ICAE 2021
31ST TRIENNIAL
INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS
AUGUST 17-31, 2021 - ONLINE

Environmental Effects of the Implementation of the ABC Plan in Matopiba: An Approach by Input-Output

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ENVIRONMENTAL EFFECTS OF THE IMPLEMENTATION OF THE ABC PLAN IN MATOPIBA: AN APPROACH BY INPUT-OUTPUT

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June 30, 2021

Abstract: This article obtained the sectoral and intersectoral effects, in terms of greenhouse gas (GHG) emissions, of the realization of the ABC Plan in the MATOPIBA region. Methodologically, a Hybrid Interregional Input-Product model was built and operated with a focus on the breakdown of the MATOPIBA region. Two scenarios were created with different levels of GHG emissions resulting from the implementation (or not) of the ABC Plan in MATOPIBA. In general, the results obtained show the importance that the actions of the ABC Plan brought to MATOPIBA. Considering the emissions originating from the Agriculture, Forest and Other Land Use sectors, it is inferred that the sectors for controlling GHG emissions in the MATOPIBA region are: Livestock, Forestry Production and Sugar Refining and Beverage and Tobacco Production.
Keywords: input-output; MATOPIBA; ABC Plan.

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INTRODUCTION

Brazilian agribusiness is recognized worldwide for its excellent economic performance, characterized by the continuous growth of production, exports and added value. Concomitantly, large-scale production represents another challenge faced by Brazil, which is maintaining good economic performance combined with environmental conservation (BROOKS, 2017; Empresa BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA, 2018). According to the EMBRAPA (2018), it is likely that meeting the growing global food demand will have extremely negative consequences for the environment, such as the expansion of deforestation, the compromise of ecosystems and higher levels of pollution, with an emphasis on greenhouse gas (GHG) emissions. According to the data in the report "Annual Estimates of Greenhouse Gas Emissions in Brazil" (Ministry of Science, Technology, Innovations and Communications - MCTIC, 2017), the country, in 2018, was the seventh largest GHG emitter in the world, producing approximately 1.939 billion gross tons of CO_2 equivalent (tCO_2eq). The Agriculture, Forest and Other Land Uses (Agriculture, Forest and Other Land Uses - AFOLU) sector was responsible for about 60% of these emissions. A considerable part of the emissions are mainly due to deforestation (EMBRAPA, 2018).

Although the reduction of deforestation is foreseen in the actions presented by the Brazilian government 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 border is located in the region known as MATOPIBA (which comprises the states of Maranhão, Tocantins, Piauí and Bahia) (EMBRAPA, 2017). This region is considered one of the last agricultural frontiers in the world. According to the current Brazilian Forest Code, up to 80% of the native forest area in this region can be legally converted into agricultural areas. Therefore, it is a territorial extension with great potential for agricultural expansion and for the creation and functioning of new markets (Instituto de Economia Agrícola - IEA, 2015).

The MATOPIBA region comprises 73 million hectares, 90% of which belong to the Cerrado biome. Approximately 5.9 million people live in the region (35% live in the countryside). Approximately 86% of the MATOPIBA area already has some type of occupation, with 337 municipalities, 324 thousand rurais establishments, in addition to settlements, quilombos and indigenous reserves. Thus, approximately 10 million hectares remain for the agricultural frontier, which can be used to open new areas for productive purposes (EMBRAPA, 2015).

Information from the Companhia Nacional de Abastecimento - CONAB (2019) indicates that MATOPIBA was responsible for the production of approximately 14.9 million tons of soybeans in the 2017/2018 harvest and about 8 million tons of corn in the same period, accounting for 11% of national grain production. At the same time, between 2000 and 2014, new areas were opened, totaling approximately 3.5 million hectares (expansion of 253% of the cultivable area). About 68% of this expansion took place in native vegetation lands, causing several risks to the local biodiversity. With the possibility of growth in the region, it is expected that between the 2017/18 to 2027/28 harvests production will be approximately 25.4 million tons. At the same time, for this to occur, it will be necessary to open new areas in the order of 13.7%, which will increase the environmental liability already existing in the region (OBSERVATÓRIO DO CLIMA, 2017).

Based on SEEG data (2019), the MATOPIBA region was responsible for the production of approximately 440 million tons of GHGs released into the atmosphere by the Cerrado between 2016 and 2017, mainly resulting from changes in land use, which occurred in the region (NOOJIPADY et al., 2017). In addition, the increase in agricultural production in the region led to the loss of 27% of its vegetation cover, causing environmental damage, such as the reduction of local biodiversity (OBSERVATÓRIO DO CLIMA, 2017). In the event of new openings of areas in the Cerrado, the possibility of species extinction is imminent, since in this region there are approximately 44% of endemic species among fauna and flora, which makes it a source of attention also due to its naturais importance (WORLD WIDE FUND FOR NATURE - WWF, 2017).

Nevertheless, there are ways to prevent further deforestation in the region. According to Agrosat Satélite (2015) and the Observatório do Clima (2017), 18 million hectares of Cerrado are land with medium or high agricultural capacity, but are currently occupied by degraded pastures. These lands could, for example, be used for mechanized planting of soybeans. MATOPIBA owns 10% of this area, in addition to having approximately 6.4 million hectares of Cerrado that are not useful for agricultural purposes, but which could be used for livestock production or even for planting forests. Therefore, in MATOPIBA there are 8.2 million hectares of degraded area that could be revitalized.

In this sense, it is possible to affirm that the advance of the Low Carbon Agriculture Plan (ABC Plan) in MATOPIBA offers the opportunity to prevent new deforestation and, at the same time, guarantees the advance of agricultural productivity in the region. Data from the Ministério da Agricultura Pecuária e Abastecimento - MAPA (2018) indicate that the implementation of the mitigation measures contained in the ABC Plan has already allowed increases in agricultural area and productivity. At the same time, a reduction in GHG emissions was generated, contributing to the achievement of Brazil's voluntary commitments proposed in COP's 15 and 21.

Given the above, 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. Through the simulation of different emission reduction scenarios and a probable increase in the final demand of the Brazilian economy, the study answered the following question: (i) Verify the intensity of GHG emissions generated by MATOPIBA's economy in hypothetical expansion scenarios final demand; (ii) Analyze the impacts on interregional emissions and identify which are the key-sectors of MATOPIBA in different scenarios of GHG emissions in view of the hypothetical increase in the final demand of the economy and; (iii) identify the main economic impacts that occurred at MATOPIBA through shocks in its final demand.

In order to answer this question, a Hybrid Interregional Input-Product model was used with the MATOPIBA region explicitly disaggregated in the data matrix. The Input-Output (IO) model was used because it considers sectors and regions, as well as the environmental factors common to each of them. Thus, it was possible to deal with a serious limitation when it comes to environmental impacts, which is to analyze each sector or industry separately, 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 was able to determine the total energy needed to deliver a certain volume of product to 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, taking into account the actions of the ABC Plan. This is fundamental information, as there is a need for more research in the MATOPIBA region that highlights the importance of its preservation.

2. METHODOLOGY[4]

In order to fulfill the main objective stated in the introduction of this article, an Input-Output (IO) model will be used. Miller and Blair (2009) recommend using the Hybrid Interregional Input-Product matrix as it is able to better capture the interconnections between sectors, thus preventing the analysis of environmental impacts from treating each segment of

[4] For more information on the Input-Product matrix please check Miller and Blair (2009)

the economy separately, ignoring the links between them. In this way, a brief literature review that deals with the subject using the Input-Output methodology will be presented.

2.1 Hybrid Interregional Input-Output Model

According to Miller and Blair (2009), there are three categories of IO models that can deal with the environment: Economic-ecological models, Product x sector models and Augmented or expanded Leontief models.

In order to verify the interrelationships between environmental actions and the economic structure, the third category will be chosen, as according to Miller and Blair (2009), in this type of model, changes in final demand can be related to the interdependence between sectors and environmental impacts demonstrating the links between regions and economic sectors. While the first two categories fail to fully demonstrate the interrelationships between sectors, the economy and energy data, thus limiting their results (ABDALLAH; MONTOYA, 1998).

The interdependence that exists between economic sectors, in the productive sphere and in issues of pollutant emissions, makes it almost impossible to identify who are the true emitters when considering only one sector (HILGEMBERG 2004). As the IO model treats all sectors together, it ends up becoming the most appropriate method for this type of verification. To analyze the environmental liabilities related to GHG emissions, the interregional product input model can be expanded to enable the investigation of polluting sectors, becoming an Interregional IO model with energy analysis.

This variant of the IO model, determines what is the total emissions spent when deforesting a certain area or what is the total energy needed for the design of any product, checking both the direct energy used 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 model is used, that is, the Leontief inverse of the conventional model is applied to calculate the necessary amount of energy, however, it is interesting to work with the energy quantity measured in physical units (MILLER; BLAIR, 2009).

In an economy with n sectors, in which m are energy sectors, the energy flow matrix will be E_{mxn}. The energy used by the final demand (in physical units) will be given by e_y, and the total energy consumption in the economy will be indicated by F, where e_y and F are column vectors with m elements. Thus,

$$E_i + e_y = F \quad (1)$$

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

Now it is necessary to build a matrix of interindustrial transactions in hybrid units, through the original transaction matrix, (Z). It is necessary to replace the lines of the energy sectors in cash flows with the corresponding energy flow matrices, E thus defining the new transaction matrix (Z^*), in which it describes the interindustrial flows of energy in physical units and the remaining flows in currency units. It is also necessary to define the corresponding total product, (X^*), and the final demand, (Y^*), as vectors in which the energy and non-energy sectors are equally measured in monetary and physical units.

The equivalent matrices, $A^* = Z^*(\widehat{X^*})^{-1}$ and $(I - A)^{-1}$, arise directly from these definitions[5]. Some characteristics of these matrices are different in relation to the conventional Leontief

[5] Matrices that are classified with "caret accents" are diagonalized matrices. Examples: $\hat{X}$ and $\hat{Z}$.

matrix, an example is the sum of the columns of (A^*) that will not necessarily be smaller than the unit as in the conventional Leontief model.

The matrix $(I - A^*)^{-1}$ will have the same existing units in $\boldsymbol{X_i^*}$, however, it will demonstrate the requirements (in CO_2eq - Equivalent Carbon Dioxide, or monetary units) per unit (CO_2eq or monetary units) of final demand (total requirement), while (A^*) demonstrates the requirement per total production unit of (direct requirement).

In order to obtain the direct *energy requirements matrix* and the *total energy requirements matrix*, the energy flow lines of (A^*) and $(I - A^*)^{-1}$ are extracted.

Thus, it is necessary to create the matrix ($\hat{F}^*$) with dimension (m x n), in which the elements (F^*) that represent energy flows are placed along the main diagonal and all other elements are equal to zero.

Constructing the product matrix $F^*(X^*)^{-1}$ it will happen that the non-null elements of (F^*) will be equal to the corresponding values of (X^*), and the result of the product will be a matrix of values "*one*" and *zeros*, in which the numbers "*one*" identify the location of the energy sectors. After performing this procedure, multiplication is performed by $(I - A^*)^{-1}$, where the total energy coefficients "α" will be extracted, that is, the energy lines of $(I - A^*)^{-1}$. Multiplying the powders by (A^*), the direct energy coefficients "δ" are obtained.

Therefore, if "δ" represents the direct requirements and "α" the total requirements:

$$\alpha = F^*(\widehat{X^*})^{-1}(I - A^*)^{-1} \quad (2)$$

$$\delta = F^*(\widehat{X^*})^{-1}A^* \quad (3)$$

The indirect energy requirements "$\boldsymbol{\gamma}$" will be obtained from the difference between "α" and "δ",

$$\gamma = F^*(\widehat{X^*})^{-1}[(I - A^*)^{-1} - A^*] \quad (4)$$

Thus, when multiplying the matrices of direct requirements and total energy requirements by $F^*(\widehat{X^*})^{-1}$, the recovery of energy coefficients will occur, that is, the energy intensity.

It is interesting to note that the construction of this energy model and its expansion to meet the need to insert CO_2*eq* emissions, follow the condition of *energy conservation*[6]. This condition will be decisive in the evaluation of a particular model of energy (and by extension, CO_2*eq* emission) verifying whether or not the pattern adequately represents the energy flows in the economy (MILLER; BLAIR, 2009).

2.2 Key-Sectors

A key-sector is one that demands inputs from other sectors in an amount higher than the average and whose production is widely used by the 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 with regard to emissions, it is necessary to structure a matrix of intersectoral elasticities of demand in association with final energy consumption. For this process, consider the scalar (Γ) that *will represent the total energy use by the productive system* and (τ') *will be the line-vector of energy use per unit of sectorial product*. According to the Leontief model, it is possible to describe,

$$\Gamma = \tau' X^* = \tau'(I - A^*)^{-1} Y^* \quad (5)$$

If the use of energy depends on the final demand of the economy, it is possible to describe,

[6] Energy conservation condition refers to the amount of primary/direct energy required for the production of a good or service in an industry, which must be equal to the total secondary/indirect energy of the product plus the amount of energy lost in the energy conversion.

$$\Delta\Gamma = \tau'\Delta X^* = \tau'(I - A^*)^{-1}Y^*\lambda \qquad (6)$$

where (λ) represents a scalar that demonstrates the proportional increase in final demand.

Calling (s) the *vector for the participation of final demands by sectors* in their respective productions, one can write,

$$s = (\widehat{X^*})^{-1}Y^* \text{ ou } Y^* = s(\widehat{X^*}) \qquad (7)$$

replacing (7) in (6), you will have,

$$\Delta\Gamma = \tau'(I - A^*)^{-1}(\widehat{X^*})s\lambda \qquad (8)$$

by dividing everything by (Γ),

$$\Gamma^{-1}\Delta\Gamma = \Gamma^{-1}\tau'(I - A^*)^{-1}(\widehat{X^*})s\lambda \qquad (9)$$

where, ($\Gamma^{-1}\Delta\Gamma$) represents the total increase in energy taking into account the increase in final demand, that is, the elasticity of (Γ) in relation to final demand. However, the expression (9) is not able to deliver any additional information, given the linear nature of the model, since ($\Gamma^{-1}\Delta\Gamma = \lambda$).

Thus, it will be necessary to perform a breakdown of elasticity. First, equation (9) is transformed, in which (d') is a vector of final energy distribution among the (n) productive sectors of the economy, in which $\sum_{i=1}^{n} d_i = 1$). Therefore, the vector of sectoral consumption coefficients (τ') can be written as follows,

$$\tau' = \Gamma d'(\widehat{X^*})^{-1} \qquad (10)$$

replacing (10) with (9)

$$\Gamma^{-1}\Delta\Gamma = d'(\widehat{X^*})^{-1}(I - A^*)^{-1}(\widehat{X^*})s\lambda \quad (11)$$

considering[7],

$$(I - D)^{-1} = (\widehat{X^*})^{-1}(I - A^*)^{-1}(\widehat{X^*}) \quad (12)$$

by diagonalizing the vector (*s*), it is possible to obtain using (11) and (12),

$$\varepsilon' = d'(I - D)^{-1}s\lambda \quad (13)$$

which will provide the proportional variation of the sectorial energy consumption in relation to a proportional change in the final demand.

By omitting (λ) and diagonalizing (d'),

$$\Gamma^{y} = \hat{d}(I - D)^{-1}\hat{s} \quad (14)$$

where ((τ_{ij}^{y}) is an element of the matrix (Γ^{y}) that represents the percentage of the increase in the final energy consumption of the sector (*i*) in response to a change of (*1%*) in the final demand of the sector (*j*), which can be understood as elasticity, since the sum of the elements of the sector column (*j*) presents the percentage of variation in energy consumption received by the entire economy in response to a change of (*1%*) in the sector's final demand (*j*).

Since (τ_{ij}^{y}) is an element of the matrix (Γ^{y}), it is possible to define,

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[7] According to Miller and Blair (2009), when two matrices P and Q are connected by the relation $P = MQM^{-1}$, they will be correlated and should be expressed as $P \approx Q$. Thus, the product on the right side of (12) will be $(I - D)^{-1} \approx (I - Z^*)^{-1}$, therefore, $(I - D)^{-1}$ can be interpreted as the approximate value of direct and indirect (total) needs for the production of goods and services in the economy, in the which are normally acquired from the matrix $(I - D)^{-1}$.

$$P_{.j} = \sum_{i=1}^{n} \tau_{ij}^{y} \; (i = 1,2, \dots , n) \quad (15) \qquad P_{i.} = \sum_{j=1}^{n} \tau_{ij}^{y} \; (j = 1,2, \dots , n) \quad (16)$$

The total impact is the percentage increase in energy consumption caused by an increase of (*1%*) in the final demand of the sector (*j*), expressed by (15) and the distributive impact is the increase in the energy consumption of the sector (*j*), which results from an increase of (*1%*) in the final demand of all sectors of the economy, expressed by (16) (ALCÁNTARA; PADILHA, 2003).

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

Sectors that fall into sector I will have their energy consumption determined, in part by the demand from other sectors, since the distributive impact is greater than the median of the economy. Quadrant II sectors are the key-sectors, since they have a total and distributive effect greater than the median values of the economy, that is, they are driven to consume energy by increasing demand from other sectors and, simultaneously, they pressure the 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 sectors with high energy content.

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, pressure on energy consumption and pressure to consume energy II
$\sum_j \tau_{ij}^{y} < \Gamma_D$	Non-relevant sectors III	Relevant sectors from the point of view of your demand IV

Source: Alcántara and Padilha (2003).

2.3 Database

For this research, two fundamental databases were used, derived from the regional IP matrix published by the Center for Regional and Núcleo de Economia Regional e Urbana da

Universidade de São Paulo (NERUS) for the year 2011, in which product flows can be found. generated by its sixty-eight (68) sectors in the twenty-seven (27) Brazilian states (HADDAD et al. 2017). And the survey by Azevedo et al., (2018) that measured gross CO_2*eq* 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 focused on sectors with higher levels of emissions of GHG.

The survey conducted by Azevedo et al., (2018) was able to measure emissions from different Brazilian states from the synthesis of the various stages of production, transformation and consumption of the energy process in the most diverse sectors. This process took into account the primary energy emissions (energy products provided by nature in their natural form, such as oil, natural gas and coal, etc.), the process of transformation into secondary energy (energy products resulting from the different transformation methods they have as destination for the various consumption sectors) and final consumption (AZEVEDO et al., 2018).

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

1. *Aggregation of lines and columns* [8]*;*
2. *Aggregation of regions*: For the construction of the MIP Hybrid, it was necessary to aggregate the states into four major regions, namely:

[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 view the aggregation chosen in Appendix A (board A1).

- *Region 1 - MATOPIBA*: Maranhão, Tocantins, Piauí e 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, Espirito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul, Mato Grosso, Goiás and the Federal District.

in which, the choice of States' disposition was made based on the need for research. As the region of interest for the work is the MATOPIBA region (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 regions follows the logic of sector aggregations.

As the information obtained on energy was for 2015 and the interregional matrix constructed used the data from 2011, it became necessary to update the interregional matrix for 2015 in order to obtain more coherent responses. For this, the IBGE database (2017) was used, which contains all the values of production by economic activity in the 27 Brazilian states from 2010 to 2015. Thus, using a proportion between the total production value of 2011 and 2015, it was possible to correct the matrix values 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 emission values.

After completing the steps listed above, the Inter-Regional Hybrid MIP was obtained, with monetary and physical values (CO_2eq emission). With this in mind, it is enough to apply the aforementioned methodology to obtain the elasticities of demand for energy consumption.

2.4 Scenarios

In order to assess the importance of the ABC Plan as one of the existing measures to mitigate emissions in the production processes, mainly in the sectors that make up AFOLU (EMBRAPA, 2018), it was necessary to build two scenarios, each characterized for a certain volume of CO_2eq emissions from the AFOLU sector. The different assumptions were made from information available in the report "Adoption and mitigation of Greenhouse Gases by the technologies of the Sectorial Plan for Mitigation and Adaptation to Climate Change (ABC Plan)" presented by MAPA (2018). The referred report informs 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 Inter-Regional Hybrid MIP, 2015 was considered for two main reasons. Initially due to the need for regional disaggregated data on CO_2eq emissions in Brazil. For this purpose, the research by Azevedo et al. (2018) was used as the basis, in which the authors evaluated for the year 2015 the total of gross CO_2eq emitted by the Brazilian states. In addition, the year 2015 allows us to consider a relatively long period since the implementation of the ABC Plan, allowing to evaluate the effectiveness of the actions proposed in the policy.

i. *Scenario 1*: represents the base situation, in which the emissions of the sectors that make up 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 by Azevedo et al. (2018), already take into account the total mitigated by the ABC Plan between the years 2010 and 2015.

ii. *Scenario 2*: represents the hypothesis that the ABC Plan has not been implemented. Thus, the level of emissions in 2015 is higher than that used in the previous scenario. Considering that between 2010 and 2015 the actions of the ABC Plan were able to mitigate approximately 100 million tCO_2eq, this value was added to the total issued in Scenario 1.

3. RESULTS AND DISCUSSION

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

The amount of emissions considered in this section, refer to the AFOLU sectors in the MATOPIBA region. The emissions generated by these sectors collaborate to a large extent with the accumulation of greenhouse gases (GHG) in the atmosphere, making them some of the main sectors responsible for this phenomenon in the region.

According to IBGE (2017) in 2015, the states that make up MATOPIBA were responsible for 6.6% of Brazilian GDP. However, this value does not necessarily represent your participation in Brazil's emission levels. The results show that the gross emissions caused by its different sectors do not necessarily depend on the concentration of its production, but on the existing intersectoral links. Thus, to analyze the relationship of these production 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 figure that represents approximately 0.5% of MATOPIBA's GDP in 2015, according to data from (IBGE, 2017)). The choice of this value was based on the economic growth that the region has been experiencing in recent years. As it is legally permitted to open new areas for economic use, this region has become the target of investments by the private sector through the acquisition of large areas for production.

In addition, the public sector expanded the granting of financing, such as the MODERINFRA (Program to Encourage Irrigation and Production in a Protected Environment), MODERAGRO (Program for the Modernization of Agriculture and Conservation of Natural Resources) and PCA (Program for Construction and Expansion of Warehouses), (EMBRAPA, 2017). All of these actions have the capacity to boost the region's agricultural sector and make the simulation of a R$ 1 billion increase in final demand plausible.

This study innovated by analyzing what would be the indirect, direct and total effects, in terms of GHG emissions, resulting from simulated expansion of increased demand in different emissions 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 Scenario 1 (real scenario).

For policy purposes, it is necessary to conduct a process analysis. Thus, it is important to assess 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 an 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 see in Figure 1 each one of these effects in the MATOPIBA region.

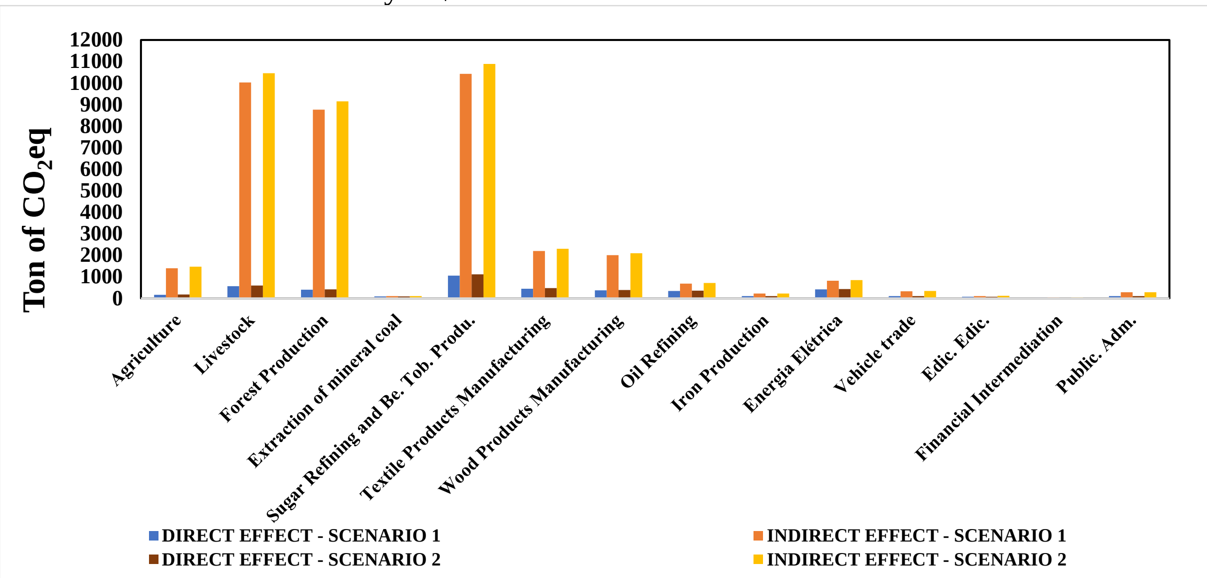
When considering only the biggest polluters, it is observed that the sectors of “Livestock”, “Forestry Production, Fisheries and Aquaculture” and “Sugar Refining and Production of Beverages and Tobacco” in MATOPIBA have their additional emissions determined, mostly, to meet intermediate demand. Thus, the variation of R$ 1 billion in final demand means that 94% of the additional generation of crude CO_2eq in the “Sugar Refining and Beverage and Tobacco Production” sector, for example, is only to satisfy its intermediate demand. It is noted that in all sectors of MATOPIBA the direct effects are low, showing that little of the additional emissions arise to satisfy the final demand: (Figure 1).

In this way, the results demonstrate that if new policies are developed using pro-environmental measures, their focus must prioritize intermediate demand, that is, actions must be sectoral. As the results of this research show, the sectors that require more attention in MATOPIBA are those that form AFOLU.

It is also important to carry out an analysis on the magnitude of the indirect and direct effects for MATOPIBA taking into account 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 final and intermediate demand is verified in the event that there is no reduction in emissions (Scenario 2).

When considering again the biggest polluters for Scenarios 1 and 2, it is observed that the sectors of "Livestock", "Forestry Production, Fisheries and Aquaculture" and "Sugar Refining and Production of Beverages and Tobacco" in MATOPIBA continue to generate their emissions to meet, in the main, the final intermediate demand. When considering the "Sugar Refining and Beverage and Tobacco Production" sector in Scenario 2, the additional generation of crude CO_2*eq* to satisfy intermediate demand is 4% higher compared to Scenario 1, as can be seen in Figure 1.

Figure 1. Direct and indirect effect on CO_2*eq* emissions in tons in scenarios 1 and 2 through the increase in final demand by R $ 1 billion in MATOPIBA.



Source: Own elaboration.

It is also noted that the lowest levels of direct effects in all sectors of MATOPIBA remain, even with changes in the quantities of GHG emitted (Figure 1). That is, the data in

Figure 1 show that policies should not only be concerned with reducing emissions, but also in 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 emissions from the AFOLU sector, the generation of gross CO_2*eq* is almost completely formed to compose the indirect effects, as can be seen in Figure 1.

As a result, when evaluating in the opposite way, it was also identified which sectors are most suitable for the application of pro-environmental measures, as they present the highest levels of emissions. As the results demonstrated the sectors linked to agriculture and livestock 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 MATOPIBA and throughout the country.

3.3 Elasticities of interregional emissions and identification of key-sectors. Measurement of Total and Distributive Impacts and identification of Key-Sectors: MATOPIBA.

As presented in section 2, the elasticity calculation (Γ) uses the Hybrid Interregional Input-Output matrix, in which the values are measured in monetary and physical units. The calculation of elasticities generates a matrix in which each of the elements present in a given column presents the portion of the direct and indirect impact of the increase of one percentage point in the final demand for production carried out by a specific sector in each sector. Thus, the sum of the entries in a given column allows the *total impact* on emissions to be obtained, that is, *the effect on emissions in the economy generated by a one percentage point increase in the final demand of some other sector*.

Similarly, each element of each line of the elasticity matrix represents the contribution of a given sector to the growth of emissions in the analyzed sector. The sum along a given line presents the *distributive impact*, that is, *the emission that would be generated in a certain sector if the final demand of each of the sectors were increased by one percentage point*.

According to section 2.2 of this research, equations (14), (15) and (16) were calculated, demonstrating that the sectors with the greatest total impact are those that carry emissions from other sectors above the median of the economy, from the increase percentage point in your final demand. In the MATOPIBA region, when considering emissions from the AFOLU sector, for Scenario 1, the median found for the distributive impact (*DI*) was 17.8 tCO_2eq additional gross in response to the increase in final demand, while for the total impact (*TI*) the median was 18.9 tCO_2eq gross. Table 2 was used as a reference to classify the activities in MATOPIBA in Scenarios 1 and 2.

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

MATOPIBA C.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. **IV**

Source: Own elaboration.

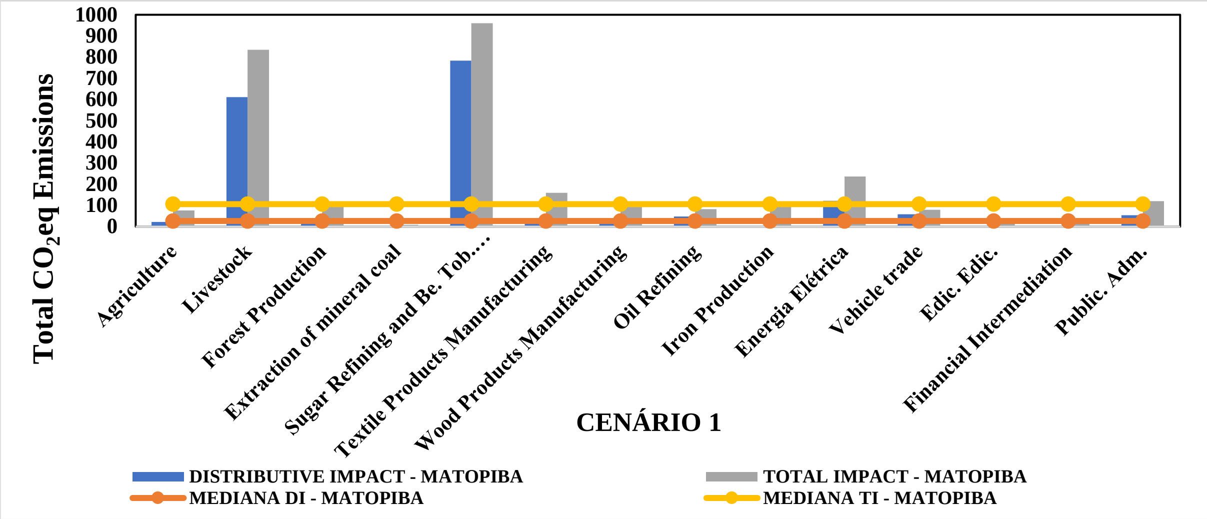
The sectors "Livestock", "Forestry Production, Fisheries and Aquaculture", "Sugar Refining and Production of Beverages and Tobacco", "Electricity" and "Public Administration, Defense and Social Security" are the key-sectors with regard to emissions. They are pressured to issue more when demand from other sectors increases and, at the same time, force other sectors to issue when their own demand increases. As can be seen in Figure 1, the key-sectors that emit the most gross CO_2eq are “Sugar Refining and Beverage and Tobacco Production” and “Livestock”. As can be seen in Figure 2, the key-sectors that emit the most gross CO_2eq are “Sugar Refining and Beverage and Tobacco Production” and “Livestock”.

The results obtained are supported by information presented by IPEA (2017) and Agrososatelite (2015), according to which, in 2015, sugarcane was the third largest annual crop produced in Brazil, behind only soybeans and corn. This fact was also true for the MATOPIBA region, which has been standing out in the expansion of this culture for the production of ethanol since 2003. However, such productive growth brought negative consequences, such as the large amount of GHG emitted in its production stages. According to Papp et al., (2016), with Brazilian ethanol production around 30 billion liters, approximately 24 million tons of CO_2eq are generated. Hence the importance of promoting cleaner production technologies, such as Carbon Capture and Storage (CCS), which could even add value to Brazilian ethanol.

In 2015, about five million hectares of the Cerrado were destined for the planting of sugar cane (Agrosatellite, 2015). Thus, the rapid increase in the cultivated areas of this crop may explain the results found in this work, in which it was identified as one of the key-sectors. It can be seen, from Figure 2, that this sector has the greatest distributive and total impacts found in the MATOPIBA region.

The high *DI* shown in Figure 2 shows that its effects on emissions from additional production to meet the demand of other sectors that need to satisfy the new final demand, are concentrated in this sector. This occurs through 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 in order to support 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 expansion required in final demand. These effects presented are in accordance with the information on increased production and cultivated areas presented by Agrosat Satélite (2015) and IPEA (2017) in recent years by this crop in the MATOPIBA region.

Figure 2. Total and distributional impacts for sectors in the MATOPIBA region



Source: Own elaboration.

In 2015, Brazil presented the largest cattle herd in the world, with about 193 million head, making this sector one of the largest GHG emitters in the country (EMBRAPA, 2017). The excellent conditions for the production of beef cattle and milk 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*, granting it characteristics similar to those of sugar cane production.

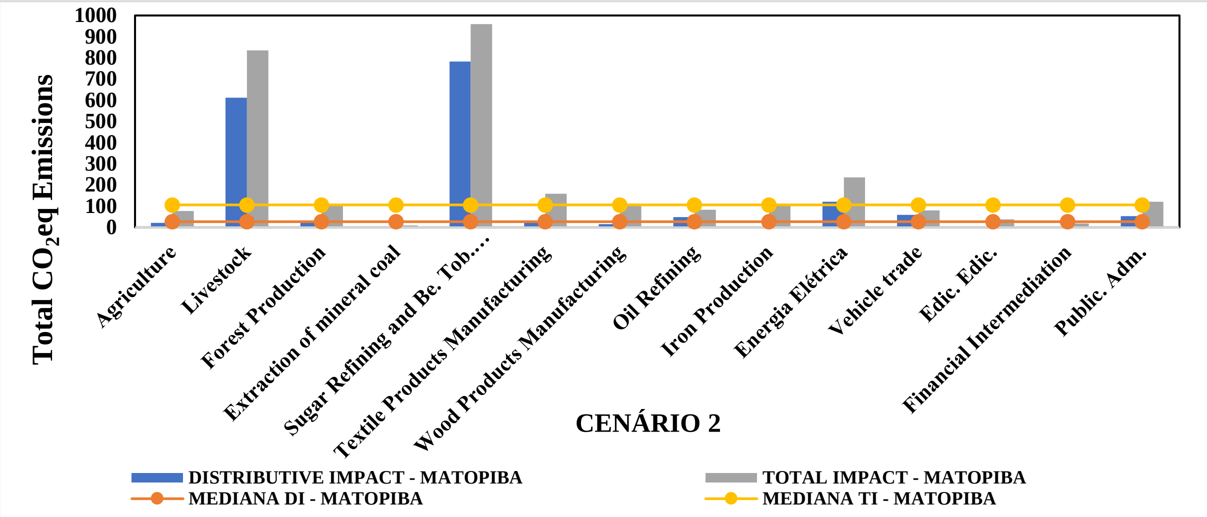
However, the development of these segments in the region, added to the legal permission that the Forest Code gives to rural producers in relation to the deforestation of 80% of native vegetation, ended up causing serious environmental impacts in the region. This can be confirmed by the high level of GHG emissions and the loss of local biodiversity through deforestation for the creation of more than 26 million head of cattle and for the production of soy, corn and sugar cane (Vieira et al ., 2017; and IPEA 2017). Thus, it can be understood that the economic importance of the agricultural sectors in the region ended up making them also the largest additional GHG emitters.

Another analysis of key-sectors was carried out using Scenario 2, in order to verify what would be the changes in the economic structure of the sectors and in the levels of emissions if Brazil had not committed itself to reduce its levels of emissions through the actions of the Plan ABC. Table 2 was also used as a reference to classify activities in MATOPIBA considering the emissions from the AFOLU sector for Scenario 2, as there were no changes in the sectorial classification in that region. The sectors "Livestock", "Forestry Production, Fisheries and Aquaculture", "Sugar Refining and Production of Beverages and Tobacco", "Electricity" and

"Public Administration", 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 actions of the ABC Plan did not exist, but more sharply, since it is possible to observe increases in their levels of emissions.

As shown in Figure 3, the “Sugar Refining and Beverage and Tobacco Production” sector has *TI* values equal to 1000 and *DI* equal to 815 tCO_2*eq* gross, while “Livestock” has *TI* value equal to 869 and *DI* equal to 636 gross tCO_2*eq*. By analyzing the TI and DI values for Scenarios 1 and 2, one can ascertain what the percentage changes in emissions would be if the ABC Plan did not exist. The “Sugar Refining and Beverage and Tobacco Production” sector grew by 4.1% for IT and 3.9% for DI, while in the “Livestock” sector the increase was 4% for both.

Figure 3. Total and distributional impacts for sectors in the MATOPIBA region



Source: Own elaboration.

The aforementioned data show that the mitigation of gross CO_2*eq* emissions resulting from the ABC Plan can be explained in part by the intersectoral changes 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 levels of emissions 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 mention is made of the possible failure that the ABC Plan would have if it continued to exist.

4. FINAL CONSIDERATIONS

In the course of the Brazilian development trajectory, the high rates of GHG emissions generated are observed, which are linked, directly or indirectly, to the high levels of deforestation and the still incipient use of sustainable production techniques from the environmental point of view. The national AFOLU sector has 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, for that, it was necessary to create representative scenarios containing different levels of GHG emissions.

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

Thus, from the perspective 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 pro-environmental actions in MATOPIBA to the production of sectors that directly participate in AFOLU.

The analysis of elasticities in the scenario with the ABC Plan indicated that 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 the 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", "Electricity" and "Public Administration" are the key-sectors in MATOPIBA. However, increases in the magnitude of 4.5% were observed in the median of the emissions of the Distributive and Total Impacts 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 controlling GHG emissions in the MATOPIBA region are “Sugar Refining and Beverage and Tobacco Production”, “Livestock”, “Electricity”, “Forest Production, Fisheries and Aquaculture” and “Public Administration”. Based on this information, it is reasonable to state that the pro-environmental actions resulting from the ABC Plan, or another mitigation plan that may be implemented in the future, 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 application of this plan alone is not sufficient 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. Thus, 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. 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 maintaining its productive performance. Therefore, the scope of the ABC Plan must be expanded and its duration extended, making it act as an example of a solution to the trade-off “commercial agricultural production versus emission reduction”. This would manage, in the future, to make all agricultural credit in the country “low carbon”, guaranteeing advances in the three pillars of sustainability: economic, social and environmental.

Finally, it is emphasized 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 emission control, both at the regional and national levels. national. Once the importance of the ABC Plan is presented, the program's possible permanence is encouraged, as well as the creation of even more ambitious emission reduction strategies. It is recommended to foster information policies, which can ensure that the program has greater reach among farmers or that new markets are made possible and products are valued from activities that use the actions contained in the ABC Plan as a productive method.

ACKNOWLEDGMENT

This 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 the grant of a Research Productivity Grant (Processes 30XXXX / 2018-8 and 42XXXX / 2016-0) and Junior Postdoctoral Scholarship (Process 43XXXX / 2016-3).

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APPENDIX

Board A1. Aggregation of sectors

Sector	Activities
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	***Editing and editing integrated with printing***
	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.