Reindustrialization and Resource-Based Industries: Productive, Occupational, and Emission Linkages

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ABSTRACT

In the past decade, industrial development and industrial policies have regained prominence in debates. In the Brazilian context, the discussion about industrial policy has gained traction under the banner of neoindustrialization proposed by the federal government. However, within the Brazilian context, this discussion must be considered in light of the abundance of natural resources, the country's competitive advantages in these activities, the industrial base related to these activities, and their linkages in terms of occupation and emissions. In this context, the relevance of Natural Resource-Based Industries (NRBIs) is emphasized, considering them as a relevant analytical object for both neoindustrialization strategy and measures necessary for decarbonizing activities. The central objective of this study is to assess the productive linkages of NRBIs in three analytical dimensions: product, occupations, and greenhouse gas emissions (GHGs). Indicators of linkages were constructed based on Pyatt and Round (1979), Stone (1985), Miller and Blair (2009), Costa and Freitas (2018), and Costa (2023) serving as methodological references for the Brazilian input-output table for the year 2019. In this context, a decomposition based on partitioning the matrix block into different activity blocks, focusing on linkages of NRBIs, divided the various Leontief impact matrix effects into intra-block, spillover, and feedback effects for the three analytical dimensions of this study. This work not only presents a new classification for NRBIs but also innovates in the form of estimating the production linkages of sectors in the Brazilian economy. It employs a methodology that isolates different blocks within the economy, enabling the analysis of distinct patterns of interdependence among sectorial aggregates for dimensions that go beyond purely productive spheres.

1. INTRODUCTION

Over the past decade, industrial development and industrial policies have regained prominence in discussions (Cherif; Husanov, 2019; Juhász; Lane; Rodrik, 2023)[1]. In the Brazilian context, the discussion on industrial policy has gained traction under the aegis of neo-industrialization proposed by the federal government, based on three premises: (i) strengthening the Brazilian industry is key to the sustainable development of Brazil from social, economic, and environmental perspectives; (ii) Brazil has been undergoing a process of early and accelerated deindustrialization since the 1980s, with a primarization of the production structure and a shortening and weakening of supply chain links; and (iii) the country's exports are concentrated in low-tech products, limiting Brazil's trade gains (MDIC, 2024).

On the other hand, the discussion of reindustrialization within the Brazilian context should consider the abundance of natural resources, the country's competitive advantages in these activities, and the industrial base related to the extraction and processing of these resources. In this perspective, literature discussing the development trajectories of Latin America based on Natural Resource-Based Development (NRBD) strategies is noteworthy. According to this literature, considering the technological shifts brought about by ICTs and changes in the international scenario with the rise of China, there would be a "window of opportunity" for Latin American countries to specialize and develop through the exploitation of their natural resources (Andersen et al., 2016; Pérez, 2010; Marin et al., 2015; Pérez; Marín, 2015). In this context, it becomes crucial to understand the potentialities of Natural Resource-Based Industries (NRBIs) and their specific characteristics in terms of production, employment, and emissions (Pérez, 2010; Danush, 2015; Andersen et al., 2016; IMF, 2018).

One central aspect for assessing the role of a productive sector within the economic system is the evaluation of its production linkages, as outlined by Hirschman (1958) and Rasmussen (1958). The use of these synthetic indices is relevant because they can analyze the direct and indirect impacts of the Leontief input-output matrix in terms of the dispersion of its linkages and the sensitivity of these sectors to stimuli from the rest of the economy. However, this analysis alone cannot provide the patterns of interdependence among sectors, merely representing the effect of that sector on the entire economy. Moreover, since the objective of this work is to understand the role of NRBIs in a potential reindustrialization of the Brazilian

[1] It is valid to emphasize that this return refers only to the media attention given to industrial policies, considering that these policies have never ceased to be practiced by developed countries, albeit under a different name and on a smaller scale. For a discussion about this "return" of industrial policies, refer to the International Monetary Fund's Working Paper "The Return of the Policy That Shall Not Be Named: Principles of Industrial Policy" by Cherif and Husanov (2019)

economy, it means comprehending NRBIs as a distinct economic bloc. Therefore, it is important to understand not only their linkage effects but also their patterns of sectorial interdependence, allowing for a deeper understanding of the dynamics of this bloc and its potential in a reindustrialization scenario. Thus, it is useful to comprehend the relationships within the NRBIs bloc and also with other productive blocs in the economy, understanding their spillover effects and, given the circular flow of income, their feedback patterns.

To achieve this, the works of Costa and Freitas (2018) and Costa (2023) are relevant as they are based on the analytical approach of Pyatt and Round (1979), capable of decomposing the Leontief input-output matrix into different effects among the sectors to be analyzed. This type of decomposition allows for the recovery of the notion of development blocs, as it is possible to measure the impacts of sector blocs on the diffusion of their economic, occupational, and environmental influence to other sectors. In this way, the aim is to present a more complex analytical perspective of the role of NRBIs within the Brazilian economy, considering the productive dimensions of employment and emissions.

However, there are elements challenging the perspective of this bloc as a dynamic element within a neo-industrialization process. Firstly, the high heterogeneity of the bloc stands out, given the idiosyncratic nature of natural resources, with activities having very distinct production patterns and demand linkage capacities. Moreover, the bloc, due to its sectors related to extraction and processing industries, represents a smaller portion of the workforce (IBGE, 2023; Pérez, 2010; Rocha, 2016), posing a challenge in terms of employment. Finally, considering the particularity of the Brazilian context with emissions concentrated in Agriculture and sectors related to the extraction and processing of fossil resources, these sectors are prone to triggering emissions throughout the production structure.

Thus, considering the variety of development strategies and contemporary challenges in the face of the climate crisis, an important area of analysis is opened, understanding the potential of this development strategy while maintaining the relevance of the industry for development. Natural Resource-Based Industries (NRBIs) as a category of analysis represent a crucial step in understanding the interaction between natural resources and industrial development in the context of neo-industrialization and decarbonization. The Brazilian case is particularly interesting due to its rich endowment of natural resources, its greenhouse gas emission pattern that is less energy-intensive and more concentrated in Agriculture and Land Use Change, and the challenges associated with the deindustrialization process observed in recent decades.

This work is divided into four sections, excluding this one. The second section involves a discussion of the context of NRBIs in the Brazilian case and the potentials and challenges in terms of production, employment, and emission linkages of this bloc. In the third section, we present the databases, the structural decomposition methodology used to compose impact matrices by blocs, and calculate sectorial interdependence patterns, as well as the calculation of synthetic linkage indicators. In section 4, we present and discuss the results of the linkage indicators. Finally, in section 5, we provide a conclusion based on the analyzed indicators' results.

2. CONTEXT AND DISCUSSION

Various development strategies throughout history have, in one way or another, involved industrial development as a means to achieve productive growth. Therefore, it is not surprising that industrial development is pointed out by various theoretical approaches as essential for overall development. Factors such as increasing returns in the industry, its potential to accelerate growth and productivity, its role in generating quality employment, and promoting innovation are aspects highlighted by different authors, especially from the structuralism tradition, to justify this special character of the industry.

However, several developing countries have undergone a process of deindustrialization, termed by authors like Rodrik (2016), Palma (2005), Tregenna (2011; 2013), and others as "premature." In other words, these countries start to deindustrialize without having reached a sufficient level of industrial development for the benefits of the industry to be fully internalized.

In this context, the Brazilian scenario is of particular relevance, given that the country has undergone a process of premature deindustrialization in recent decades (Nassif, 2008; Cano, 2012; Araújo et al., 2021; Oreiro; Feijó, 2010; Morceiro; Guilhoto, 2019). This deindustrialization process makes the reflection on an industrial development strategy a challenging task, as it implies overcoming this recent trend, starting from the perspective that the loss of the industry's share of output and employment is a problem, or at the very least, an issue to be addressed or balanced; otherwise, there would be no sense in implementing strategies seeking a new wave of increased industrial participation.

On the other hand, Passoni (2019) argues that, although there has been a process of deindustrialization in the Brazilian economy in recent decades, this phenomenon may not be as pronounced as suggested by some of the literature. The author emphasizes that other structural factors must be considered to assess the deindustrialization process, going beyond the perspective of the relative participation of industrial production in total output. These factors include changes in relative prices, the connection between the production of manufacturing industries and the pace of economic growth and capital accumulation, the pattern of integration of industrial activities into the global economy, and the analysis of technological dynamism in high-tech industrial sectors.

Therefore, despite the relative loss of industrial participation in Brazil during this period, especially in high-tech sectors, the industry still plays a fundamental role in the national productive sector, in contrast to other economies facing premature deindustrialization. This is an element that distinguishes the Brazilian economy from other experiences of premature deindustrialization, reinforcing the importance of analyzing the Brazilian context.

In this context, it starts from an existing industrial structure, which means that this process, portrayed in the literature as "reindustrialization" (Tregenna, 2013), is not about repeating processes like import substitution that occurred in Latin America in the mid-20th century or industrialization in the mold of East Asian countries. Nor is it simply a process contrary to deindustrialization. As highlighted by Tregenna (2013, p.16), "(...) it is not simply a case of 'reverse deindustrialization' because it has its own dynamics."

In this sense, there has been a growing debate recently about re-industrialization strategies under the banner of what the current management of the federal government has termed "neoindustrialization" (Brazil, 2023). This concept seeks to guide this debate from the perspective that industry is not only essential for development but also for ensuring environmental sustainability, overcoming socio-economic inequalities, and being crucial for strengthening Brazilian productive chains and increasing the technological content of production (MDIC, 2024).

This is an important dimension to be addressed, given that, in the current era of climate change, contemplating industrial development is a task that needs to be in line with environmental preservation, considering the industry's potential to emit greenhouse gases (GHGs), both through its production processes and its energy demand (IPCC, 2022). This is another context in which Brazil is unique, specifically in its greenhouse gas emissions profile, as its energy matrix is considerably less reliant on fossil fuels compared to the rest of the world. According to the Energy Research Company (EPE) (2021), in 2020, non-renewable energy generation represented about 15.8% of the national total, with hydroelectric generation contributing almost 64% to the total electricity generated (EPE, 2021). In comparison, global electricity generation from fossil fuels in 2019 was just under 63% of the total electricity generated, according to the International Energy Agency (2020). Thus, while for much of the world, the challenges of combating global warming revolve around energy efficiency and transitioning the energy matrix, in Brazil; the emissions pattern presents a different dynamic.

Considering the plurality of possible development strategies, the literature highlighting the discussion on the development trajectories of Latin America based on a Natural Resource-Based Development (NRBD) strategy stands out. According to this literature, given the revolution in technological patterns brought about by Information and Communication Technologies (ICTs) and changes in the international landscape with the emergence of China as a global superpower, there would be a "window of opportunity" for Latin American countries to specialize and develop based on the exploitation of their natural resources (Andersen et al., 2018; Pérez, 2010; Marin et al., 2015; Pérez; Marín, 2015).

In light of this window of opportunity and the role of industry in development, a relevant analytical category for thinking about NRBD is precisely the intersection between natural resources and industry, i.e., the so-called Natural Resource-Based Industries (NRBIs). According to data from the Greenhouse Gas Emission Estimation System (SEEG), emissions in Brazil are mainly concentrated in Agriculture and Land Use Change and Forests; these two categories combined for the year 2021 represented over 73% of all emissions (SEEG, 2023). In this sense, it is evident that, unlike the rest of the world, Brazil's emissions are closely related to the exploitation of natural resources, especially through the agro-industrial complex. Therefore, to the extent that the dynamic core of emissions in Brazil is primarily in the exploitation of natural resources, particularly land, an NRBD based on NRBIs may result in a high chain of emissions, posing a challenge to this development strategy.

In this context, it is noteworthy that one of the main criticisms of Natural Resources is based on the perspective that these sectors have low linkage effects (Humpreys, Sachs and Stiglitz, 2007; Auty, 2001; Rollin, 1971; Hirschman, 1958). This view is primarily grounded in a theoretical perspective advocated by Hirschman (1958), as he understands that in a productive structure, there are "key sectors" crucial for the functioning and development of the production system. Accordingly, some sectors have greater potential for growth, development, and innovation than others. Hirschman, using the methodological perspective derived from input-output matrices, estimates the backward and forward linkages generated by various sectors of the economy as a way to analyze the importance of a given sector in the production structure. According to the author, backward linkages represent "the effects of input provision, i.e., any non-primary economic activity that will induce demand for supplies, through national production, necessary for that activity." Meanwhile, forward linkages are "the effects on product utilization, i.e., any activity that, by its nature, does not exclusively meet final demands but induces the use of its production as inputs in other activities" (Hirschman, 1958, p.100).

Considering this theoretical perspective, Hirschman pointed out that one characteristic of underdevelopment was the lack of interdependence among the links in the production chain. In this sense, the author indicated that agriculture, as well as other primary sectors specialized in the production of Natural Resources (NRs), would have limited backward and forward linkage capacity. This is because:

> Agriculture in general and subsistence agriculture in particular, are naturally characterized by a scarcity of linkage effects. By definition, all primary production must exclude any substantial degree of backward linkages (...). Forward linkage effects are also weak in agriculture and mining. A large proportion of agricultural production is directly destined for consumption or export; another significant portion undergoes some processing in industries that can be characterized as satellites, as the value they add to the agricultural product (such as milling wheat, rice, coffee, etc.) is small compared to the value of the product itself (Hirschman, 1958, p.109).

Nevertheless, in light of the NRBD literature and the resulting "window of opportunity" for NRBD, it is necessary to examine the maintenance of the perspective expressed in Hirschman (1958) regarding the low dynamism of Natural Resources. In particular, it is essential to estimate the linkage effects of NRBIs as well as the associated patterns of interdependence, given the lack of studies directly addressing this group, especially in the Brazilian context. In this context, to contemplate the role of NRBIs in the Brazilian neoindustrialization process, it is crucial to consider the linkage effects of this group. Emphasizing the importance of thinking about this group in an aggregated manner is essential for analyzing its linkage patterns and interdependence as a distinct block, providing a deeper understanding of its role within the Brazilian production structure.

3. DATA AND METHODOLOGY

3.1 DATA

In order to decompose the impact matrix in the three dimensions analyzed in this study, it is necessary to define the variables of interest in this work, namely, production, occupation, and emissions. Production data comes directly from the composition of the Input-Output Matrices, requiring no prior manipulation. Although, the database used for the Brazilian Input Output Table is the estimated IOT for the year of 2019[2] by the method proposed in Passoni and Freitas (2020) based on data from IBGE table and available on GIC-IE/UFRJ.

However, for the matrices expanded by occupations and emissions, it is necessary to define these vectors. For occupations, data from the National Accounts System (NAS) of the Brazilian Institute of Geography and Statistics (IBGE) for the year 2019 is used. To obtain the occupation impact matrix, a diagonal matrix was used with sectorial employment coefficients per unit of sectorial production value (l). Effectively, taking the coefficients from matrix l, there is a relationship between the vector of labor input use per sector (n) and the vector of sectorial production value g, so that:

$$n = \hat{l}g \tag{1}$$

For emissions, a similar exercise to occupations is conducted. Data from the Greenhouse Gas Emission Estimation System (GGEES) is used, compatible with the classification present in the Input-Output Matrices (IOTs) for the year 2019, with the exclusion of the Land Use Change category. Thus, to obtain the emission impact matrix, a diagonal matrix was used with sectorial emission coefficients per unit of sectorial production value (e). Effectively, taking the coefficients from matrix *'e'*, there is a relationship between the vector of emission input use per sector (E) and the vector of sectorial production value g, so that:

$$E = \hat{e}g \tag{2}$$

3.2 DECOMPOSITION OF MATRICES BY BLOCS

[2] The use of 2019 as the base year can be justified because, in addition to the absence of official MIP (Input-Output Matrix) data for a more recent year, the matrices estimated by the Passoni and Freitas method (2020) extend up to 2020, and 2020 is an atypical year due to the pandemic.

Once the vectors of emissions and occupations are defined, it is possible to decompose the matrix of direct and indirect effects into three effects: intra-group effect, spillover effect, and feedback effect. To achieve this, the methodology closely follows Costa and Freitas (2018) and Costa (2022) based on Miller and Blair (2009), Stone (1985), Pyatt and Round (1979). Additionally, the division of matrix blocks will be made based on the classification determined in Appendix A.

The decomposition of matrix blocks is interesting because it allows an analysis of economically relevant blocks in an aggregated manner, examining their patterns of internal and external interdependence, without losing the sectorial dimension of the activities that make up the blocks. In this context, given the objective of analyzing the productive, occupational, and emission linkages of NRBIs, the partition of the Leontief Inverse Matrix into different groups characterized in Appendix A allows for the analysis of this group as a development pole. This approach provides a better understanding of its role within the Brazilian productive structure, its relationship with other industries, and with other sectors of the economy.

Therefore, before performing the traditional partition decomposition of the input-output impact matrix, it is interesting to first conduct a multiplicative decomposition of the impact matrix to break it down into three effects as proposed by Miller and Blair (2009). This initial decomposition will be useful in the context of the block-wise decomposition as it allows for a better understanding of the interdependence patterns between the blocks, providing a deeper perspective on the role and characteristics of each block.

Thus, to carry out this decomposition, we start first from the main accounting relationship of the IOTs:

$$g = Ag + f \tag{3}$$

Where g represents the vector of total production value, A is the matrix of technical coefficients, and f is the vector of final demand. Given a matrix $\tilde{A}$, which represents the sub matrices of matrix *A* on the main diagonal, thus representing the intra-block coefficients, if we subtract and add $\tilde{A}g$ from equation 3, we have that:

$$g = Ag - \tilde{A}g + \tilde{A}g + f \Rightarrow (I - \tilde{A})^{-1}g = (A - \tilde{A})^{-1}g + f \tag{4}$$

And, by solving for g, the following relationship is found:

$$g = (I - \tilde{A})^{-1}(A - \tilde{A})^{-1}g + (I - \tilde{A})^{-1}f \quad (5)$$

Let $A^{*} = (I - \tilde{A})^{-1} (A - \tilde{A})^{-1}$, then:

$$g = A^{*}g + (I - \tilde{A})^{-1}f \quad (8)$$

Pre-multiplying both sides by A^{*}:

$$A^{*}g = (A^{*})^{2}g + A^{*}(I - \tilde{A})^{-1}f \quad (7)$$

Substituting 6 in 7:

$$g = (A^{*})^{2}g + A^{*}(I - \tilde{A})^{-1}f + (I - \tilde{A})^{-1}f = (A^{*})^{2}g + (I + A^{*})(I - \tilde{A})^{-1}f \quad (8)$$

Finally, solving for *g:*

$$g = \underbrace{[I - (A^{*})^{2}]^{-1}}_{M3} \cdot \underbrace{(I + A^{*})}_{M2} \cdot \underbrace{(I - \tilde{A})^{-1}}_{M1} f \quad (9)$$

Equation 9 above decomposes the Leontief impact matrix into three effects. According to Pyatt and Round (1979), matrix M1 captures the effects of direct transfers within the economy, i.e., the transfers of goods between activities and income distribution. Matrices M2 and M3 capture the effects of the circular flow of income within the economy. Specifically, matrix M2 captures the cross-effects of the multiplier process, where an injection in one part of the system has repercussions in other parts. Finally, matrix M3 represents all circular effects of an income injection bypassing the system and returning to its point of origin.

In the context of partitioning the impact matrix into blocks of matrices or subsystems (Costa, 2023), the decomposition between these three effects takes on another rationality, precisely relating to the relationships of the sectors within a block through their intra-block interactions and between blocks of matrices, i.e., inter-block relationships. In this context, it is possible to understand matrices M1, M2, and M3 as:

(i) M1 is the matrix of internal multiplier, revealing the internal propagation to each group of sectors;

(ii) M2 is the matrix of external multiplier, capturing spillover effects or the transmission of influence between the two groups of sectors but without considering feedback effects.

(iii) M3 is the matrix of external multiplier, capturing feedback effects or circular interdependence between groups of natural resource-based industrial sectors, the rest of the industrial sectors, and non-industrial sectors. Feedback effects, by capturing all the complexity in terms of direct and indirect effects generated by demand for intermediate inputs, are the most important in terms of propagation or diffusion of intermediate demand circuits.

Given the decomposition of the impact matrix into these three highlighted effects, it is possible to proceed with the actual matrix block decomposition. Thus, the sectors of an economy are divided into three groups: i) Group I formed by the sectors of agriculture, livestock, and forestry production; ii) Group II formed by the sectors of industries based on natural resources; iii) Group III formed by the remaining industries; while iv) Group IV composed of the sectors trade, services, public utilities and public administration. If there are "a" sectors in Group I, "r" sectors in Group II, "i" sectors in Group III, and "o" sectors in Group IV, then the total number of sectors is equal to $n = a + r + i + o$. Thus, we can represent the coefficient matrix A in a 4x4 matrix as follows:

$$A = \begin{bmatrix} A_{aa} & A_{ar} & A_{ai} & A_{ao} \\ A_{ra} & A_{rr} & A_{ri} & A_{ro} \\ A_{ia} & A_{ir} & A_{ii} & A_{io} \\ A_{oa} & A_{or} & A_{oi} & A_{oo} \end{bmatrix} \tag{10}$$

The matrices A_{aa}, A_{rr}, A_{ii}, and A_{oo} are square matrices of dimensions $a \times a$, $r \times r$, $i \times i$, and $o \times o$, respectively. The matrices A_{ar}, A_{ai}, A_{ao}, A_{ra}, A_{ri}, A_{ro}, A_{ia}, A_{ir}, A_{io}, A_{oa}, A_{or}, and A_{oi} are rectangular matrices with dimensions varying between a, r, i, and o. The subscripts a, r, i, and o represent the Agriculture and Livestock (*AL*), Natural Resource-Based Industries (*NRBIs*), Manufacturing Industries except NRBIs (*MIeN)* and Services and Public Utilities (*SPU*) sectors, respectively.

From the block-divided matrix A, we can define two other matrices that will help us isolate the effects. Thus, we can represent matrix A by isolating the intra-block ($\tilde{A}$) and inter-block ($\hat{A}$) as follows:

$$A = \tilde{A} + \hat{A} = \underbrace{\begin{bmatrix} A_{aa} & 0 & 0 & 0 \\ 0 & A_{rr} & 0 & 0 \\ 0 & 0 & A_{ii} & 0 \\ 0 & 0 & 0 & A_{oo} \end{bmatrix}}_{\hat{A}} + \underbrace{\begin{bmatrix} 0 & A_{ar} & A_{ai} & A_{ao} \\ A_{ra} & 0 & A_{ri} & A_{ro} \\ A_{ia} & A_{ir} & 0 & A_{io} \\ A_{oa} & A_{or} & A_{oi} & 0 \end{bmatrix}}_{\tilde{A}} \tag{11}$$

From equation 9 and matrix Ã, it is possible to find the effects of the intra-block impact matrix M1, so that:

$$M1 = (I - \tilde{A})^{-1} = \underbrace{\begin{bmatrix} (I - A_{aa})^{-1} & 0 & 0 & 0 \\ 0 & (I - A_{rr})^{-1} & 0 & 0 \\ 0 & 0 & (I - A_{ii})^{-1} & 0 \\ 0 & 0 & 0 & (I - A_{oo})^{-1} \end{bmatrix}} \tag{12}$$

Furthermore, from this result, it is also possible to define a matrix A^* as follows

$$A^* = M1 \cdot \hat{A} = \begin{bmatrix} 0 & (I - A_{aa})^{-1}A_{ar} & (I - A_{aa})^{-1}A_{ai} & (I - A_{aa})^{-1}A_{ao} \\ (I - A_{rr})^{-1}A_{ra} & 0 & (I - A_{rr})^{-1}A_{ri} & (I - A_{rr})^{-1}A_{ro} \\ (I - A_{ii})^{-1}A_{ia} & (I - A_{ii})^{-1}A_{ir} & 0 & (I - A_{ii})^{-1}A_{io} \\ (I - A_{oo})^{-1}A_{oa} & (I - A_{oo})^{-1}A_{or} & (I - A_{oo})^{-1}A_{oi} & 0 \end{bmatrix} \tag{13}$$

Thus, again according to equation 9, it is possible to represent the external multiplier matrix M2 as follows:

$$M2 = I + A^* = \begin{bmatrix} I & (I - A_{aa})^{-1}A_{ar} & (I - A_{aa})^{-1}A_{ai} & (I - A_{aa})^{-1}A_{ao} \\ (I - A_{rr})^{-1}A_{ra} & I & (I - A_{rr})^{-1}A_{ri} & (I - A_{rr})^{-1}A_{ro} \\ (I - A_{ii})^{-1}A_{ia} & (I - A_{ii})^{-1}A_{ir} & I & (I - A_{ii})^{-1}A_{io} \\ (I - A_{oo})^{-1}A_{oa} & (I - A_{oo})^{-1}A_{or} & (I - A_{oo})^{-1}A_{oi} & I \end{bmatrix} \tag{14}$$

Finally, to find the feedback effect M3, it is necessary to perform the matrix multiplication of matrix A* by itself and then subtract it from the identity matrix and invert it as follows:

$$M3 = (I - (A^*)^2)^{-1} \tag{15}$$

From matrices 12, 14, and 15, it is possible to represent the Leontief impact matrix expressed in equation 9 in the following way:

$$M = M3 \cdot M2 \cdot M1 \tag{16}$$

In order to analyze the effects in relative terms of the elements under the total, another transformation in matrix M is necessary. Thus, we can express equation 16 through a transformation that isolates the net effects (Costa; Freitas, 2018; Miller; Blair, 2009):

$$M = I + (M_1 - I) + (M_2 - I)M_1 + (M_3 - I)M_2M_1 \tag{16a}$$

Where $(M_1 - I)$ is M_1 transformed to additive, $(M_2 - I)M_1$ *is* M_2 transformed to additive, and is $(M_3 - I)M_2M_1$ is M_3 transformed. This transformation presents the effects in net terms of intra-block, spillover, and feedback effects.

It is possible to perform the same exercise to decompose the effects on the dimensions of occupation and emission. Thus, it is sufficient to pre-multiply the Leontief impact matrix M by the diagonal matrices e and l, as shown in equations 1 and 2, which represent the coefficient of direct emissions per sector and the coefficient of sectorial employment per unit of sectorial production value, respectively, so that:

$$\hat{e}M = \hat{e}I + \hat{e}(M_1 - I) + \hat{e}(M_2 - I)M_1 + \hat{e}(M_3 - I)M_2M_1 = ME \tag{17}$$

$$\hat{l}M = \hat{l}\, I + \hat{l}(M_1 - I) + \hat{l}(M_2 - I)M_1 + \hat{l}(M_3 - I)M_2M_1 = MO \tag{18}$$

3.3 SYNTHETIC INDICATORS OF PRODUCTION, EMPLOYMENT AND EMISSIONS

It is possible to create two linkage indices to analyze the role of sectors in the dynamics of the production structure: i) Dispersal Power Index (DPI) and ii) Dispersal Sensitivity Index (DSI). These indices are weighted measures that assess the ability of sectors to propagate their respective influences, both in terms of the dispersion of the effects and the sensibility of the sector in relation with a variation in the rest of the economy (Costa; Freitas, 2018; Costa, 2023).

Starting with DPI, we can interpret the meaning of each column in the coefficients table of the multiplier matrix M as the direct and indirect required production in each sector *k* when the final demand for sector *j* increases by one unit. Thus, the total sum of the column indicates the repercussions on the production scale of all sectors, resulting from that one-unit change in final demand. Therefore, to calculate DPI, the vertical sum of each column for sectors *j* in M. This sum shows the magnitudes of the repercussions on production. This index is called DPI and is calculated as follows:

$$DPI_j = \Sigma_k l_{kj} \quad (19)$$

For the calculation of DSI, a similar logic to DPI is applied. However, for DSI, it is necessary to interpret each row in M as the production related to the inputs required directly and indirectly in each sector *k* when the final demand for sector *j* increases by one unit. The index will indicate the influences of a unit of final demand on sector *k*. This index is called DSI, which can be calculated as follows:

$$DSI_i = \Sigma_j l_{kj} \quad (20)$$

From these indices, we can generate an indicator based on the effects of the matrices M1, M2, and M3 that make up the matrix M. In other words, an indicator that measures the importance of sector groups in generating intra-block, spillover, and feedback effects. Given that the matrix *M*, the Leontief inverse, is the multiplier matrix, it is possible to calculate, from decomposition 18, the weight of each sector in the DPI and DSI indices. Thus, WPD represents the weight of the DPI of M1 for matrix M, for example:

$$\frac{DPI_k^{M_1}}{DPI_k^{M}} = WPD_M^{M1} \quad (21)$$

If we take the average of these weights, we obtain the average DPI of M1 with respect to M. Finally, to find the relationship between the WPD and the average DPI, is need to[3]:

$$\frac{WPD_M^{M1}}{Average\ WPD_M^{M1}} = \text{DPI Normalized} \tag{22}$$

4. ANALYSIS OF RESULTS

To calculate the chaining indicators, the methodology indicated in the previous section was used for the three dimensions of analysis: production, occupations and emissions. The results for the aggregate of analyzed blocks, as well as the analysis of these indicators are below.

Table 3 presents the average of the Dispersion Power Index of the productive effects of the matrix *M* decomposed into intra-block effects (M_1), overflow (M_2) and feedback (M_3) for the estimated IOT for the year 2019 for the groups of matrices *AL*, *NBRIs, MIeN* and *SPU* as well as the standard deviations of each block.

Table 1 - Weight of sectors in relation to the sectorial average weight of the Dispersion Power Index for selected groups

	M1	SD* M1	M2	SD M2	M3	SD M3
AL	0,207	0,097	1,316	0,331	1,498	0,505
IBRN	0,682	0,526	1,561	0,279	1,575	0,676
MIeN	0,791	0,260	1,411	0,158	1,123	0,339
SPU	1,371	0,551	0,428	0,313	0,585	0,454

Source: Own elaboration based on the Input-Output Table (IOT) for the year 2019 estimated by Passoni and Freitas (2020).

*SD stands for Standard Deviation

The DPI Weights measure the importance of groups of sectors in generating backward chaining effects, for intra-block, spillover and feedback effects and indicates the importance of this group of sectors for chaining effects back.

Concerning *AL*, it is possible to understand a pattern of smaller effect, on average, within the group (*M1*) being the smallest among the blocks analyzed, which indicates a pattern of little intra-block trade flow, that is, the sectors in this block have low backwards

[3]This process is carried out for each of the three effects for each of the DPI and DSI indicators for the three dimensions of the work.

effects within this block. However, when looking at the average spillover effects (*M2*) and, mainly, feedback (*M3*) it is possible to perceive a high average backward chaining effect, mainly for the feedback effect, that is, it returns to this group again. The high importance of the effect *M2* and *M3* indicates the relative importance of *AL* for the Brazilian economy from the perspective of the backwards and in terms of the circularity of this effect.

To the *NBRIs*, it is possible to notice a pattern similar to that found in *AL*, with the difference of having, on average, greater relative weights for intragroup effects (*M1*) (but still low compared to the rest of the blocks) and for the effects of linear intergroup diffusion (*M2*), which are the largest of the sectors analyzed, indicating the potential of this block in terms of its direct and indirect links to the rest of the economy from the perspective of its backwards effects. This result is in line with what was exposed in Passoni (2019), as it confirms the high chaining effects placed on the groups of *Agricultural Commodities and Industrial Commodities*. For intra-bloc purposes, the sectors linked to the transformation industry related to the extraction of minerals stand out, with emphasis on the activities of *Oil refining and coke ovens, Production of pig iron/ferroalloys, steelmaking and seamless steel tubes, Metallurgy of non-ferrous metals and metal smelting.* It stands out, also in relation to the effects*M1*, high heterogeneity, greater than the *AL* e as *MIeN*, indicating that the chaining potential differs across the block.

As for spillover effects (*M2*), there is greater emphasis, on average, on activities linked to Agriculture, such as *Manufacture and refining of sugar, Manufacture of tobacco products, Other food products, Slaughter and meat products, including dairy and fishery products.* Still, for the purposes *M2* heterogeneity, although greater than the *MIeN*, has a less pronounced role, evidenced by the smaller standard deviation.

Regarding feedback effects (*M3)* It is possible to notice a pattern similar to the effects *M2* in terms of both the high weight in the effect, on average, of all activities and in the composition of the main activities, that is, again the main sectors are those linked to Agriculture such as *Manufacture and refining of sugar, Manufacture of tobacco products, Manufacture of biofuels, Slaughter and meat products, including dairy and fish products, Other food products*. From the perspective of spillover effects, heterogeneity again becomes a relevant issue, as it has the greatest heterogeneity of effects among all the blocks analyzed. This high heterogeneity can be explained by the idiosyncrasy of natural resources, with each one having its own dynamics dictated by the technical and productive characteristics of the natural resources in question.

The importance of sectors linked to agriculture can be understood from the perspective that DPI is an indicator of the backward linkages therefore; precisely the sectors that have the greatest effects are those that are directly related to the first links in the production chain. This indicator also reinforces the characterization made in Appendix A as it reinforces the perspective of the proximity of these industrial sectors to natural resources.

Still regarding the *NBRIs*, this data is an important indicator that this block of sectors has, in the current structure of Brazilian production, a relevant role within the Brazilian economy, being central, from the perspective of backwards effects, in triggering effects for the other sectors and, on the other hand, be influenced by the rest of the economy. Thus, this indicator confirms the perspective that *NBRIs* play an important role in the chains and suggests that a reindustrialization strategy focusing on *NBRIs* as a dynamic link can be a possible path to *neoindustrialization.*

As for the block of *MIeN*, a pattern similar to the block of *NBRIs*, but with a greater role of intra-block chaining effects (*M1)*, indicating the importance of this group of sectors for the industrial dynamics of the economy. Regarding spillover and feedback effects, the lower weight of this block stands out compared to the block of *NBRIs*. On the other hand, *MIeN* are a less heterogeneous bloc than the *NBRIs* with a more similar production dynamic between activities for all purposes analyzed.

Finally, for the block *SPU* the dynamics present in the other blocks for backward chaining effects are reversed, with a greater role for intragroup effects and a lesser role for spillover and feedback effects. This element suggests that the productive dynamics of the backwards effects by this group are more concentrated within the provision of services, with a backward network that is less long and complex compared to industrial sectors. Still, it is worth highlighting that given the heterogeneity intrinsic to the aggregation of very different activities (this block covers almost half of all activities in the economy), it was expected that this block would have a high standard deviation. However, only for intra-bloc effects, the standard deviation is higher than for *NBRIs*, thus reinforcing the heterogeneity of *NBRIs* compared to the other blocks.

Table 4 presents the average of the Dispersion Sensitivity Index of the productive effects of the matrix *M* decomposed into intra-block effects (M_1), overflow (M_2) and feedback (M_3) for the estimated IOT for the year 2019 for the groups of matrices *AL*, *NBRIs, MIeN* and *SPU* as well as the standard deviations of each block.

Table 2 - Weight of sectors in relation to the sectorial average weight of the Dispersion Sensitivity Index for selected groups

	M1	SD* M1	M2	SD M2	M3	SD M3
AL	0,229	0,118	2,193	1,550	1,389	0,778
NRBIs	0,860	0,628	1,080	0,688	1,168	1,262
MIeN	0,995	0,644	0,758	0,528	1,007	0,960
SPU	1,150	0,732	0,994	0,914	0,873	0,859

Source: Own elaboration based on the Input-Output Table (IOT) for the year 2019 estimated by Passoni and Freitas (2020).

*SD stands for Standard Deviation

DSI weights measure the importance of sector groups in generating forward chaining effects for intra-sector, spillover and feedback effects. Thus, an DSI weight indicates the high importance of this group of sectors for chaining effects.

To the *AL* it is possible, as well as from the DPI perspective, to apprehend a low capacity to generate chains within the groups themselves (*M1*) compared to the other groups studied, however, the *AL* presents high spillover effects (*M2)* and feedback (*M3)* presenting the highest weights within the groups analyzed for these two effects. This indicates its important a forward role for the rest of the economy, even though it still has a high intra-group standard deviation. This result was already expected as this block represents the first links in the production chain serving as inputs for other sectors, therefore its forward effects on other sectors are expected to be higher and above the economy average. The high standard deviation is mainly due to the composition of this block covering only three sectors, with the sector *Forestry production; fishing and aquaculture* presenting a dynamic distinct from other sectors.

Regarding the *NBRIs,* This block presents a similar dynamic to *AL,* for also representing the first links of the industrial production chain, concentrating sectors for the extraction and processing of natural resources, being crucial for the functioning of other sectors. Regarding the intragroup effect (*M1*) as *NBRIs* have superior forward chaining effects than those of *AL*, but smaller than the other blocks of the economy, not having a high forward linking capacity, suggesting that these are groups of sectors that do not have a high internal productive dynamic, with their effects prevailing outside the block. For intra-bloc effects, as well as from the perspective of *DPI,* the main activities are those linked to the mineral processing industry, such as *Extraction of oil and gas, including support activities, Oil* *refining and coking plants* and *Extraction of iron ore, including processing and agglomeration,* with the exception of the activity of *Other food products*.

In this context, it is interesting to note that its spillover effects (*M2*) are superior compared to the *MIeN* but below the general average for the economy. This result is interesting because, although it is expected that industrial sectors have high linkages to other sectors, if compared to *MIeN* it is clear that the spillover effect of production is even more significant for this block, therefore being central industries for the production process serving as a catalyst for other activities. It is worth highlighting that the sectors that stand out most for this purpose are *Oil refining and coke ovens, Pig iron/ferroalloy production, steelmaking and seamless steel tubes* and *Metallurgy of non-ferrous metals and metal casting* precisely sectors linked to the extraction and processing of ores.

These indicators, together with DPI indicators, reinforce the perspective that a reindustrialization strategy focusing on *NBRIs* it is capable of acting as a dynamic link in this process, spilling over productive effects to other sectors, and on the other hand being influenced again by other sectors through the feedback effect. However, it is once again necessary to highlight the heterogeneity of this block, as not all IBRN activities have the same spillover capacity.

Finally, regarding the feedback effect (*M3)*, it is highlighted that this is where the *NBRIs* present greater weight compared to the effects *M1* and *M2*, and being just below the weight of the *AL*. This result points to a high sensitivity of this block in relation to other sectors of the economy from a ISD perspective, which is a result that is in line with the perception of these industries as "*process industries"*, that is, at the beginning of the industrial production chain. Furthermore, it draws attention to the high standard deviation of this block, which is mainly due to the outliers *Oil refining and coke plants and Oil and gas extraction, including support activities* and *Production of pig iron/ferroalloys, steelmaking and seamless steel tubes*, which reinforces the high heterogeneity of the effects of these groups.

Regarding the *MIeN*, for spillover effects (*M2*) and feedback (*M3)* the weight of the forward chaining effects of this block is lower, on average, than at *NBRIs*. Specifically for this purpose (*M1*) this block presents a dynamic slightly higher than the pattern observed for *NBRIs* suggesting a richer intra-bloc dynamic from a foward perspective. As for effects outside the block, it appears that the *MIeN* have a less pronounced role compared to the *NBRIs.* This data can be explained from the perspective of the location of the production chains where these blocks are located, with the *NBRIs* closer to the first links in the chain and thus having a greater role in forward chains, and the *MIeN* on the other hand, representing the end of the industry's production chains, in general, and with a less relevant role moving forward. It is noteworthy that the sector has low heterogeneity compared to NBRIs, in this sense since the heterogeneity of *NBRIs* is higher than that of *MIeN*, except for those made intrablock, implying that this distinction captured precisely the sectors with the greatest idiosyncrasy within the industrial sectors.

Finally, the group *SPU* in addition to drawing attention to the fact that the average has a high standard deviation (which is expected precisely because it is an aggregation of the group of services), it also has an effect *M1* higher than the other blocks of the economy, in line with the DPI perspective. From this perspective, overflows (*M2*) are higher than those *MIeN* but lower than *NBRIs.* Finally, for feedback, they are inferior to the other industrial blocks, that is, *NBRIs* and *MIeN*.

Table 5 presents the average of the Dispersion Power Index of the productive effects of the matrix *M* expanded by the vector of occupations "*l*" and decomposed into effects of intra-block effects (M_1), overflow (M_2) and feedback (M_3) for the estimated IOT for the year 2019 for the groups of matrices *AL*, *NBRIs*, *MIeN* and *SPU* as well as the standard deviations of each block.

Table 3 - Weight of sectors in relation to the sectorial average weight of the Occupation Dispersion Power Index for selected groups

	M1	Dp M1	M2	Dp M2	M3	Dp M3
AL	0,275	0,095	0,233	0,069	0,605	0,270
NRBIs	0,271	0,214	2,124	0,692	1,399	0,355
MIeN	0,511	0,191	1,581	0,584	1,340	0,563
SPU	1,747	1,133	0,147	0,108	0,625	0,520

Source: Own preparation based on the 2019 IOT estimated by Passoni and Freitas (2020) and occupation data from SCN/IBGE.

In the indicators that measure the relative importance of sectors in terms of occupation from the perspective of backward effects for the *AL* All intra-bloc effects are verified; *AL* has, on average, a low linking capacity, which indicates that agricultural forward networks have a low capacity for linking jobs.

Now for the *NBRIs*, in line with the VBP indicators, there is a low role for intra-bloc effects (*M1)* which suggests a low capacity of this sector to chain jobs as an isolated subsystem, the smallest among all the blocks analyzed. Compared to the other effects of

NBRIs, this data becomes even more evident given the importance of this sector in the chain of occupations for spillover effects (*M2*) and feedback (*M3*). In particular for spillover effects, the block, through its backward chain, plays a very important role for the rest of the economy in promoting occupations with almost all activities with a linkage weight greater than 2, having the highest average among the analyzed blocks and the five highest weights. Among the groups analyzed, the following stand out, in order, *Extraction of iron ore, including processing and agglomeration*; *Oil and gas extraction, including support activities*; *Manufacture of tobacco products*; *Oil refining and coke plants*; and *Slaughter and meat products, including dairy and fish products*. Furthermore, it is worth highlighting that from the perspective of occupations, the issue of heterogeneity of effects is also present, even if less clearly than from the perspective of VBP

For feedback purposes (*M3),* it is also possible to find a pattern similar to that of *M2*, presenting a high average effect, higher than the other blocks, with the difference that the block of *NBRIs* demonstrate less heterogeneity. The main sectors within the bloc for this purpose are *Extraction of iron ore, including processing and agglomeration*; *Manufacture of tobacco products*; *Oil and gas extraction, including support activities*; *Manufacture of biofuels;* and *Production of pig iron/ferroalloys, steelmaking and seamless steel tubes.*

To the *MIeN,* a pattern similar to the *NBRIs,* but with a role for intragroup effects (*M1)* more pronounced, indicating a more pronounced dynamic in the promotion of occupations within the bloc. Even so, even though it presents a similar pattern for the other effects, on average they are smaller than in the *NBRIs.* This similarity between patterns arises from the dynamics of industrial production chains being longer, with more complex and larger supplier networks capable of influencing the entire economy in a more intense way (Costa; Freitas, 2018). Even so, the distinction between both blocks demonstrates a greater role for sectors closer to natural resources in promoting employment than other industrial sectors, suggesting that the Brazilian productive structure has a greater capacity to generate employment within the circuit of *NBRIs.*

Finally, for the group *SPU,* there is a different dynamic than the other blocks analyzed, in that there is a greater importance of intra-group effects seen from the perspective of the backward effects from these sectors on spillover and feedback effects. In fact, the others block has the highest average intra-block effects among all the groups analyzed and this is mainly due to the sectorial composition of the service groups that have a high density of occupations but their production networks are smaller and with less linking capacity. of the economy as a whole, evidenced by the low spillover and feedback weights.

Table 6 presents the average of the Dispersion Sensitivity Index of the productive effects of the matrix *M* expanded by the vector of occupations "*l*" and decomposed into effects of intra-block effects (M_1), overflow (M_2) and feedback (M_3) for the estimated IOT for the year 2019 for the groups of matrices *AL*, *NBRIs*, *MIeN* and *SPU* as well as the standard deviations of each block.

Table 4 - Weight of sectors in relation to the sectorial average weight of the Occupation Dispersion Sensitivity Index for selected groups

	M1	Dp M1	M2	Dp M2	M3	Dp M3
AL	0,229	0,118	2,193	1,550	1,389	0,778
NRBIs	0,860	0,816	1,080	0,688	1,168	1,262
MIeN	0,995	0,644	0,758	0,528	1,007	0,960
SPU	1,150	0,732	0,994	0,914	0,873	0,859

Source: Own preparation based on the 2019 IOT estimated by Passoni and Freitas (2020) and occupation data from SCN/IBGE.

The DSI is an indicator that estimates the direct and indirect forward chain, in this case the chains are thought of in terms of occupancy. Thus, the *AL* which represents the beginning of the production chain has a high importance in the forward chaining capacity in all observed effects, except for. Only for intra-bloc purposes (*M1*) an *AL* does not have the highest average effect among the blocks analyzed. In particular for spillover effects (*M2*) a *AL* presents the greatest potential for linking, indicating the importance of this sector for generating jobs for other sectors of the economy, and for the feedback effect (*M3)* which estimates the circular chain effects that return to the bloc, indicating its sensitivity towards other sectors of the economy.

Regarding the *NBRIs*, on average, there is a very similar pattern to that found for VBP for all the effects analyzed. This pattern from the forward perspective differs from the pattern observed from the backward perspective, where *NBRIs* have low intrablock effects (*M1*) and a greater role for spillover (*M2*) to the extent that they have, for forward a more pronounced role for feedback ‘effects (*M3*). Still, from an intra-block perspective, the *NBRIs*, compared to the *MIeN*, have a lower average weight, with emphasis on the *Oil and gas extraction, including support activities*; *Oil refining and coke plants*; *Other food products*; and *Extraction* *of iron ore, including processing and agglomeration,* mainly linked to mineral extractive sectors.

Still, the most important pattern of the spillover effect (*M2*) with respect to intragroup effects (*M1)* is also found from a forward perspective, which indicates that it continues to have a stronger dynamic with other blocks than within the block. In particular, the sectors linked to mineral processing stand out again *Production of pig iron/ferroalloys, steelmaking and seamless steel tubes*; *Oil refining and coke plants*; and *Metallurgy of non-ferrous metals and metal casting*, with the exception of *Other food products Manufacture of textile products* which also have high effects.

For feedback purposes (*M3*), it can be seen that the block is the one with the greatest chaining effects from a forward perspective, demonstrating the capacity of this block to not only overflow but to relate to other blocks, once again obtaining a chaining effect in terms of occupations. From this perspective, the main sectors are those linked to mineral processing *Oil refining and coke plants*; *Oil and gas extraction, including support activities*; and *Production of pig iron/ferroalloys, steelmaking and seamless steel tubes* with the exception of *Other food products* and *Manufacture of biofuels.*

Again, for all intents and purposes, the heterogeneity of this group is highlighted, evidenced by the high standard deviation, especially when compared to the *MIeN*, being superior for all analyzed purposes. In particular, heterogeneity is superior to other blocks of the economy, except for the effects *M2.*

The block *MIeN*, following the trend for VBP, plays an important role from the perspective of offering chaining effects intrablock (*M1),* being the only effect that is superior to the *NBRIs*. This fact suggests that these industries play an important role in the dynamics of occupations within the industrial sphere of the economy. For spillover effects (*M2*) presents a less accentuated dynamic and for feedback purposes, it is the second block with the highest average of chaining effects.

Finally, it is highlighted that the block *SPU*, maintains its internal pattern of greater relevance of intra-block effects (*M1*) with respect to spillover effects (*M2*) and feedback (*M3*).

Table 7 presents the average of the Dispersion Power Index of the productive effects of the matrix *M* expanded by the emissions vector "*e",* decomposed into intra-block effects (M_1), overflow (M_2) and feedback (M_3) for the estimated IOT for the year 2019 for the groups of matrices *AL*, *NBRIs*, *MIeN*, and *SPU* as well as the standard deviations of each block.

Table 5 - Weight of sectors in relation to the sectorial average weight of the Emission Dispersion Power Index for selected groups

	M1	Dp M1	M2	Dp M2	M3	Dp M3
AL	0,285	0,238	0,345	0,323	0,462	0,394
NRBIs	0,418	0,413	1,186	0,691	0,621	0,358
MIeN	0,267	0,197	1,639	0,316	1,266	0,501
SPU	1,827	0,985	0,568	0,403	1,075	0,595

Source: Own elaboration based on the 2019 IOT estimated by Passoni and Freitas (2020) and SEEG data with the exclusion of *Land Use Change*.

Table 7 presents the weights of each block in relation to the average weight based on the DPI, for the four analysis blocks. To the *AL*, from the perspective of backwards effects, it can be seen that the block has low, on average, chaining effects, especially for effects within the block, concentrated, above all, on spillover effects (*M2)* and feedback (*M3)*. This result must be balanced by the notion that DPI captures the backward effects of the economy, and being the *AL* the first links of the production chain, it was expected that the backward spillover effect would not be so pronounced for the other blocks.

Now for the *NBRIs* It is clear that, in contrast to the pattern observed from other perspectives, the block plays a relevant role in intra-block effects. This role becomes even more pronounced when compared to the *MIeN*, which, although these are also industrial sectors with longer and more complex production chains, presents a lower weight for this purpose. This particular dynamic and different from the *MIeN* reinforces the importance of analyzing this block of sectors separately from the rest of the industry, demonstrating its weight in the chain of emissions within the Brazilian productive structure. This stronger role of intra-bloc effects occurs mainly in industries related to activities linked to mineral processing, such as *Oil refining and coke plants; Metallurgy of non-ferrous metals and smelting of metals and Extraction of non-ferrous metallic minerals, including processing*. It is also noteworthy that for this purpose, heterogeneity is also present, which is just not superior to the block *SPU.*

As for spillover effects (*M2*) this block is highly important in the backward chain of emissions, even if not to the same extent as the block *MIeN.* In particular, on average, its effects are superior to other non-industrial blocks, demonstrating its role in the backward chain of emissions. Another relevant point is that this pattern can be considered from the perspective that *NBRIs*, in general, are processing sectors closer to the beginning of the chain, thus explaining the difference between *MIeN*. Even so, we highlight again that the block is also more heterogeneous in terms of emissions from the perspective of spillover than the other blocks of the economy, with emphasis on sectors linked to agriculture such as *Manufacture of tobacco products*; *Other food products*; *Manufacturing of wood products*; *Biofuel manufacturing*; *Manufacturing of textile products*; and *Sugar manufacturing and refining.*

For feedback purposes (*M3*) it appears that from the perspective of the backward, this block has low effects, on average, compared to *MIeN*, in addition to its heterogeneity of emissions being the smallest among the blocks analyzed. Even so, the activities of *Manufacturing of wood products* and *Manufacturing of textile products* diverge from the others activities of the group.

The block of *MIeN*, despite being of little importance in terms of its effects within the bloc, which can be explained by the absence of sectors related to oil exploration or agriculture, it plays an important role in spillover effects (*M2)* and under the effects of feedback *(M3)* which are higher than the *NBRIs*. This data is in line with the argument presented in Costa (2023) that, although industrial sectors are not *per si* emissions-intensive, due to their long and complex production chains, they act as an important driver of demand for emissions from other more emissions-intensive sectors, and thus are a crucial group for thinking about decarbonization strategies as their emission effects emission demand must be taken into account in policy planning.

Already on the block *SPU*, there is a prevalence of importance under intra-block effects (*M1)* and feedback (*M3*) in relation to spillover effects (*M2)*, although for almost all purposes the sector presents a high heterogeneity, especially for those purposes in which the sector is, on average, larger.

Table 8 presents the average of the Dispersion Sensitivity Index of the productive effects of the matrix *M* expanded by the emissions vector "*e"*, decomposed into intra-block effects (M_1), overflow (M_2) and feedback (M_3) for the estimated IOT for the year 2019 for the groups of matrices *AL*, *NBRIs*, *MIeN* and *SPU* as well as the standard deviations of each block.

Table 6 - Weight of sectors in relation to the average sectorial weight of the Emissions Dispersion Sensitivity Index for selected groups

	M1	Dp M1	M2	Dp M2	M3	Dp M3
AL	0,248	0,127	2,303	1,627	1,452	0,813
NRBIs	0,929	0,560	1,134	0,722	1,220	1,318

MIeN	1,076	0,695	0,796	0,554	1,052	1,003
SPU	1,063	0,828	0,932	0,962	0,812	0,894

Source: Own elaboration based on the 2019 IOT estimated by Passoni and Freitas (2020) and GGEES data with the exclusion of *Land Use Change*.

There is a central relevance of this group for effects outside the block, that is, the spillover effect (*M2*) which presents a very high average in the participation of these forward effects, and feedback effects (*M3*) that clash with the other indicators analyzed. Given the emission pattern of the Brazilian economy, it was expected that precisely the greatest weights in the forward chain effects would be related to the group of *AL*, even with the exclusion of land use change data in the construction of the emissions vector. This specific pattern of emissions in the Brazilian economy justifies understanding the *AL*, even though it presents few sectors, as a particular sector block with its own dynamic and relevant to being highlighted from the other sectors analyzed in this study, indicating its centrality in understanding decarbonization strategies.

Another block that also stands out from the forward perspective in terms of the relative importance of chaining effects is that of *NBRIs*, which despite not having effects as pronounced as the *AL*, have a higher importance in forward chain effects than the other groups and higher than the economy average for the effects*M2* and *M3*. In this context, Table 8 indicates stability in the effects of the block of *NBRIs* for all effects studied, being close to unity, this indicates an important role of this block in inducing emissions both inside and outside the group studied.

In particular for intra-bloc effects, despite being inferior to the blocks of *MIeN* and *SPU*, are close to these. The intra-block heterogeneity within this context is smaller compared to these blocks, with emphasis on sectors linked to the extraction of oil and minerals, such as *Oil and gas extraction, including support activities*; *Oil refining and coke plants*; *Extraction of iron ore, including processing and agglomeration*, with the exception of the activity of *Other food products*.

It is from the perspective of the effects *M2* and *M3* that this block stands out that although they are inferior to the *AL*, are superior to *MIeN* also being more heterogeneous than the *MIeN*. Indicating that this block is central from the perspective of forward chain emissions to other productive sectors and that these effects return to the block, indicating sensitivity in relation to the economy's emissions. In particular, the main sectors from the perspective of the spillover effect are those linked to mining, such as *Production of pig iron/ferroalloys*, *steelmaking and seamless steel tubes*; *Oil refining and coke plants*; and *Metallurgy of non-ferrous metals and metal casting* with the exception of *Manufacture of textile products Other food products.* For feedback purposes, this pattern also occurs, however with the change in order with activities linked to the oil sector being the main ones, such as *Oil refining and coke plants*; *Oil and gas extraction, including support activities*; however, with the presence of *Production of pig iron/ferroalloys, steelmaking and seamless steel tubes*; *Other food products*; and *Manufacture of biofuels.*

Furthermore, it is important to highlight that the standard deviation of this block is a relevant fact to be highlighted, mainly due to the feedback effect *(M3*) which is superior to the other blocks analyzed. For the standard deviation of the spillover effect (*M2)* even though it is not bigger than the blocks *AL* and *SPU* are superior to *MIeN*.

Therefore, it is possible to see that the *NBRIs* both from a backward perspective and from a forward perspective play an important role in the chain of emissions not only within the block, but also outside and for the circular effect of emissions. This emissions pattern is very different from that MIeN which has a more pronounced chaining pattern in backwards than in forward Still, it is important to highlight the high heterogeneity within the block, which implies the possibility, from a perspective of neo industrialization Starting at *NBRIs,* of a particular industrial decarbonization policy for different activities within the block, with activities related to the extraction of ores and their processing, especially the petrochemical sector, having the greatest effects of chaining emissions.

In the block of *MIeN,* in line, as highlighted in Costa (2023), presents a superiority of the intra-bloc effects in relation to the other effects of the bloc, which points to an important role in the propagation of emissions within the bloc, although less pronounced than outside. It is also worth highlighting that the pattern presented in the *MIeN* differs considerably from the pattern found in *NBRIs,* indicating the importance of analyzing this block of sectors in a particular way in relation to other industrial sectors.

Finally, the group *SPU* presents, on average, a role for forward linkages from the larger economy to the effects within the bloc. However, it is important to highlight that within this block, as expected given the type of aggregation carried out, there is high heterogeneity, captured by the high standard deviation.

The emissions standard of *NBRIs* propose challenges for the role of the *NRBIs* in a neoindustrialization, as it exposes the weight of these sectors in the chain of emissions throughout the Brazilian economy from the perspective of backward and forward, precisely due to their proximity to the *AL* and with oil extractive sectors and also due to the fact that these industrial sectors have longer and more complex production chains. Thus, the *NBRIs* are capable of triggering emissions in the rest of the economy as a whole, acting as an important diffuser of emissions from the perspective of their backward

5. CONCLUDING REMARKS

The objective of this article was from a perspective grounded in the notion development blocks and the Input-Output Table (IOTs) methodology, create indicators related to productive, occupational, and emission linkages were presented for the blocks analyzed in this study, namely *AL*, *NRBIs*, *MIeN*, and SPU. By merging the analysis of development blocks with the decomposition of effects based on Pyatt and Round (1979), it was possible to isolate intra-block, inter-block, and feedback linkages. The purpose of this exercise is based on the comparative discussion of NRBIs linkages with other sector blocks to assess the potential of NRBIs as a dynamic element in a possible neoindustrialization of the Brazilian economy.

However, before obtaining occupational and especially emission linkages, data processing was necessary to match the structure present in the IOTs. Concerning occupations, the exercise is more straightforward, as the Brazilian Institute of Geography and Statistics (IBGE) already provides occupation data at the activity level from the National Accounts System (NAS). On the other hand, to reconcile the SEEG database with the IOTs, information processing was required, as detailed in Alvarenga, Costa e Costa (2024).

As a result, information on linkages in the three highlighted dimensions for the three effects analyzed was obtained for the studied blocks, characterized from Appendix A. Regarding production-level effects, NRBIs, on average, play a more prominent role outside the block than within the block, meaning in the linkage of their effects to other sectors of the economy. They are also sensitive, on average, to other blocks, as evidenced by the high feedback effect. Particularly, NRBIs have a higher potential, on average, when viewed from the backward perspective (DPI) than from the forward perspective (DSI). Still, in terms of production, NRBIs outperform MIeN on average for all effects, except internal ones.

Another central aspect of this work concerns the high heterogeneity within this sector block, especially concerning backward linkages. In particular, the main sectors capable of generating productive linkages in this block are: Petroleum refining and coking; *Oil and gas* *extraction, including support activities; Other food products; Production of pig iron/ferroalloys, steelmaking, and seamless steel tubes;* and *Biofuel manufacturing*.

Regarding the dimension of occupations, again, there is a greater emphasis on backward linkages, especially in the spillover (inter-block) and feedback effects, with low intra-block effects. Also, it is crucial to highlight that for occupational effects, the block is also heterogeneous, especially from the forward perspective, indicating that heterogeneity also plays a significant role in the occupational dimension. In particular, the main sectors capable of generating occupational linkages in this block are: *Petroleum refining and coking; Oil and gas extraction, including support activities; Production of pig iron/ferroalloys, steelmaking, and seamless steel tubes; Other food products;* and *Non-ferrous metal metallurgy and metal casting sectors mainly linked to ore extraction and processing.*

Finally, concerning the emission perspective, it is emphasized that NRBIs, on average, have a prominent role in terms of their more pronounced "forward" linkages than "backward" ones. These data present a different pattern from MIeN, which show emission propagation dynamic centered on the backward perspective. Still, an essential element is the heterogeneity within this block, which is higher from the backward perspective for spillover effects and from the forward perspective for feedback effects. In particular, the main activities capable of chaining emissions are: Petroleum refining and coking; Oil and gas extraction, including support activities; Other food products; Textile product manufacturing; and Production of pig iron/ferroalloys, steelmaking, and seamless steel tubes, mainly linked to ore extraction and processing.

APPENDIX A - CHARACTERIZATION OF NRBIS (NATURAL RESOURCE-BASED INDUSTRIES)

In order to assess the linkages of the NRBIs group, as well as a neoindustrialization stemming from these industries, it is necessary to develop a theoretical approach capable of representing this group within the context of the Brazilian Institute of Geography and Statistics (IBGE) National Accounts System. This means that it is necessary to elaborate a classification of the sectors in the National Accounts System (NAS) that allows us to isolate these sectors from the rest of the economy. Furthermore, the definition provided by the literature on NRBIs is often vague and not easily translated into the NAS sector classification. For instance, Andersen, Marìn, and Simensen (2018) only define NRBIs as "industries in the primary sector." Given these issues, we chose to work with our own characterization of NRBIs based on the relative participation of the intermediate consumption of sectors in natural resources. This characterization has the benefit of being simple to calculate and define the sectors, not relying on other classifications that may not align with the purpose of this study. It is expected that this characterization will better capture the essence of these industries, providing a more reliable analysis of the group.

To perform this classification, we will be using the Input-Output Matrices (IOTs) estimated by the Passoni and Freitas method (2020) for the year 2019, as this will be the base year for the calculations. Firstly, to assess the intermediate consumption of sectors in natural resources, it is necessary to define which products can be classified as natural resources. In order to define these products, we used the classification present in the National Classification of Economic Activities (CNAEs) for groups A - Agriculture, livestock, forestry, fishing, and aquaculture, and B - Extractive industries. The result is presented in Table A1 below.

Chart A1 - Classification of Natural Resources by Products

Product Code	Product Description at Level 126
1911	Rice, wheat, and other cereals
1912	Corn in grain
1913	Herbaceous cotton, other fibers of temporary crops
1914	Sugarcane

Product Code	Product Description at Level 126
1915	Soybeans in grain
1916	Other products and services of temporary crops
1917	Orange
1918	Coffee in grain
1919	Other products of permanent crops
1921	Cattle and other live animals, animal products, hunting, and services
1922	Cow's milk and milk from other animals
1923	Swine
1924	Poultry and eggs
2801	Products from forestry and silviculture
2802	Fishing and aquaculture (fish, crustaceans, and mollusks)
5801	Coal
5802	Non-metallic minerals
6801	Petroleum, natural gas, and support services
7911	Iron ore
7921	Non-ferrous metallic minerals

Source: Own Elaboration

Based on this classification, the products were grouped into a single category called "In *natura* products". From this aggregation, the share of fresh products for intermediate consumption in the industrial sectors was calculated, resulting in table A1 below.

Table A1 - Participation of Natural Resources in Industrial Sectors by Activities

(Continues)

Activity Description at level 67	Participation of natural resources
Sugar manufacturing and refining	0.65
Biofuel manufacturing	0.57
Manufacture of tobacco products	0.56
Slaughter and meat products, including dairy and fish products	0.39
Oil refining and coke plants	0.36
Other food products	0.34
Production of pig iron/ferroalloys, steelmaking and seamless steel tubes	0.32
Metallurgy of non-ferrous metals and metal casting	0.14
Manufacturing of textile products	0.12
Manufacture of products from non-metallic minerals	0.11
Manufacturing of wood products	0.11
Extraction of non-ferrous metallic minerals, including processing	0.11
Manufacture of pulp, paper and paper products	0.06

Activity Description at level 67	Participation of natural resources
Oil and gas extraction, including support activities	0.06
Beverage manufacturing	0.04
Manufacture of organic and inorganic chemicals, resins and elastomers	0.04
Extraction of iron ore, including processing and agglomeration	0.04
Extraction of mineral coal and non-metallic minerals	0.03
Manufacture of rubber and plastic products	0.01
Manufacture of metal products, except machinery and equipment	0.01
Manufacture of parts and accessories for motor vehicles	0.00
Manufacture of pesticides, disinfectants, paints and various chemicals	0.00
Manufacture of electrical machinery and equipment	0.00
Manufacture of furniture and products for various industries	0.00
Manufacture of pharmochemical and pharmaceutical products	0.00
Manufacture of cleaning, cosmetics/perfumery and personal hygiene products	0.00
Manufacture of cars, trucks and buses, except parts	0.00
Manufacture of shoes and leather goods	0.00
Production of clothing items and accessories	0.00
Manufacture of machines and mechanical equipment	0.00
Printing and playing back recordings	0.00
Manufacture of computer equipment, electronic and optical products	0.00
Manufacture of other transport equipment, except motor vehicles	0.00
Maintenance, repair and installation of machines and equipment	0.00

Source: Own elaboration.

The results represent the participation of *"Products in Natura"* for each industrial sector. As can be seen, the vast majority of sectors do not reach 30% of the share of their Intermediate Consumption *in natura* products, with only seven sectors showing a share greater than 30%. These data, however, do not give us insight relative how much the "*Natural Products"* represent in each sector, as an example, it is possible that in some sectors the share of Intermediate Consumption is more diluted in other products, or more concentrated in others, so that it would be difficult to understand the role of *Natural products for* inputs for each sector. In this sense, it is important to understand the position of *Natural products* within intermediate consumption.

To solve this problem, it is proposed to define NBRIs if the intermediate consumption of *Natural products be* among the top three inputs demanded by the sector. As a result of this analysis, Table A2 below is obtained.

Table A2 - Top-3 Intermediate Consumption of Natural Resources

Activities	NR.s Top 3 IC
Extraction of mineral coal and non-metallic minerals	No

Activities	NR.s Top 3 IC
Oil and gas extraction, including support activities	No
Extraction of iron ore, including processing and agglomeration	No
Extraction of non-ferrous metallic minerals, including processing	Yes
Slaughter and meat products, including dairy and fish products	Yes
Sugar manufacturing and refining	Yes
Other food products	Yes
Beverage manufacturing	No
Manufacture of tobacco products	Yes
Manufacturing of textile products	Yes
Production of clothing items and accessories	No
Manufacture of shoes and leather goods	No
Manufacturing of wood products	Yes
Manufacture of pulp, paper and paper products	No
Printing and playing back recordings	No
Oil refining and coke plants	Yes
Biofuel manufacturing	Yes
Manufacture of organic and inorganic chemicals, resins and elastomers	No
Manufacture of pesticides, disinfectants, paints and various chemicals	No
Manufacture of cleaning, cosmetics/perfumery and personal hygiene products	No
Manufacture of pharmochemical and pharmaceutical products	No
Manufacture of rubber and plastic products	No
Manufacture of products from non-metallic minerals	Yes
Production of pig iron/ferroalloys, steelmaking and seamless steel tubes	Yes
Metallurgy of non-ferrous metals and metal casting	Yes
Manufacture of metal products, except machinery and equipment	No
Manufacture of computer equipment, electronic and optical products	No
Manufacture of electrical machinery and equipment	No
Manufacture of machines and mechanical equipment	No
Manufacture of cars, trucks and buses, except parts	No
Manufacture of parts and accessories for motor vehicles	No
Manufacture of other transport equipment, except motor vehicles	No
Manufacture of furniture and products for various industries	No
Maintenance, repair and installation of machines and equipment	No

Source: Own elaboration.

Finally, the extractive industries (Group B of the CNAEs) even though the *Natural products* They are not among the three largest shares in Intermediate Consumption in the sector, they are by definition Industries that are directly linked to natural resources, with the production of these Resources being the target of their production process. Therefore, aggregating the sectors that have the *Natural products* with Extractive Industries, the characterization used in this work of NBRIs is obtained. It is also worth highlighting that, although the Beverage Manufacturing activity is commonly associated with the Other Food Products activity, in this characterization this activity was left out, precisely because of its low consumption of natural resources, given that the "Beverages" product is not included in our classification as an *In Natura Product*. The results of the Classification to be used can be seen in Table A3.

Table A3 - Classification of Matrix Blocks by Activities

Block	Activities
Agriculture and Livestock (AL)	Agriculture, including agricultural and post-harvest support
	Livestock, including support for livestock farming
	Forestry production; fishing and aquaculture
NRBIs	Extraction of mineral coal and non-metallic minerals
	Oil and gas extraction, including support activities
	Extraction of iron ore, including processing and agglomeration
	Extraction of non-ferrous metallic minerals, including processing
	Slaughter and meat products, including dairy and fish products
	Sugar manufacturing and refining
	Other food products
	Manufacture of tobacco products
	Manufacturing of textile products
	Manufacturing of wood products
	Oil refining and coke plants
	Biofuel manufacturing
	Manufacture of products from non-metallic minerals
	Production of pig iron/ferroalloys, steelmaking and seamless steel tubes
	Metallurgy of non-ferrous metals and metal casting
Manufacturing Industries, except NBRIs (MIeN)	Beverage manufacturing
	Production of clothing items and accessories
	Manufacture of shoes and leather goods
	Manufacture of pulp, paper and paper products
	Printing and playing back recordings
	Manufacture of organic and inorganic chemicals, resins and elastomers

Block	Activities
	Manufacture of pesticides, disinfectants, paints and various chemicals Manufacture of cleaning, cosmetics/perfumery and personal hygiene products Manufacture of pharmochemical and pharmaceutical products Manufacture of rubber and plastic products Manufacture of metal products, except machinery and equipment Manufacture of computer equipment, electronic and optical products Manufacture of electrical machinery and equipment Manufacture of machines and mechanical equipment Manufacture of cars, trucks and buses, except parts Manufacture of parts and accessories for motor vehicles Manufacture of other transport equipment, except motor vehicles Manufacture of furniture and products for various industries Maintenance, repair and installation of machines and equipment
Services and Public Utilities (SPU)	Electricity, natural gas and other utilities Water, sewage and waste management Construction Wholesale and retail trade Ground transportation Water transportation Air Transport Storage, auxiliary transport and mail activities Accommodation Food Print-integrated publishing and editing Television, radio, cinema and sound and image recording/editing activities Telecommunications Development of systems and other information services Financial intermediation, insurance and supplementary pension Real estate activities Legal, accounting, consultancy and company headquarters activities Architecture, engineering, technical testing/analysis and R&D services Other professional, scientific and technical activities Non-real estate rentals and intellectual property asset management Other administrative activities and complementary services

Block	Activities
	Surveillance, security and investigation activities Public administration, defense and social security Public education Private education Public health Private healthcare Artistic, creative and performance activities Membership Organizations and Other Personal Services Domestic services

Source: Own elaboration.

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