DOI: 10.5433/2317-627X.2022v10n3p194

Economia & Região
E-ISSN: 2317-627X

Sectoral analysis and identification of key sectors in MATOPIBA: an input-product approach

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Recebido em: 16/03/2022
Aprovado em: 17/07/2022

Abstract

The present study obtained the sectorial and intersectoral effects, in relation to greenhouse gas (GHG) emissions, through the realization of the ABC Plan in the MATOPIBA region. A Hybrid Inter-Reginal Input-Output model focusing on the breakdown of the MATOPIBA region was built and operationalized for this purpose. Two scenarios were created with different levels of GHG emissions resulting from the implementation (or not) of the ABC Plan in the region. The results show the importance that the actions of the ABC Plan brought to the study region, the main key sectors for the control of GHG emissions in the region, in addition to corroborating the permanence of pro-environmental actions in MATOPIBA.

Key words: input-output; Matopiba; ABC plan.

JEL Classification System: F18; F60; F64.

Análise setorial e identificação dos setores-chave no MATOPIBA: uma abordagem por insumo-produto

Resumo

O presente estudo obteve os efeitos setoriais e intersetoriais, em relação às emissões de gases de efeito estufa (GEE), por meio da realização do Plano ABC na região do MATOPIBA. Para isso, foi construído e operacionalizado um modelo Híbrido Inter-regional Input-Output com foco no desdobramento da região do MATOPIBA. Foram criados dois cenários com diferentes níveis de emissões de GEE decorrentes da implantação (ou não) do Plano ABC na região. Os resultados mostram a importância que as ações do Plano ABC trouxeram para a região de estudo, os principais setores-chave para o controle das emissões de GEE na região, além de corroborar a permanência de ações pró-ambientais no MATOPIBA.

Palavras-chave: insumo-produto; matopiba; plano ABC.

Classificação JEL : F18; F60; F64.

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Introduction

Brazil has global importance for food production and conservation of natural resources (POLIZEL *et al.*, 2021; SPAROVEK *et al.*, 2018; WAROUX *et al.*, 2019). The supply of food, bioenergy, feed and animal protein to a growing global population is linked to deforestation, loss of habitat and negative impacts on biodiversity, greenhouse gas (GHG) emissions and depletion of water resources (RUSSO LOPES; LIMA; REIS, 2021; SOLIDARIDAD, 2021; SUELA; NAZARETH; CUNHA, 2020). Thus, large-scale production represents major challenges for Brazil: maintaining good economic performance combined with environmental conservation (AZEVEDO JUNIOR; RODRIGUES; SILVA, 2022; BROOKS, 2017; EMBRAPA, 2018; SUELA; NAZARETH; CUNHA, 2020).

According to data from the Greenhouse Gas Emissions Estimation System - SEEG (2021), Brazil, in 2020, was the sixth largest GHG emitter in the world, producing approximately 2.16 billion gross tons of CO2 equivalent (GtCO CO_2eq). The Agriculture, Forestry and Other Land Uses (AFOLU) sector was responsible for about 70% of these emissions (SEEG, 2021) and a considerable part of the emissions result mainly from deforestation (EMBRAPA, 2018; SEEG, 2021).

However, even if deforestation reductions are foreseen in its pro-environmental actions agreed at the Conference of the Parties (COP, editions 15 and 21), the country still aims to use a large part of its existing agricultural frontier. This frontier is located in the region known as MATOPIBA (acronym for the states of Maranhão, Tocantins, Piaui and Bahia) which is also known as the last agricultural frontier of Brazil and is currently being widely cultivated for agricultural commodities and beef production (Figure 1) (RUSSO LOPES; LIMA; REIS, 2021).

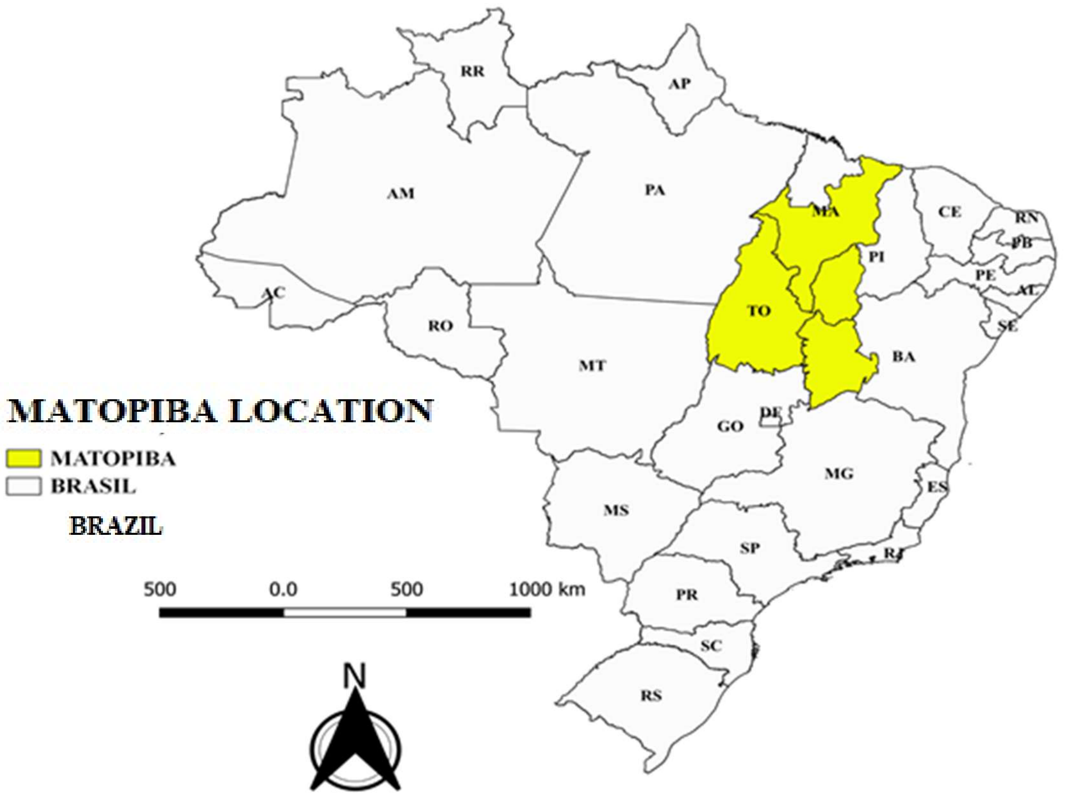
The MATOPIBA region extends over areas adjacent to three northeastern states (Maranhão, Bahia and Piauí) and a state in the northern region of the country (Tocantins), covering the Cerrado biomes with 90.94% (of the entire area), Amazon, with 7.27%, and Caatinga, with 1.64% (EMBRAPA, 2015). There are 337 municipalities, 324,000 agricultural establishments, 46 conservation units, 35 indigenous lands, 36 quilombolas and 1,053 agrarian reform settlements in a total area of 73,173,485 hectares (REZENDE *et al.*, 2018; BASTOS LIMA; PERSSON, 2020)[2]. It is noted that this region is not only suitable for agricultural production, but also rich in human and cultural capital (FIAN INTERNATIONAL, 2018).

Despite the abundant cultural diversification taking advantage of the region, MATOPIBA still holds approximately 8.5 million hectares (Mha) of area for agricultural and forestry use and, consequently, the demand for expansion of national agricultural production is being boosted to this region (AGROSATÉLITE GEOTECNOLOGIA APLICADA, 2020; SOLIDARIDAD, 2021)[3].

[2]MATOPIBA is a territorial division created through a technical cooperation agreement signed in 2014 between some ministries and federal agencies to designate the potential area for agricultural expansion in an area that has been constantly described by Brazilian governments as the "last frontier". world agriculture. In May 2015, the Brazilian government created, by decree, the MATOPIBA special region and launched the MATOPIBA Agricultural Development Plan (PDA), designating the area for the development of agricultural and mining activities (EMBRAPA, 2015).

[3]This area is divided between pastures suitable for agricultural use, degraded pastures, but which still have agricultural aptitude and Legal Reserve Surplus (ERL), for more information, read "Regional Potential for Soy Expansion in MATOPIBA" (SOLIDARIDAD, 2021).

Figure 1 - Map of Brazil containing the highlighted MATOPIBA area



Source: Authors' elaboration

Information from the Companhia Nacional de Abastecimento - CONAB (2020) corroborates this information. Their data indicate that MATOPIBA was responsible for the production of approximately 12.8 million tons (Mt) of soybeans in the 2018/2019 harvest and about 8 Mt of corn in the same period, using an area of 4.9 million tons. Mha, corresponding to 12% of the national grain production. At the same time, between 2000 and 2020, new areas were opened, totaling about 4.18 Mha (expansion of 253% of the arable area). About 76% of this expansion took place on land with native vegetation, causing several risks to local biodiversity (BRASIL, 2020). With the possibility of growth in the region, it is expected that between the 2018/19 and 2028/29 harvests, grain production will reach approximately 32.7 million tons. At the same time, for this to occur, it will be necessary to open new areas totaling 8.9 Mha, which will increase the existing environmental liabilities in the region (BRASIL, 2020; OBSERVATÓRIO DO CLIMA, 2017).

In this context, agriculture and conservation stand out as extremely relevant topics (FIAN INTERNATIONAL, 2018; FREITAS, 2019; RUSSO LOPES; LIMA; REIS, 2021). According to Agrosatélite Geotecnologia Aplicada (2020) and Solidaridad (2021), 26 million hectares of Cerrado are land with medium or high agricultural aptitude but are currently occupied with degraded pastures. These lands could, for example, be reused for mechanized soy planting. MATOPIBA holds 15% of this total (4 Mha), which can be revitalized, for example, through the strategies contained in the ABC+ Plan (sectoral plan for adaptation to climate change and low carbon emissions in agriculture with a view to sustainable development)[4], successor to the former ABC Plan (Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low-Carbon Economy in Agriculture), a plan that has already proven to be effective (LIMA *et al.*, 2019; BRASIL, 2018; SPAROVEK *et al.*, 2018).

In this sense, it is possible to affirm that the advance of the existing actions in the ABC+ Plan in MATOPIBA can offer the opportunity to prevent further suppression of native forest and, at the same time, guarantee the advance of agricultural productivity in the region. Data from Brasil (2018) indicate that the implementation of mitigation measures existing in the ABC Plan allowed increases in agricultural area and productivity throughout Brazil. At the same time, the reduction of GHG emissions was generated, contributing to the achievement of Brazil's voluntary commitments proposed in COP's 15 and 21.

In view of what has been presented, this study sought to analyze the impacts of the reduction of GHG emissions obtained by investing in the actions of the ABC Plan in the MATOPIBA region, with the aim of presenting the to present the importance that this plan had for the region and verifying, also, which would be the main issuing sectors of MATOPIBA. The study tries, through its results, to corroborate with the permanence of the ABC+ Plan strategies, successor of the ABC Plan. For this, different scenarios were simulated with different emission levels. The study verified the following questions: (i) It analyzed the intensity of GHG emissions generated by the MATOPIBA economy in hypothetical scenarios of expansion of final demand; (ii) Verified the impacts on interregional emissions and identify which MATOPIBA key sectors would be in different GHG emission scenarios in the face of a hypothetical increase in the final demand of the economy and; (iii) identify the main impacts on energy demand occurring at MATOPIBA through shocks to its final demand.

To answer these questions, a Hybrid Inter-Regional Input-Output model was used with the MATOPIBA region explicitly disaggregated in the data matrix. The input-output (IO) model was used to consider sectors and regions, as well as the environmental factors common to each one of them. In this way, it was possible to work with a serious limitation when it comes to environmental impacts, which is: separately analyze each sector or industry, recognizing the real importance of intersectoral links. As the AFOLU sector uses a considerable amount of energy and industrial inputs in its production processes, the IO model with energy analysis was implemented in this research because it manages to establish the total energy needed to deliver a certain volume of product to the final demand (CARVALHO; PEROBELLI, 2009). In this way, the research sought to innovate by implicitly considering the trade-off that involves the expansion of agricultural production versus environmental conservation in the MATOPIBA region, considering the actions of the ABC Plan. This is fundamental information, as there is a need for more research in the MATOPIBA region to show the importance of its preservation.

[4]For further clarification on the strategies contained in the ABC+ Plan, please read “Sectoral plan for adaptation to climate change and low carbon emissions in agriculture with a view to sustainable development (2020-2030)” Brasil (2021).

Methodology[5]

To fulfill the main objective stated in the introduction, a Hybrid Inter-Regional Input-Output model will be used in this study. Miller and Blair (2009) propose using the Hybrid Inter-Regional Input-Output (IO) matrix to capture the interconnections between sectors, thus preventing the analysis of environmental impacts from treating each segment of the economy differently ignoring the links between them. In this way, a brief literature review will be presented that addresses the subject using the Hybrid Inter-Regional Input-Output methodology.

Hybrid Inter-Regional Input-Output Model

To verify the interrelationships between environmental actions and the economic structure, the method of the augmented or expanded model of Leontief will be chosen, because according to Miller and Blair (2009), in this type of model, changes in final demand may be related to the interdependence between sectors and environmental impacts demonstrating the links between regions and economic sectors.

This variant of the IO model determines the total emissions spent when deforesting a certain area or the total energy required for the design of a product, verifying both the direct energy spent and the indirect energy used. This process monitors the inputs and resources used in production. The first round of energy inputs demonstrates the direct need for energy. The following rounds of energy inputs define the indirect energy requirement. The sum of these two requirements shows the total energy requirement, which is often called *energy intensity* (MILLER; BLAIR, 2009).

For the evaluation of *energy intensity*, a set of matrices analogous to the traditional IO[6] model is used, that is, the Leontief inverse of the conventional model is applied to calculate the required amount of energy, however, it is interesting to work with the energy quantity measured in physical units (MILLER; BLAIR, 2009).

$$Ei + ey = F \tag{1}$$

where *(i)* is a column vector (n x 1), where all elements are numbers *one*. The total amount of energy consumed by inter-industry sectors plus final demand consumption is the total energy consumed and produced by the economy.

Key Sectors[7]

A key sector is one that demands inputs from other sectors in a higher quantity than the average and whose production is widely used by other sectors (HILGEMBERG, 2004). The method used to identify these sectors was developed by Rasmussen and is based on Leontief's inverse matrix (MILLER; BLAIR, 2009).

To discover the key sectors in terms of emissions, it is necessary to structure a matrix of intersectoral elasticities of demand in association with final energy

[5]For more information on the Input-Output matrix, please see Hilgemberg (2004) and Miller and Blair (2009).

[6]For more information on the matrix of inter-industry transactions in hybrid units and Matrix of direct and indirect coefficients, or the Leontief matrix $(I - A)^{-1}$, please check Miller and Blair (2009).

[7]For more information on the Input-Output matrix, please see Hilgemberg (2004) and Miller and Blair (2009).

consumption. For this process, consider the scalar (Γ) that *will represent the total energy use by the production system and (τ') will be the line-vector of energy use per unit of sectoral product*.

The total impact is the percentage increase in energy consumption caused by a (1%) increase in the final demand of sector (j), and the distributive impact is the increase in energy consumption of sector (j), which results from an increase of (1%) in the final demand of all sectors of the economy (ALCÁNTARA; PADILHA, 2003).

By defining (Γ_T) as the median value of total impacts and (Γ_D) the median values of distributive impacts, Alcántara and Padilha (2003) assume the classification established in Table 1.

Table 1 - Classification of sectors

	$\sum_j \tau_{ij}^y < \Gamma_T$	$\sum_j \tau_{ij}^y > \Gamma_T$
$\sum_j \tau_{ij}^y > \Gamma_D$	Relevant sectors from the point of view of demand from other sectors I	Key sectors put pressure on energy consumption and are pressured to consume energy II
$\sum_j \tau_{ij}^y < \Gamma_D$	not relevant sectors III	Relevant sectors from the point of view of your demand IV

Source: Alcántara and Padilha (2003).

The sectors that fall into sector I will have their energy consumption determined, in part by the demand of the other sectors, since the distributive impact is greater than the median of the economy. The sectors in quadrant II are the key sectors, as they have a greater total and distributive effect than the median values of the economy, that is, they are driven to consume energy by the increase in demand from other sectors and, simultaneously, they put pressure on the economy. energy consumption of other sectors by increasing their own demand. Quadrant III has the least important sectors in terms of emissions. And quadrant IV has the sectors with high energy content.

Database

For this research, two fundamental databases were used, derived from the regional IO matrix published by the Regional and Urban Economics Center of the University of São Paulo (NERUS) for the year 2011, in which the flows of products can be found. generated by its sixty-eight (68) sectors in the twenty-seven (27) Brazilian states (HADDAD; GONÇALVES JUNIOR; NASCIMENTO, 2017). And from the research by Azevedo *et al.*, (2018) which measured gross CO_2eq emissions for all Brazilian states in 2015.

As the two data sources consider information of a different nature, it was necessary to make regions and sectors compatible. It aimed to preserve, as much as possible, the allocation of sectors in relation to their type of production and, at the same time, meet the main focus of the present study, insofar as attention is concentrated on sectors with higher levels of GHG emissions.

After making these two databases compatible, the Hybrid Inter-Regional IOM was obtained with energy and product flows. However, to achieve the construction of the Hybrid Inter-Regional IOM, there were adaptations in the original matrix to obtain practicality in the application of the methodology. Thus, it was necessary to use some procedures, such as:

1. *Aggregation of rows and columns*[8],

2. *Aggregation of regions: For the construction of the Hybrid IOM, it was necessary to aggregate the states into four large regions, they are:*

   - Region 1 - MATOPIBA: Maranhão, Tocantins, Piauí and Bahia;
   - Region 2 - Rest of the North: Rondônia, Acre, Amazonas, Roraima, Pará and Amapá;
   - Region 3 - Rest of the Northeast: Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas and Sergipe;
   - Region 4 - Rest of Brazil: Minas Gerais, Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul, Mato Grosso, Goiás and Distrito Federal.

in which, the choice of the disposition of the States was carried out based on the need for the research. As the region of interest of the work is the region of MATOPIBA (Maranhão, Tocantins, Piauí and Bahia), it was important to aggregate these four states, which also triggered the formulation of the remaining regions. The aggregation of the regions follows the logic of the aggregations of the sectors.

As the information obtained on energy referred to 2015 and the interregional matrix constructed used data from 2011, it became necessary to update the interregional matrix to 2015 to obtain more coherent answers. For this, the database of the INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE (2017) was used, which contains all the values of production by economic activity of the 27 Brazilian states from 2010 to 2015, proportion between the total production value of 2011 and 2015, it was possible to correct the values of the matrix for the year 2015 with a simple rebalancing of the same. With the application of this method, the 2011 interregional matrix started to have the same base year as the emissions values.

After carrying out the steps listed above, the Hybrid Inter-Regional IOM was obtained, with monetary and physical values (CO_2eq emission). We need to apply the aforementioned methodology to obtain the elasticities of demand for energy consumption.

Scenarios

To assess the importance of the ABC Plan as one of the existing measures to mitigate emissions in production processes, especially in the sectors that make up AFOLU (EMBRAPA, 2018), it was necessary to build two scenarios, each one characterized by a certain volume of CO_2eq emissions from the AFOLU sector. The different assumptions were made based on information available in the report "Adoption and mitigation of Greenhouse Gases by technologies of the Sectorial Plan for Mitigation and Adaptation to Climate Change (ABC Plan)" presented by MAPA

[8]This procedure, through the aggregation of rows and columns, transforms the number of sectors leaving the database with 14 main sectors. It is possible to visualize the aggregation chosen in Appendix A (Board A1).

(2018). The aforementioned report states that "the ABC Plan has already mitigated between 100.21 and 154.38 million tons of gross CO_2eq, in the period from 2010 to 2018" (EMBRAPA, 2018).

For the constitution of the Hybrid Inter-Regional IOM, the year 2015 was considered for two main reasons. Initially due to the need for regionally disaggregated data on CO2eq emissions in Brazil. For this, the research by Azevedo *et al.*, (2018) was used as a basis, in which the authors evaluated the gross total of CO2eq emitted by Brazilian states for the year 2015. In addition, the year 2015 allows considering a relatively long period since the implementation of the ABC Plan, allowing the evaluation of the effectiveness of the actions proposed in the policy, and, if necessary, evaluating the economic use of this rural credit in Brazil.

I. Scenario 1: represents the base situation, in which the emissions of the sectors that make up the AFOLU are considered, as they are two of the largest GHG emitters in Brazil in 2015. It is worth mentioning that the data used, based on the calculations of Azevedo *et al.*, (2018), already take into account the total mitigated by the ABC Plan between 2010 and 2015.
II. Scenario 2: represents the hypothesis that the ABC Plan has not been implemented. Thus, the level of emissions in 2015 presents a volume higher than that used in the previous scenario. Considering that between 2010 and 2015, the ABC Plan actions were able to mitigate approximately 100 million tCO_2eq, this value was added to the total emitted in Scenario 1.

Results and discussion

Intensity of CO2 emissions generated by the Brazilian economy: total effects Scenarios 1 and 2

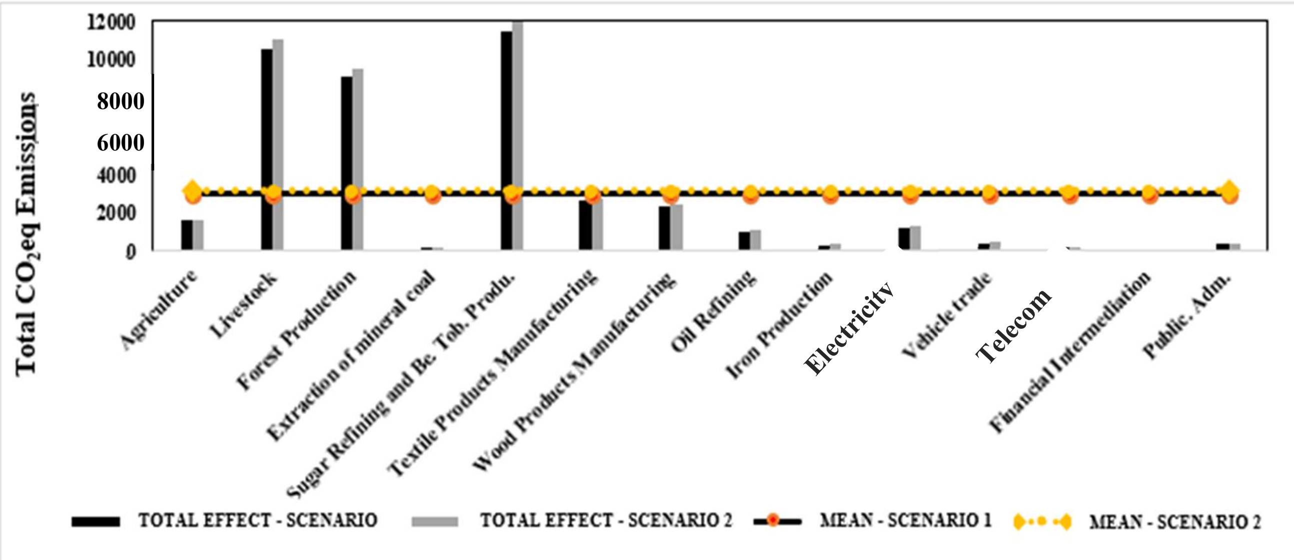
The amount of emissions considered in this section refers to the AFOLU sectors of the MATOPIBA region. The emissions generated by these sectors largely collaborate with the accumulation of greenhouse gases (GHG) in the atmosphere, making them some of the main sectors responsible for this phenomenon in the region. As this work is based on an inter-regional analysis, it is possible to identify which are the impacts on emissions that each economic sector of MATOPIBA will cause in the other sectors of the same region to satisfy their demand.

According to IBGE (2017) in 2015, the states that make up the MATOPIBA were responsible for 6.6% of the Brazilian GDP. However, this value does not necessarily represent its share in Brazil's emission levels. The results demonstrate that the gross GHG emissions caused by its different sectors do not necessarily depend on the concentration of their production, but on the existing intersectoral links. Thus, to study the relationship of these productive structures with the emissions generated mainly by the AFOLU sector, a simulation was carried out regarding the addition of R$ 1 billion in final demand (a value that represents about 0.5% of MATOPIBA's GDP in 2015, according to data from (IBGE, 2017; RUSSO LOPES; LIMA; REIS, 2021; STRASSBURG *et al.*, 2017). The choice of this value was based on the economic growth that the region has been experiencing in recent years. According to Embrapa (2015) and Russo Lopes, Lima and Reis (2021), as the opening of new areas for economic use is legally permitted, this region has become the target of private sector investments from the acquisition of large areas for production.

In addition, the public sector has expanded funding, such as the programs MODERINFRA (Programa de Incentivo à Irrigação e à Produção em Ambiente Protegido), MODERAGRO (Programa de Modernização da Agricultura e Conservação dos Recursos Naturais) and PCA (Programa para Construção e Ampliação de Armazéns), (EMBRAPA, 2017). All these actions have the capacity to boost the region's agricultural sector and make it plausible to simulate a R$1 billion increase in final demand.

When considering the R$ 1 billion increase in the final demand of the sectors, it can be seen that the “Sugar Refining and Production of Beverages and Tobacco” and “Livestock (including support for Livestock)” in the MATOPIBA region jointly produce the greatest total additional effect on the economy of its region, with the value of approximately 11.5 thousand tCO_2eq gross for the first sector and 10.5 thousand tCO_2eq gross for the second, which represents approximately 51% of the additional total emitted. These are the sectors in MATOPIBA that most contribute to the increase in GHG emissions through the increase in final demand, as can be seen in Figure 2.

Figure 2 - Total effect on CO_2eq emissions in tons in all scenarios through the increase in final demand by R$ 1 billion in MATOPIBA



Source: Own elaboration.

The average emissions by sector in relation to the simulation of an increase in final demand was around 2.9 thousand tCO_2eq gross. When considering this average, it is noted that the sectors of "Livestock" and "Forestry, Fishing and Aquaculture", in addition to the "Sugar Refining and Production of Beverages and Tobacco", are the ones that contributed the most to the total increase of emissions in MATOPIBA, as can be seen in Figure 2.

Between 2003 and 2013, the area cultivated with sugarcane in MATOPIBA increased by approximately 300%, which made it the third largest growing crop in the region (EMBRAPA, 2018). By having means of production that involve the use of large plots of land, chemicals and intensive use of water, Sugar Refining ends up causing negative impacts on the environment (SEEG, 2021). In this way, all processes that encompass the sugar culture end up becoming major gross emitters of GHGs in the region, which makes them "potential candidates" to undergo pro-environmental command and control measures.

Furthermore, according to information from Embrapa (2017), there were approximately 26 million head of cattle in the Cerrado biome in 2015. Extensive cattle ranching, mainly since the 1970s, has caused deforestation and soil degradation in MATOPIBA (EMBRAPA, 2017). Overall, the growth of agricultural commodity production and large-scale agriculture has caused massive deforestation, growth in GHG emissions, as well as changes in rainfall and temperature regimes across the Cerrado (SASSEN, 2016).

In 2018, through the development of actions contained in the ABC Plan, more than 150 million gross tCO_2eq had already been mitigated, at the cost of approximately R$ 17 billion from program resources (BRASIL, 2018). The main benefits obtained from the financing were the fulfillment of 70% of the stipulated target for the recovery of degraded areas, in addition to the expansion of the forest area by 1.1 million hectares. From the mentioned data, it was possible to build the counterfactual scenario, indicating what the emission levels would be in 2015 if Brazil had not been able to meet the proposed targets. In this sense, it was considered for this study that between 2010 and 2015, the actions of the ABC Plan would have managed to mitigate around 100 million tCO_2eq.

This counterfactual scenario was named in this research as Scenario 2. It contains in its emissions the amount emitted already existing in Scenario 1 (real scenario) plus these 100 million tCO_2eq, which would have been mitigated until 2015, permitting to analyze what would be the consequences of the total effects when considering the pro-environmental policy in the model. The distribution of this new share of emissions was carried out proportionally, considering the total produced by the sectors and, consequently, each state.

According to the new level of emissions, the simulation of increases of R$ 1 billion in final demand was carried out again. It is noted that the "Sugar Refining and Production of Beverages and Tobacco" and the "Livestock" sector in the MATOPIBA region would continue to have the greatest total effect on emissions, as found in Scenario 1 (Figure 2). However, there was an increase in the total effect generated by these sectors by around 4%, totaling an increase in emissions of 500 tons of gross CO_2eq. There was also a growth in the average of emissions by sector of approximately 132 tons CO_2eq or 5% in relation to what happens in Scenario 1, as can be seen in Figure 2. These results show the importance of using sustainable actions in the various forms of production. The data show emission reductions in all sectors when considering the pro-environmental actions of the ABC Plan in the model, proving the generation of positive impacts caused by its mitigation measures and the need for its perpetuation through the ABC+ Plan.

Direct and indirect effects on emissions from the increase in final demand

This study innovated by analyzing what would be the indirect, direct and total effects, in terms of GHG emissions, resulting from the simulated expansion of increased demand in different emission scenarios with and without the ABC Plan. Therefore, this subsection will present how the direct and indirect effects behaved when simulating in the model the scenarios without the ABC Plan (Scenario 2) comparing it with the Scenario 1 (Actual Scenario).

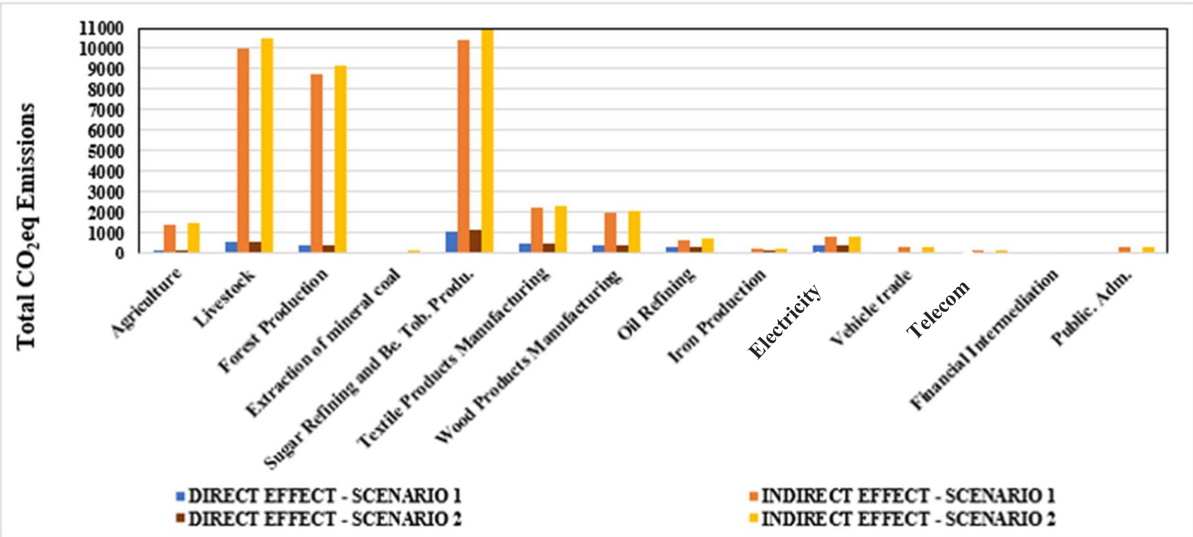
For political purposes, it is necessary to carry out a process analysis. Thus, it is important to assess not only the total effects, but also to identify the direct and indirect effects on emissions caused by the simulated increase of R$ 1 billion in final demand. The direct impact refers to the effect generated from the growth in emissions, through the increase in total production to directly meet the consumption of final demand. The indirect effect is the impact on emissions to meet the intermediate consumption of the various sectors of the economy in the regions considered in this research. It is possible to visualize in Figure 3 each of these effects in the MATOPIBA region.

When considering only the biggest polluters, it is observed that the sectors of "Livestock", "Forestry, Fishing and Aquaculture" and "Sugar Refining and Production of Beverages and Tobacco" in MATOPIBA have their additional emissions determined, mostly, to meet to intermediate demand. In this way, the variation of R$ 1 billion in final demand means that 94% of the additional generation of gross CO_2eq in the "Sugar Refining and Production of Beverages and Tobacco", for example, is to satisfy only its intermediate demand. It is noted that in all sectors of MATOPIBA the direct effects are low, evidencing that little of the additional emissions arise to satisfy the final demand: (Figure 3).

Thus, the results justify that if new policies are developed using pro-environmental measures, their focus should prioritize the intermediate demand, that is, the actions should be sectorial. As the results of this research show, the sectors that require more attention in MATOPIBA are those that make up AFOLU.

It is also important to carry out the analysis on the magnitude of the indirect and direct effects for MATOPIBA considering the emissions found in Scenario 2. This will enable a better understanding of the total effects for this hypothetical scenario. Thus, the behavior of emissions in the final and intermediate demand is analyzed in the case where there is no reduction in emissions (Scenario 2).

Figure 3 - Direct and indirect effect on CO_2eq emissions in tons in scenarios 1 and 2 through an increase in final demand by R$ 1 billion in MATOPIBA



Source: Own elaboration.

When considering again the biggest polluters for Scenarios 1 and 2, it is observed that the sectors of "Livestock", "Forestry, Fishing and Aquaculture" and "Sugar Refining and Production of Beverages and Tobacco" in MATOPIBA continue to produce their emissions to meet, mostly, the intermediate final demand. When considering the “Sugar Refining and Production of Beverages and Tobacco” sector in Scenario 2, the additional generation of gross CO_2eq to satisfy the intermediate demand is 4% higher compared to Scenario 1, as can be seen in Figure 3.

It is still possible to observe the persistence of the lowest levels of direct effects in all sectors of MATOPIBA, even with changes in the amounts of GHG emitted (Figure 3). That is, the data in Figure 3 shows that policies should not only be concerned with reducing emissions, but also with which sectors these actions should be inserted to obtain the best results.

This research found that in 2015, the biggest bottlenecks in relation to emissions come mainly from the sectors that make up the intermediate demand in MATOPIBA. That is, when considering the emissions from the AFOLU sector, the gross CO_2eq generation is almost completely formed to compose the indirect effects, as can be seen in figure 3.

As a result, when evaluating in the opposite way, it was also identified which are the most suitable sectors for the application of pro-environmental measures, as they present the highest levels of emissions. As the results showed the sectors linked to agriculture as the biggest polluters, it is proved that the permanence of the actions foreseen in the ABC Plan would be very important for the control of GHG emissions in the MATOPIBA region.

Measurement of Total and Distributive Impacts and identification of MATOPIBA's Key Sectors

According to section 2.2, the sectors with the greatest total impact are those that carry emissions from other sectors above the median of the economy, from the increase of one percentage point in their final demand. In MATOPIBA, when considering emissions from the AFOLU sector, for Scenario 1, the median found for the distributive impact (DI) was 17.8 additional gross tCO_2eq in response to the increase in final demand, while for the total impact (TI) the median was 18.9 gross tCO_2eq. Table 2 was used as a reference to classify the activities in MATOPIBA in Scenario 1 and 2.

The sectors “Livestock”, “Forest Production, Fisheries and Aquaculture”, “Sugar Refining and Production of Beverages and Tobacco”, “Electric Energy” and “Public Administration, Defense and Social Security” are the key sectors with regard to to emissions. They are pressured to emit more when demand from other sectors increases, and at the same time they force other sectors to emit when their own demand increases. As can be seen in Figure 4, the key sectors that emit the most gross CO_2eq are “Sugar Refining and Beverage and Tobacco Production”, with TI and DI equal to 959.9 and 783 tCO_2eq, respectively, and “Livestock”, with TI equal to 835 tCO_2eq and DI equal to 611.4 tCO_2eq.

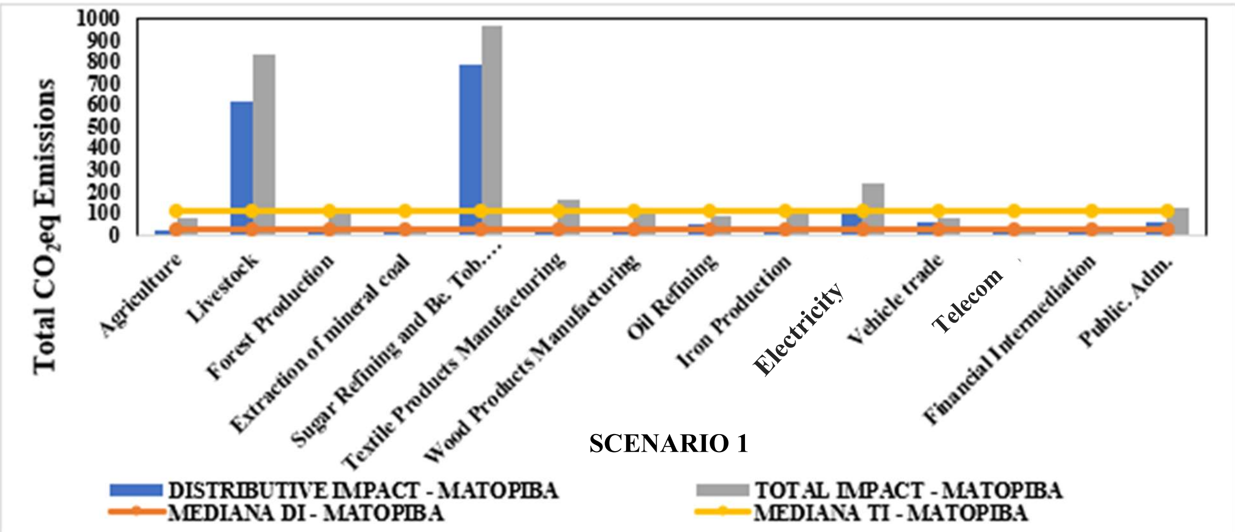
Table 2 - Classification of sectors in MATOPIBA, Scenario 1 and 2

MATOPIBA SC.1 e 2	$\sum_i \tau_{ij}^y < \Gamma_T$	$\sum_i \tau_{ij}^y > \Gamma_T$
$\sum_j \tau_{ij}^y > \Gamma_D$	Oil refining and coking plants. Trade and repair of motor vehicles and motorcycles. I	Livestock, including support for livestock. Forestry production fisheries and aquaculture. Sugar refining and production of beverages and tobacco. Electricity, natural gas and other utilities. Public administration, defense and social security. II
$\sum_j \tau_{ij}^y < \Gamma_D$	Extraction of mineral coal and non-metallic minerals. Production of pig iron / ferroalloys, steel and seamless steel tubes. Editing and editing integrated with printing. Financial intermediation, insurance and private pension. III	Agriculture, including support for agriculture and post-harvest. Manufacture of textile products. Manufacture of wood products.

Source: Search results.

The results obtained are supported by the information presented by the INSTITUTO DE PESQUISA ECONÔMICA APLICADA - IPEA (2017) and Agrosatélite Geotecnologia Aplicada (2015), according to which in 2015 sugarcane was the third largest annual crop produced in Brazil, behind only soy and corn. This fact was also true for the last agricultural frontier in the world, which has been standing out in the expansion of this crop for production of ethanol since 2003.

Figure 4 - Total and distributive impacts for sectors in the MATOPIBA region, Scenario 1.



Source: Search results.

However, such productive growth brought with it negative consequences, such as the large amount of GHG emitted in its production stages. With the Brazilian production of ethanol around 30 billion liters, approximately 24 Mt of CO_2eq are generated (PAPP *et al.*, 2016). For this reason, it is important to promote cleaner production technologies, such as Carbon Capture and Storage (CCS), which could even add value to Brazilian ethanol.

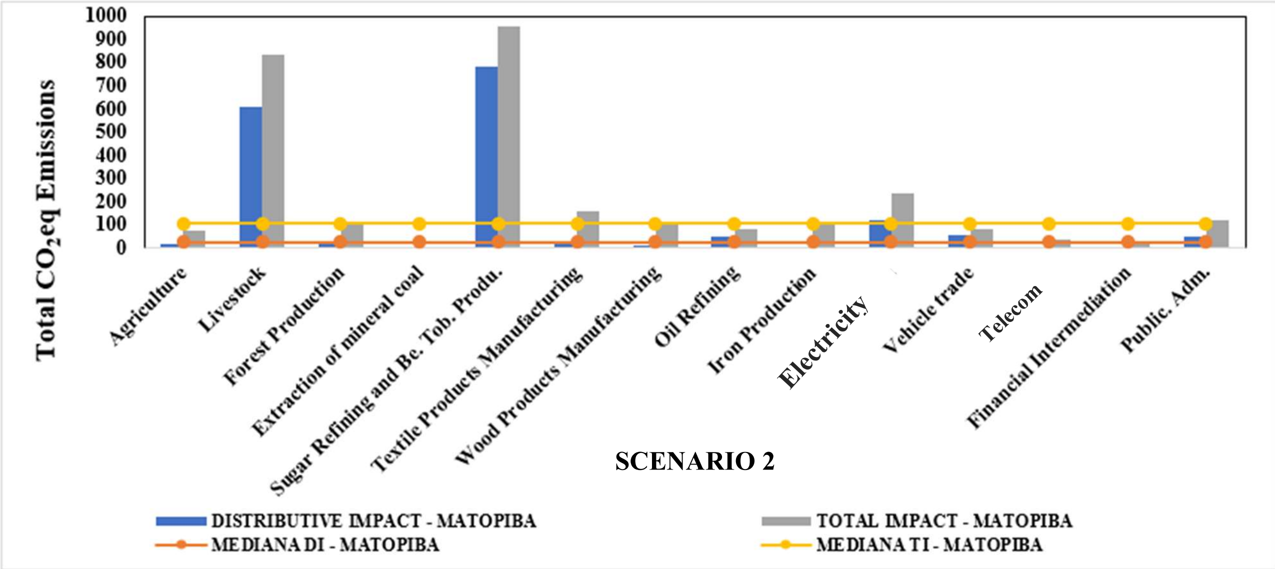
In 2015, approximately five million hectares of the Cerrado were used to plant sugarcane (AGROSATÉLITE GEOTECNOLOGIA APLICADA, 2015). Thus, the rapid increase in cultivated areas of this culture can explain the results found in this work, in which it was identified as one of the key sectors. From Figure 4, we verified that this sector has the greatest distributive and total impacts found in the MATOPIBA region.

The high DI in Figure 4 demonstrates that its effects on emissions from additional production to meet the demand of the other sectors that need to satisfy the new final demand are concentrated in this sector. This occurs from the large-scale generation of its final product, which has great economic importance for the country. In addition, the high value of TI confirms that this sector tends to increase its emissions to accommodate the increase in production that directly meets final demand. This result proves the importance that the segment has in the study region, as it is one of the most important in meeting the required expansion in the final demand. These effects agree with the information on increased production and cultivated areas presented by Agrosatélite Geotecnologia Aplicada (2015) and IPEA (2017) in recent years for this crop in the MATOPIBA region.

In 2015, Brazil had the largest cattle herd in the world, with about 193 million heads, making this sector one of the largest GHG emitters in the country (EMBRAPA, 2017). The excellent conditions for production of beef and dairy cattle in the states that make up MATOPIBA have made the region an important target for producers, which may explain the fact that this sector has become a key sector (EMBRAPA, 2017). This sector was identified in the model as the second largest generator of DI and TI, giving it characteristics similar to sugarcane production.

However, the development of these segments in the region, added to the legal permission that the Forest Code grants to rural producers in relation to the deforestation of 80% of the native vegetation, ended up causing serious environmental impacts in the region. This can be confirmed by the high level of GHG emissions and the loss of local biodiversity through deforestation for the creation of more than 26 million head of cattle and to produce soy, corn and sugarcane (IPEA 2017; SILVA, T. *et al.*, 2021; SILVA, G.. *et al.*, 2021; VIEIRA *et al.*, 2017). In this way, it can be understood that the economic importance of the agricultural sectors in the region also ended up making them the largest additional emitters of GHGs.

Figure 5 - Total and distributive impacts for sectors in the MATOPIBA region, Scenario 1

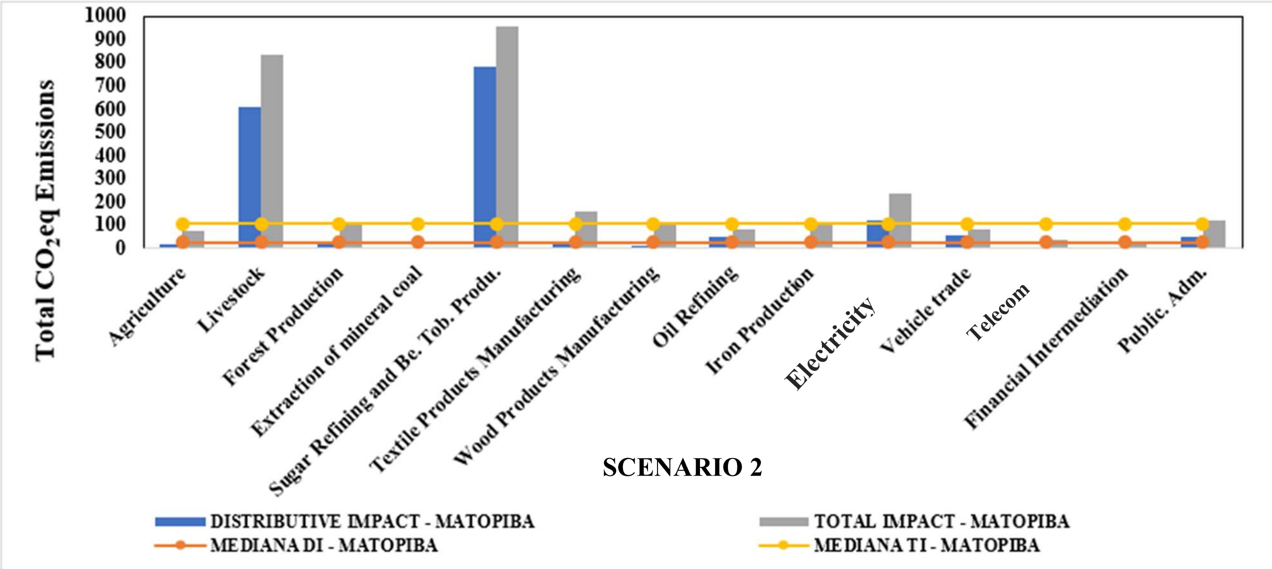


Source: Search results.

A new analysis of key sectors was carried out using Scenario 2, to verify what would be the changes in the economic structure of the sectors and in the emission levels if the Brazilian government had not committed to reducing its emission levels through the ABC Plan actions. Table 2 was also used as a reference to classify the activities in MATOPIBA considering emissions from the AFOLU sector for Scenario 2, as there were no changes in the sectoral classification in this region. The “Livestock”, “Forestry, Fishing and Aquaculture”, “Sugar Refining and Production of Beverages and Tobacco”, “Electric Energy” and “Public Administration” sectors of this new scenario continue to be the same key sectors of Scenario 1 The analysis shows that these sectors would continue to be the biggest polluters if the ABC Plan were not implemented, but in a more accentuated way, since it is possible to observe increases in their emission levels.

As shown in Figure 6, the "Sugar Refining and Production of Beverages and Tobacco" sector has TI values equal to 1000 and DI equal to 815 tCO_2eq gross, while "Livestock" has a TI value equal to 869 and DI equal to 636 gross tCO_2eq. By verifying the values of the TI and DI of Scenarios 1 and 2, it is possible to verify what the percentage variations in emissions would be if there was no ABC Plan. The “Sugar Refining and Production of Beverages and Tobacco” sector presented growth of 4.1% for TI and 3.9% for DI, while in the “Livestock” sector the increase was 4% for both.

Figure 6 - Total and distributive impacts for sectors in the MATOPIBA region, Scenario 2



Source: Search results.

The data presented above show that the mitigation of gross CO_2eq emissions resulting from the ABC Plan can be partly explained by the intersectoral changes that appeared in the model and also by those foreseen in the plan itself. The model built was able to demonstrate that, without the objectives contained in the pro-environmental policy, the emission levels in the MATOPIBA region, consequently, throughout Brazil, would be higher, mainly due to the greater number of sectors with high polluting capacity. This result offers an alternative view to Angelo (2012) in which the possible failure that the ABC Plan would have if it continued to exist is mentioned and corroborates with the continuity of the program through the perpetuation of the ABC+ Plan.

Analysis of the share of direct requirements (DR) and indirect requirements (IR) in total energy requirements

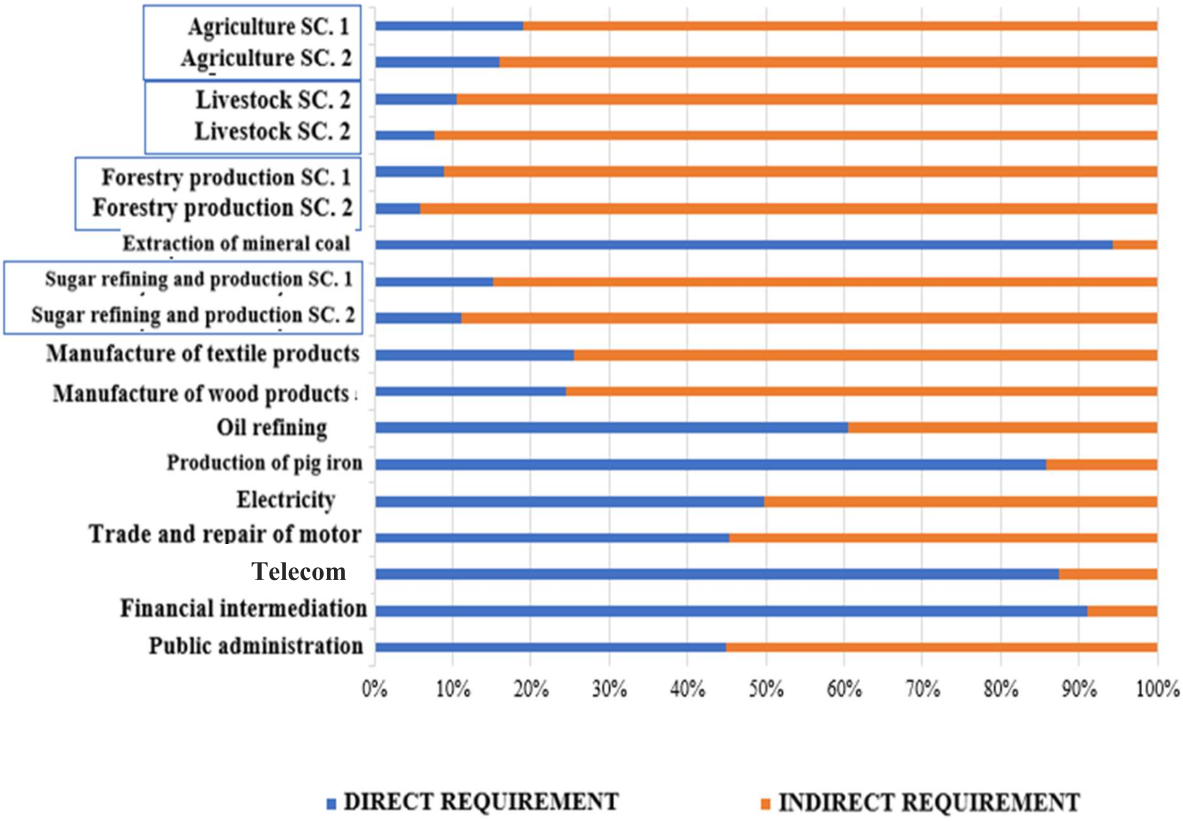
In order to better characterize the key sectors, the analysis of direct (DR) and indirect (IR) requirements was carried out. According to Miller and Blair (2009), DR and IR can reveal the immediate and secondary effects of a variation in final demand, thus revealing the multiplier power that a given activity in a sector has on energy consumption within a region and consequently what it is the level of demand that other sectors have on a given sector.

According to Perobelli, Mattos and Faria (2007), the lower the ratio (DR) versus (IR), the greater the multiplier power that the activity of a given sector exerts on energy consumption within a region. Those sectors with a high weight in the energy demand of a given region in which, at the same time, demonstrate a low ratio (DR) versus (IR) tend to produce the strongest demand pressures on the regional energy sector. On the contrary, sectors that have a reduced weight in the region's energy demand are those that demonstrate a high (DR) versus (IR) ratio, which consequently exhibit low pressure on the region's energy sector. This relationship reveals great similarity with the main characteristics of a key sector. And between these extremes are the sectors with the most varied degrees of pressure on territorial energy demand.

Figure 6 presents the percentage ratio of (DR) versus (IR) for each sector presented by the survey. In order to inform about the consequences that occurred when using the ABC Plan or not, it was decided to analyze the results achieved for the two scenarios created, directing the verification to the three sectors that make up the AFOLU sector (as it was the initial focus of the research) and also to the Sugar Manufacturing and Refining sector (for having had a great impact on emissions in the MATOPIBA region).

The creation of the alternative scenario proposed by the research reveals what would be the impacts that would occur if the ABC Plan were not implemented in the MATOPIBA region. As can be seen in Figure 7, the “Agriculture”, “Livestock”, “Forest Production” and “Sugar Manufacturing” sectors have the lowest DR versus IR ratios among the other sectors. These four sectors in almost all the scenarios studied exhibited IR above 80%, with “Livestock” and “Forest Production” showing the lowest DR versus IR ratios.

Figure 7 - Sectoral share in percentage (%) of direct (DR) and indirect (DR) requirements in total energy requirements Scenarios 1 and 2 – MATOPIBA



Source: Search results.

Using the base scenario (Scenario 1), it is observed that in 2015 these four sectors were the ones that presented the greatest power of multiplication on energy consumption in the study region. Consequently, they became the sectors that suffered the most pressure from demand in relation to energy generation and, at the same time, presented the necessary conditions to impose a strong pressure of demand on the energy sector. Such results have strong theoretical support that confirm that the key sectors pointed to in the MATOPIBA region are indeed true. Since, according to Miller and Blair (2009), a key sector is one that demands and is demanded by the other sectors above average, evidencing the connection of this sector with the other productive sectors of the economy.

As can be seen in Figure 7, in all sectors identified as the main issuers of MATOPIBA, the IR versus DR ratio suffers a percentage reduction when considering Scenario 1 in contrast to Scenario 2, which can be interpreted by an increase in the requirement energy that these sectors impose and suffer from other sectors in the region, if the ABC Plan had not existed. Because, as a higher level of emissions is being considered in Scenario 2, the IR versus DR ratio has reduced, which has led to the considered sectors to present greater multiplier power in relation to consumption and generation of gross CO_2eq, as well as to a greater degree of demand from other sectors for its production in the MATOPIBA region. This result proves the importance of the ABC Plan actions in the study region, since, in addition to having acted positively through actions to mitigate gross CO_2eq, the ABC Plan had the ability to make the sectors in question less GHG emitters.

Final considerations

In the Brazilian development trajectory, high rates of GHG emissions can be observed, which are linked, directly or indirectly, to high levels of deforestation and the still incipient use of sustainable production techniques from an environmental point of view. The national AFOLU sector plays a prominent role in this process. Therefore, this work analyzed which are the main GHG emitters and key sectors in the MATOPIBA region and what were the contributions resulting from the use of the ABC Plan in the country, to support its continuity, for this, it was necessary to creation of representative scenarios containing different levels of GHG emissions.

The simulations built for the MATOPIBA region showed that, for each additional R$ 1 billion in the final demand of the sectors, the average value of CO_2eq emissions resulting from a hypothetical scenario without the ABC Plan would be about 4.5% higher compared to the case with the implementation of said plan. In the different simulated scenarios, the sectors “Sugar Refining and Production of Beverages and Tobacco”, “Livestock” and “Forestry, Fishing and Aquaculture” were the ones that most emitted GHG above average, that is, they are the ones that present the most applicants in sustainable production actions.

Considering only the most polluting sectors in the MATOPIBA region in the scenario with the ABC Plan, additional emissions are generated to supply mainly intermediate consumption linked to “Sugar Refining and Production of Beverages and Tobacco”, “Livestock” and “Forestry Production, Fishing and Aquaculture”. In the remaining sectors, this effect is felt to a lesser extent, with final demand consumption gaining greater projections on additional emissions.

Thus, from the point of view of formulating emission reduction policies, the results showed that in all regions the focus should be on the effect of additional production on the consumption of the sectors (indirect effect). It is suggested to direct the pro-environmental actions in MATOPIBA to the production of the sectors that participate directly in the AFOLU.

The analysis of elasticities in the ABC Plan scenario indicated that the GHG emissions derived from the consumption of the most polluting sectors in MATOPIBA are due more to final demand than to intermediate consumption. Likewise, the results obtained for the simulation without ABC Plan showed that the levels of GHG generated are due more to final demand than to intermediate consumption. For the two situations studied, the sectors of “Livestock”, “Sugar Refining and Production of Beverages and Tobacco”, “Electric Energy” and “Public Administration” are the key sectors in MATOPIBA. However, increases in the magnitude of 4.5% were observed in the median of Distributive and Total Impact emissions in all sectors of the second simulation compared to the first scenario.

Considering the emissions from the AFOLU sector, it is concluded that the key sectors for the control of GHG emissions in the MATOPIBA region are “Sugar Refining and Production of Beverages and Tobacco”, “Livestock”, “Electric Energy”, “Forestry, Fisheries and Aquaculture Production” and “Public Administration”. Based on this information, it is coherent to say that the pro-environmental actions resulting from the ABC Plan, or another mitigation plan that may be implemented in the future, such as the ABC+ Plan, will be more efficient if they are directed to these specific sectors. Most of them are highly dependent on land use and their means of production lead other sectors to emit much more.

The discussion mainly addressed the positive impacts of applying the ABC Plan. However, it is understood that the implementation of this plan alone is not enough to advance Brazil's environmental goals, including the control of deforestation. It is necessary to create measures that are sustainable both from an environmental and socioeconomic point of view, thus guaranteeing the interest of producers in adopting pro-environmental measures. In this way, the discussion about which new policies should be created and how they could be implemented constitutes a debate about which future works should be deepened.

The results achieved show the importance that the actions of the ABC Plan had for MATOPIBA and how the continuity of the program is important for the region. It is also possible to conclude that agriculture can be used as a tool for environmental conservation, through the reduction of GHG emissions, and at the same time maintain its productive performance. Therefore, the scope of the ABC Plan should be expanded, and its duration increased, making it act as an example of a solution to the trade-off “commercial agricultural production versus emissions reduction”. This would, in the future, make all agricultural credit in the country “low carbon”, guaranteeing advances in the three pillars of sustainability: economic, social and environmental.

Finally, it is highlighted that the main contribution of this work is to provide public policy makers with information for decision making regarding the best strategy, from an environmental point of view, in relation to emissions control, both at regional and national levels. Once the importance of the ABC Plan is presented, the possible permanence of the program is encouraged through the development of actions such as those contained in the new ABC Plan or the ABC+ Plan, as well as the creation of even more ambitious strategies to reduce emissions. It is recommended to promote information policies, which can guarantee that the program has greater reach among farmers or that new markets are made viable and that products from activities that use the actions contained in the ABC Plan as a productive method are used.

Acknowledgment

The present work was carried out with the support of the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Financing Code 001. The authors also thank the National Council for Scientific and Technological Development - CNPq for granting a Productivity Scholarship in Research and Junior Post-Doctoral Scholarship.

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APPENDIX

Board A1. Aggregation of sectors

S1	***Agriculture, including support for agriculture and post-harvest***
S2	***Livestock, including support for livestock*** Slaughter and meat products, including dairy and fishery products
S3	***Forest production; fisheries and aquaculture***
S4	**Extraction of mineral coal and non-metallic minerals** Oil and gas extraction, including support activities Iron ore extraction, including beneficiation and agglomeration Extraction of non-ferrous metallic minerals, including processing
S5	***Sugar Refining and Beverage and Tobacco Production*** Other food products Beverage Manufacturing Manufacture of tobacco products
S6	***Manufacture of textile products*** Manufacture of clothing artifacts and accessories Manufacture of footwear and leather goods
S7	***Manufacture of wood products*** Manufacture of cellulose, paper and paper products Printing and playback of recordings Manufacture of furniture and products from different industries
S8	***Oil refining and coking plants*** Manufacture of biofuels Manufacture of organic and inorganic chemicals, resins and elastomers Manufacture of pesticides, disinfectants, paints and various chemicals Manufacture of cleaning products, cosmetics / perfumery and personal hygiene Manufacture of pharmaceutical chemicals and pharmaceutical products Manufacture of rubber and plastic products Manufacture of non-metallic mineral products
S9	***Production of pig iron / ferroalloys, steel and seamless steel tubes*** Non-ferrous metal metallurgy and metal casting Manufacture of metal products, except machinery and equipment Manufacture of computer equipment, electronic and optical products Manufacture of electrical machinery and equipment Manufacture of machinery 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 Maintenance, repair and installation of machinery and equipment
S10	***Electric power, natural gas and other utilities*** Water, sewage and waste management Construction Accommodation Food
S11	***Trade and repair of motor vehicles and motorcycles*** Wholesale and retail trade, except motor vehicles Ground transportation Water transportation Air Transport Storage, auxiliary transport and mail activities
S12	***[illegible]ng*** Television, radio, cinema and sound / image recording / editing activities Telecommunications Development of systems and other information services
S13	***Financial intermediation, insurance and private pension*** Real estate activities Legal, accounting, consulting and corporate headquarters activities Architectural, engineering, technical testing / analysis and R & D services Other professional, scientific and technical activities Non-real estate rentals and management of intellectual property assets Other administrative activities and complementary services Surveillance, security and investigation activities
S14	***Public administration, defense and social security*** Public education Private education Public health Private health Artistic, creative and entertainment activities Membership organizations and other personal services Domestic services

Source: Own elaboration.