brazilian structural change effects over economic complexity. We emphasize that the productive structure of emerging or developing economies is a critical field of research as it allows us to evaluate sectoral growth policies that can support economic growth in the medium and long term.

The general results indicate that the production structure of the Brazilian economy remains frayed, i.e., with de-densification in important sectors, based on a service-oriented economy with few and weak linkages with manufacturing. Furthermore, meanwhile services in general are more integrated with themselves, manufacturing passed through a de-densification, that is, lost linkage intensity and relevant economic connection with the rest of the Brazilian economy.

In the analyzed period, on average, the production multipliers decreased by 2,14%, considering all sectors. However, 75% of the greatest fall (greater than two standard deviations) was concentrated in the industry and 25% in the service sector. Concerning employment multiplier, just around 35,71% increased, the other sectors presented a sharp decrease (greater than 10%), except sectors 9, 12, 16, 19, 20, 25, and 35, which also registered a negative decrease, but in a more moderate magnitude (less than 10%). It is worth mentioning that 53,3% of employment multipliers increases were from manufacturing. The income multiplier did not change much between the two analyzed years, and the service sector, in general, presented the greatest income multipliers.

We verified that the vast majority of the total output change is due to final demand change, not technological change. When taking sectors in consideration, just civil construction presented a negative final demand change. Most importantly, several manufacturing industries with important multipliers presented a negative technological change. This result is closely linked to the field of influence analysis. The weak interaction between knowledge-intensive services and the economy at large as well as the loss of links among producer services and manufacturing results in an output change where the technological component is negative or less intense.

The findings of this work suggest a reduced inter-sectoral convergence process in terms of growing service-manufacturing links in Brazil. Furthermore, this means that manufacturing in Brazil is not increasingly service-oriented once the stronger links in the field of influence analysis are concentrated among services activities (i.e., intra-sectorial). As the econometric sections presented, in aggregate terms, this sector influences developing countries' economic complexity and economic growth in less magnitude. Therefore, structural change and inter-sectoral convergence between service and manufacturing suggest a growth-enhancing pattern, as verified in the relevant literature.

Recent evidence in the literature regarding productive growth in developing economies highlight the importance of technological advancement toward highly complex products and coherent economic development policies (Hartmann *et al*., 2021). Despite the significant changes brought about by trade integration between countries and advances in international trade policies, most developing economies, such as Brazil, remain dependent on policies to stimulate aggregate demand and are incapable of absorbing and diffusing technologies (Sousa Filho *et al*., 2020). In general, the most benefited industrial sectors were those natural-resources intensive or final-use products with low added value.

The analysis of productive interdependence, structural changes, and econometric methods have been used in a wide scope of research on the economic structure of developed and developing countries (Molina-Domene & Pietrobelli, 2012; Borghi, 2017; Gabriel & Ribeiro, 2019; Nassif *et al*., 2020; Gabriel *et al*., 2020). Despite the methodological differences, a considerable part of the research indicates that the manufacturing sector works as a relevant driver for the continuity of growth and increased income in emerging economies. In addition, early deindustrialization as a result of the rise in the share of service sectors in GDP is harmful to the extent that these developing countries are still in a stage of high productive and technological dependence on the external sector.

Finally, this paper does not intend to exhaust the discussions on productive structures in developed or developing countries but rather to bring more evidence based on input-output and econometric methods that address potential growth challenges and more significant effective linkages among sectors. Increasing complexity and generating value-added to production is a strategy that Brazil and other developing countries should adopt. In a strategically complex and competitive economy, the demand for medium and high technology goods and services can generate virtuous circles that link sectors and trigger global gains in efficiency and productivity, bringing relevant structural changes.

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