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Regional Development and Greenhouse Gases Emission: the case of the Amazon Region

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Abstract
The purpose of this work is to verify the existence of possible tradeoffs between policies direct to reduce the emissions of greenhouse gases (GHGs) with the ones direct to foster the development of the Brazilian Amazon Region, considering its economic relations with the rest of the country and the international markets. In order to achieve this goal, this paper uses an interregional input-output (I-O) model, estimated for the Brazilian economy for the year of 2004. The I-O model is used to make a comparison between the economical and the environmental relevance of each sector in the Amazon region and the rest of Brazil. This study considers the greenhouse gases emissions not only from the economic activities by itself, but, also for the more important factor of the land-use changes. This is a fact of most importance, given that in 2005, about 60% of the Brazilian GHGs emissions were due to the land-use change in its different biomes. Moreover, in the Brazilian Amazon region, especially in the last decades, the deforestation was linked mainly to economic factors than to policies conducted by the government. The results show that the sectors with the greatest importance in terms of emissions are cattle and soybean production. Also, they are also the most prominent for the region's economic development. This poses a dilemma that needs to be faced not only by Brazil, but also by the developed nations, as the burden of the reduction in the greenhouse gases emission in the Brazilian Amazon region cannot be only put on the poor population of the region!

Resumo
O objetivo do presente trabalho é verificar a existência de possíveis impasses entre políticas que visem à redução das emissões de gases do efeito estufa e outras que objetivem o desenvolvimento da Região Amazônica, considerando suas relações econômicas com o resto do país e com os mercados internacionais. De modo a atingir esse propósito, o artigo emprega um modelo de insumo-produto inter-regional, estimado para a economia brasileira referente ao ano de 2004. O modelo é empregado para se realizar uma comparação entre as relevâncias econômicas e ambientais de cada setor da região Amazônica e do resto do Brasil. O estudo considera os gases do efeito estufa decorrentes não somente das atividades econômicas por si só, mas também da mudança de uso da terra. Trata-se de um ponto de grande importância, uma vez que em 2005 aproximadamente 60% das emissões brasileiras de gases do efeito estufa foram devidas à mudança de uso da terra em seus diversos biomas. Ademais, tem-se que na Amazônia, especialmente nas últimas décadas, o desmatamento esteve relacionado mais a fatores econômicos do que a políticas governamentais. Os resultados mostram que os setores mais importantes em termos de emissões são os de gado bovino e de soja, os quais também se mostram proeminentes para o desenvolvimento econômico da região. Impõe-se, assim, um dilema que deve ser enfrentado não apenas pelo Brasil, mas também pelos países desenvolvidos, uma vez que o ônus da redução das emissões de gases do efeito estufa não pode ser imposto apenas à população carente da região.

Key Words: Amazon Region, Greenhouse Gases, Input-Output, Regional Development, Productive Structure
Palavras-chave: Região Amazônica, Gases do Efeito Estufa, Insumo-Produto, Desenvolvimento Regional, Estrutura Produtiva

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1. Introduction

The phenomenon of global warming, caused by the emission of greenhouse gases (GHGs), is an issue of great concern nowadays. Much of the high interest in the emission of GHGs is related to the gravity of this issue. According to Nicholas Stern, the climatic change is an externality which, due to its possible consequences and, mainly, its potential severity, is the biggest market failure that ever existed. (STERN, 2008, p. xviii). Considering the large number of consequences of this effect and its gravity, the position of Brazil, especially of the Brazilian Rain forest (the area where major part of the national emissions occurs, as this work will mention later) cannot be ignored. According to the World Resources Institute (WRI), in 2005 the country was responsible for a significant portion of the global emissions: 6.47% of GHGs emission in the world took place in Brazil that year. The following table shows this situation relatively to the global biggest emitters.

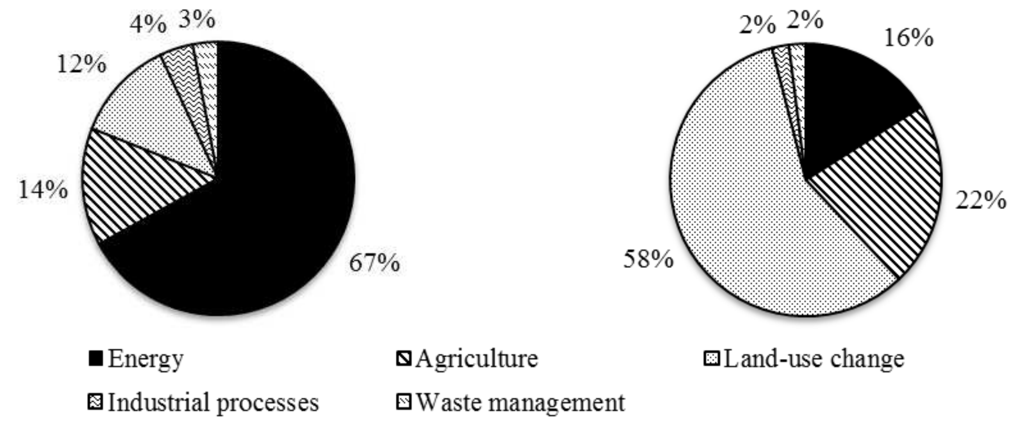
Table 1 – Percentage of CO2eq emission per country, GWP-100, 2005

Origin	Percentage of Global emissions, 2005
China	16.36%
U.S.	15.74%
European Union	12.08%
Brazil	6.47%
Indonesia	4.63%
Russia	4.58%
India	4.25%
Japan	3.17%
Germany	2.27%
Canada	1.83%

Source: World Resources Institute (2010)

However, the Brazilian pattern of emissions is strictly different of the global pattern. It can be seen in the following figure, which presents the patterns of CO2eq emissions across the globe and in Brazil.

Figure 1 – Global pattern (left) and Brazilian pattern (right) of emissions of CO2eq, GWP-100, 2005



Source: World Resources Institute (2010) and Ministry of Science and Technology (2010)

Comparing these two patterns, it is possible to notice two outstanding differences. The first difference refers to the weight of emissions that are caused by the use and production of energy. While these activities are the major responsible for anthropogenic emissions of GHGs in the world, in Brazil they have a rather secondary role. This is related to the fact that Brazil is a country where energy is considered "clean", which, in theory, would give to the country advantages in a scheme for global mobilization to reduce GHGs emissions (CONEJERO; FARINA, 2003, p. 3). The second difference refers to the importance of emissions brought by land-use changes. The largest part (58%) of Brazilian emissions is caused by this activity, which consists basically of deforestation. In global terms, deforestation is less intensively but still relevant for GHGs emissions: land-use change is responsible for 12% of emissions in the world as a whole.

It is needed to consider that 20% of global emissions caused by land-use changes are consequence of deforestation in Brazilian lands, concentrated in the Rain Forest (STERN, 2008, p. 196). That is a fact that cannot be ignored in the analysis of the global warming phenomenon. Thus, the deforestation of the Amazon forest in Brazil is directly responsible for more than 2% of all emissions in the world, giving it a position of considerable importance in a scenario of fighting global warming.

Therefore, the goal of the present work is to identify the possible benefits and losses of a policy aimed to reduce emissions of GHGs in the Amazon forest. For this purpose, it uses the input-output methodology, in order to identify which sectors are the most responsible for these emissions, in addition to their importance in the economy in terms of production, employment and income. Another important point concerns the components of final demand that account for the GHGs emissions in the economy. Particularly, international trade is an important factor in shaping the economic structure and, consequently, in affecting its GHGs emissions (MACHADO et al, 2001). Therefore, the present work will evaluate how responsible are the exports of each region for the emissions of each one of them. Such participation should be taken into account when we try to point out until which extent Brazil should bear the costs of reducing deforestation and, consequently, GHGs emissions in the Amazon Region.

Another important point to be analyzed relates to the expansion of cultivation of inputs for biofuel production. Biofuels are a source of renewable and cleaner energy, being mentioned by many, including the Brazilian government itself, as one of the solutions to reduce GHGs emissions. However, there are indications that the expansion of its cultivation in Brazil could not reduce GHGs emissions, since the areas where their inputs (basically, sugarcane and soybean) are planted would invade part of the land in the Amazon region, so that emissions reduced by the use of biofuels produced would then be "compensated" by the new issues brought by deforestation caused by the expansion of planted area (LAPOLA et al, 2006, p. 1).

The paper is composed by five sections, as follows: section 2 presents a panorama of the Amazon region and its deforestation in the Brazilian economy; section 3 introduces the theoretical background of the input-output model and the indicators applied in the analysis; section 4 includes the results of the study; section 5 presents some concluding remarks.

2. Panorama of the Amazon region in the Brazilian context

This section presents some basic contextualization of the Amazon region in the Brazilian scenario, stressing the relationship between deforestation and economic growth in this region. In the present work, one will consider it as composed by the Brazilian states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins, Mato Grosso and Maranhão. Its area accounts for 61% of Brazil, but comprises just over 12% of the national population.

The 1990's changed the character of the process of deforestation of the Amazon region. Since there were changes in legislation, in development policies, in law enforcement and in the public sectors' attitude towards the deforestation problem, several public organizations began to criticize the predictive models of deforestation, arguing that they were based on a previous reality, and that therefore they did not take into account such progress. However, the change in the governmental posture towards this issue seems to not have caused significantly changes in the actual panorama. One can point out two reasons for this phenomenon.

The first one consists of the cultivation of grains, especially soybeans, in the Amazon region. It was only after the 1980's that this cultivation moved in direction of the North region of Brazil, occupying also part of the Central-West region of the country. Most part of this expansion is due to the advances of transport infrastructure in the region (VERA-DIAZ et al, 2009, pp. 3-4). This movement was not only a result of the need of lands. There was an extensive search, with a prominent role of Embrapa, in order to improve soybean crops, so that it could be cultivated in other regions.

Today, the state of Mato Grosso is the largest producer of soybeans in Brazil, illustrating how this cultivation can threaten the Amazon forest. Although it is not known whether the growth of the area used in grain production in the early 2000s occupied areas already cleared for cattle ranching or new deforestation was required, data for the year 2003 shows that 23% of Amazon deforestation in Mato Grosso was directly related to grain production. It also indicates that the weight of this activity in deforestation is growing steadily; an increase in prices of grain in the international market may intensify this process (MORTON et al, 2006, p. 14637).

One may also indicate the cattle activity as the main cause of the deforestation phenomenon in recent years in the Amazon region. According to some authors, the grains expansion has rather a secondary role in the deforestation. One indicator of this is the fact that for every hectare cleared for grain production, six are for the cattle. Even with the growth of grain production in the region this panorama persists (KAIMOWITZ et al, 2004, p. 2).

In economic terms, the Amazon region presented an increase of its importance for Brazil in recent years, and nowadays it accounts for almost a tenth of the national GDP. It is also worth noting that the region has a larger share of rural areas than the national average: according to the Brazilian Institute of Applied Economic Research (IPEA), between 1970 and 2000 the proportion of the national population residing in the Amazon region increased from 8% to 12%, while the regional participation in the rural population of Brazil increased from nearly 11% to 20%. This is reflected in the fact that the agricultural sector has a greater relative importance to the economy of the Amazon region than for the Brazilian economy.

Despite the mentioned increase of importance of the Amazon region for the Brazilian economy, however, this region is lagging behind the average of the Brazilian economic development indicators. Through years, one can see better results for indicators of demographic, education, development and domicile aspects, but the indicators of the Amazon region are still significant lower than the ones for the country as a whole.[1] Moreover, despite these advances, there was an increase in income distribution inequality in the region. Illustrating this fact, IPEA indicates that between 1981 and 2008 the average Gini index increased from 0.49 to 0.52 in the states of the Amazon region, while in country as a whole this index decreased from 0.58 to 0.55. In other words, the progress of the Amazon has been accompanied by deterioration in the distribution of income, although in the last decade this has begun to change.

It is important to point out that possibly this process of slight improvement in the Amazon region could not have occurred, or have occurred in a less intense way, without the establishment of the activities that caused deforestation. This issue is particularly relevant when it is discussed forms of reducing emissions from this practice. The role of such economic activities, if they are in fact crucial for the well-being of local people, involve a possible tradeoff between reducing emissions and maintenance of the development process in the region.

3. Theoretical Background

The input-output model developed by Leontief (1951) shows the flows of goods and services among the sectors and agents of the economy for a given year. The inter-industries flows are determined by economic as well as technological factors and can be expressed through a system of simultaneous equations (Miller and Blair, 2009).

In matrix terms the inter-industries flows in the economy can be represented by

[1] Some data from IPEA are able to illustrate this point:
- Average life expectancy, 1970 and 2000: 50.2 and 64.9 in the Amazon region, 51.3 and 67.7 in Brazil;
- Infant mortality per 1000 live births, 1970 and 200: 122.4 and 43.9 in the Amazon region, 123.6 and 34.1 in Brazil;
- Adult illiteracy (%), 1991 and 2000: 37.5 and 25.2 in the Amazon region, 31.2 and 21.8 in Brazil;
- Tap water availability (% of the households), 1991 and 2000: 21.7 and 36.4 in the Amazon region, 53.3 and 68.7 in Brazil;
- Electricity availability (% of the households), 1991 and 2000: 44.6 and 69.2 in the Amazon region, 69.4 and 86.6 in Brazil;
- Human Development Index, 1970 and 2000: 0.32 and 0.66 in the Amazon region, 0.36 and 0.7 in Brazil.

$$AX + Y = X \quad (1)$$

where:

X is a vector (*n x 1*) and it contains the value of total production by sector; *Y* is also a vector (*n x 1*) and it contains the final demand values; and *A* is a (*n x n*) matrix which contains the production technical coefficient

In the model above, the final demand vector is usually considered exogenous to the system; thus, the total production vector is determined only by the final demand vector, which is given by:

$$Y = BX \quad (2)$$

$$B = (I - A)^{-1} \quad (3)$$

where:

B, the Leontief inverse, is a (*n x n*) matrix of direct and indirect coefficients, in which the element b_{ij} shows the total amount of production that is required from sector *i* to produce one unit of final demand of sector *j*.

From equation (3) one can estimate the output multipliers of type (I), which shows the direct and indirect effects for a given sector (Miller and Blair 2009), i.e., the total amount of production generated in the economy to produce one unit of final demand of the given sector, and is given by:

$$P_j = \sum_{i=1}^{n} b_{ij} \quad (4)$$

where:

P_j is the output multiplier of sector *j*.

One can also estimate, for each sector in the economy, the total amount of employment, value added, emissions, etc, that is generated directly and indirectly in the economy to produce one unit of final demand of the given sector. In order to do so, one needs to calculate the direct coefficient of the variable of interest:

$$v_i = \frac{V_i}{X_i} \quad (5)$$

where:

v_i is the direct coefficient of the variable of interest of sector *i*; V_i is the total of the variable of interest corresponding to sector *i* (for example, total employment of sector *i*); and X_i is the value of total production of sector *i*.

Then, the total impact, direct and indirect, on the variable of interest will be given by:

$$GV_j = \sum_{i=1}^{n} b_{ij} v_i \quad (6)$$

where:

GV_j is the generator of the variable of interest corresponding to sector *j*, which represents the total impact, direct and indirect, on the variable of interest given a new final demand of one monetary unit in sector *j*.

Based on the Leontief system other indicators can be estimated and used to better understand the economic relations and the productive structure of a given economy. In this way, this paper makes use of backward and forward linkages to understand the productive structure of the Brazilian economy. These indicators are described and defined in the following sections.

3.1. The Hirschman-Rasmussen Approach

The work of Rasmussen (1956) and Hirschman (1958) led to the development of indices of linkage that have now become part of the generally accepted procedures for identifying key sectors in the economy. Being b_{ij} a typical element of the Leontief inverse matrix, B; B^* the average value of all elements of B, and $B_{\bullet j}$ associated typical column sums, then the backward linkage index can be defined as follows:

$$U_j = [B_{\bullet j} / n] / B^* \tag{7}$$

Defining F as the matrix of row coefficients derived from the matrix of intermediate consumption, G as the Ghosh matrix given by $G = (I - F)^{-1}$ (Miller and Blair, 2009), G^* as the average of all elements of G, and G_{i*} as being the sum of a typical row of G, the forward linkages can be defined as:

$$U_i = [G_{i*} / n] G^* \tag{8}$$

The Hirschman-Rasmussen indices of linkages measure the importance of a sector in the economy in terms of buyer (backward) or supplier (forward) of inputs. The Pure linkage approach presented below is similar to the Hirschman-Rasmussen, however it also takes into consideration the total production value of each sector in the economy, i.e., the size of the sector. The sectors indicated as the most important inside the economy, using the Pure linkage, in general are sectors with a great interaction among the other sectors and with a significant level of production.

In general the Hirschman-Rasmussen are concerned mainly with the technical coefficients, while the pure linkage also take into consideration the importance of the values supplied and demanded by each economic sector.

3.2. The Pure Linkage Approach

As presented by Guilhoto, Sonis and Hewings (2005) the pure linkage approach can be used to measure the importance of the sectors in terms of production generation in the economy.

Consider a two-region input-output system represented by the following block matrix, A, of direct inputs:

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{A}_{jj} & \boldsymbol{A}_{jr} \\ \boldsymbol{A}_{rj} & \boldsymbol{A}_{rr} \end{bmatrix} = \begin{bmatrix} \boldsymbol{A}_{jj} & \boldsymbol{A}_{jr} \\ \boldsymbol{A}_{rj} & \boldsymbol{0} \end{bmatrix} + \begin{bmatrix} \boldsymbol{0} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{A}_{rr} \end{bmatrix} = \boldsymbol{A}_j + \boldsymbol{A}_r \tag{9}$$

where A_{jj} and A_{rr} are the quadrate matrices of direct inputs within the first and second region and A_{jr} and A_{rj} are the rectangular matrices showing the direct inputs purchased by the second region and vice versa.

From (7), one can generate the following expression:

$$\boldsymbol{B} = (\mathbf{I} - \boldsymbol{A})^{-1} = \begin{pmatrix} \boldsymbol{B}_{jj} & \boldsymbol{B}_{jr} \\ \boldsymbol{B}_{rj} & \boldsymbol{B}_{rr} \end{pmatrix} = \begin{pmatrix} \boldsymbol{\Delta}_{jj} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{\Delta}_{rr} \end{pmatrix} \begin{pmatrix} \boldsymbol{\Delta}_j & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{\Delta}_r \end{pmatrix} \begin{pmatrix} \boldsymbol{I} & \boldsymbol{A}_{jr}\boldsymbol{\Delta}_r \\ \boldsymbol{A}_{rj}\boldsymbol{\Delta}_j & \boldsymbol{I} \end{pmatrix} \tag{10}$$

where:

$$\Delta_j = (I - A_{jj})^{-1}$$

$$\Delta_r = (I - A_{rr})^{-1}$$

$$\Delta_{jj} = (I - \Delta_j A_{jr} \Delta_r A_{rj})^{-1}$$

$$\Delta_{rr} = (I - \Delta_j A_{rj} \Delta_j A_{jr})^{-1}$$

From equation (8) it is possible to reveal the process of production in an economy as well as derive the Pure Backward Linkage (*PBL*) and the Pure Forward Linkage (*PFL*), i.e.,

$$PBL = \boldsymbol{\Delta}_r \boldsymbol{A}_{rj} \boldsymbol{\Delta}_j \boldsymbol{Y}_j \tag{11}$$

$$PFL = \boldsymbol{\Delta}_j \boldsymbol{A}_{jr} \boldsymbol{\Delta}_r \boldsymbol{Y}_r \tag{12}$$

where the *PBL* will give the pure impact on the rest of the economy of the value of the total production in region, i.e., the impact that is free from a) the demand inputs that region j makes from region j , and b) the feedbacks from the rest of the economy to region j and vice-versa. The *PFL* will give the pure impact on region j of the total production in the rest of the economy.

Other advantage of the Pure linkages in relation to the Hirschman-Rasmussen linkages is that it is possible to get the Pure Total linkage in the economy (*PTL*) by adding the *PBL* and the *PFL*, given that this index are measured in current values, i.e.,

$$PTL = PBL + PFL \tag{13}$$

To facilitate a comparative analysis of the pure linkages with the Hirschman-Rasmussen linkages one can do a normalization of the pure linkages. This normalization is done by dividing the pure linkage in each sector by the average value of the pure linkage for the whole economy, in such a way that the pure linkages normalized are given by the following equations for the backward (PBLN), forward (PFLN) and total (PTLN) linkages:

$$PBLN_i = PBL_i \Big/ \left(\sum_{i=1}^{n} PBL_i \Big/ n \right) \tag{14}$$

$$PFLN_i = PFL_i \Big/ \left(\sum_{i=1}^{n} PFL_i \Big/ n \right) \tag{15}$$

$$PTLN_i = PTL_i \Big/ \left(\sum_{i=1}^{n} PTL_i \Big/ n \right) \tag{16}$$

3.3. Interregional model: Amazon and the other Brazilian regions

The interregional model was obtained according to the methodology presented in Guilhoto and Sesso Filho (2005a) and the Brazilian national table was estimated according to the methodology of Guilhoto et al (2010). The definition of the two regions, Amazon (AMZ) and rest of Brazil (RBR), was based in the states that compose each of them. On the other hand, the sectorial definition was determined so that the relationship with GHGs emissions would be explicit. The final system is composed by 24 sectors.

3.4. Brazilian greenhouse gas emissions

The data source for emissions was the second Brazilian Inventory of Anthropogenic Emissions and Removals of Greenhouse Gases, elaborated by the Ministry of Science and Technology and published in the late 2010. In general terms, the Inventory classifies the emissions in those resulting from use of energy, industrial processes, land-use change, agriculture and waste management. In the present paper, one will analyze the emissions of the GHGs Carbon Dioxide (CO2), Methane (CH4) and Nitrous Oxide (N2O).[2]

In order to aggregate the mentioned emissions – and also those of Perfluorocarbons (PFCs) and Sulfur hexafluoride (SF6) – in units of CO2 equivalent, two alternative metric will be utilized: the 100 years Global Warming Potential (GWP) and the 100 years Global Temperature Potential (GTP). The Brazilian Ministry of Science and Technology argues that the GWP (based on the relative importance of GHGs in relation to CO2 in the production of a certain amount of energy per unit area) does not fairly represent an appropriate relative contribution of different GHGs to climate change. The use of GWP, then, would provide inadequate mitigation policies. Moreover, its use would greatly and mistakenly emphasize the importance of GHGs with short period of permanence in the atmosphere, especially CH4. Thus, the Brazilian Ministry presents the GTP as a more appropriate metric to measure the effects of different gases on climate change, despite the greater uncertainty in its calculation due to the requirement of considering the sensitivity of the climate system (Ministry of Science and Technology, 2010).

An important point is that emissions from the residential subsector, that is, families, were discarded, since the focus of the work is those resulting from economic activities. Among the emissions from the residential subsector, there are those produced by passenger cars, responsible for approximately 2.2% of the Brazilian CO2 emissions in 2005.

Another important point is that the sectorial aggregation provided by the Inventory is different from that adopted by this work, with different numbers, aggregation and sorts of sectors. Emissions, therefore, had to be distributed among the sectors of our input-output model. Special attention was needed

[2] The first caveat is that emissions are related to the year 2005, while our input-output data refer to 2004. It is reasonable to assume that in this span of time there were not significant changes in the economy structure and the pattern and magnitude of emissions. However, in future developments of the work, both data sets will be harmonized.

for the emissions resulting from land-use change, since, as previously indicated, it is responsible for almost 60% of GHGs emissions in Brazil[3]. The methodology for the sectorial allocation can be found in Imori et al (2011).

4. Results

The present section aims to present and describe the results obtained by employing the methodology previously described. However, before that, there is a brief assessment of the productive structure of the two regions through the assessment of the sectorial participation in production and employment, as well as the share of exports in the composition of total production for each sector. Then, the multipliers mentioned above will be presented and discussed, being followed by the analysis of key sectors of each region according to the HR linkages and Pure linkages. After that, the effects of new demands on GHGs emissions will be presented.

4.1. Productive Structure

The present section will highlight the most important aspects concerning the productive structure of the Amazon region. A more complete analysis, encompassing the 24 sectors of the input-output tables and the rest of Brazil, can be found in Imori et al (2011).

A relevant aspect in determining the importance of each sector in regional level is its contribution to the total production. In the case of the Amazon region, the main sectors relatively to the production value are: Other Services, Public Administration, Food Products, Wholesale and Retail Trade, and Electrical and Electronic Equipment. The activities of agriculture and livestock as a whole also have a considerable role for the regional production, having contributed with approximately 14% of the total production value in 2004.

Regarding the regional distribution, the Amazon region is responsible for near 8% of the national production value. This region stands out principally for its production value of the Soybean sector – it accounted for almost one third of the Brazilian production in 2004. The Cattle sector of the region is also very important to the national production. Besides this, the production of the Electrical and Electronic Equipment sector is outstanding in the Amazon Region, due to the Manaus Free Trade Zone.

The same analysis can be applied to the number of employed persons in each sector. In the Amazon region, the Other Services, Wholesale and Retail Trade and Public Administration sectors play a crucial role in population employment, as well as on the question of production value. However, considering the activities of agriculture and livestock as a whole, it is the main employer sector in the region, absorbing almost 40% of the total number of employed persons in the region. It is also worth noting that the Cattle sector alone accounts for more than 12% of the regional jobs.

Among the sectors in the Amazon region, the Cattle sector is the one that presents the largest participation in the sectorial total employment. More than 30% of employed persons in the Brazilian Cattle sector are located in the Amazon region. This fact highlights the probably poor efficiency of the sector in the region: its participation in employment is considerably higher than in the total sectorial production value. However, the opposite statement can be made in relation to the Soybean and Electrical and Electronic Equipment sectors, which present higher participation in sectorial production value than in employment.

Concerning the value added of the economy, generally speaking, in both regions of our model, the participation of most of agricultural and services sectors is lower in the total regional value added than in its production value. In the Amazon region, the Other Services, Public Administration, and Wholesale

[3] Emissions related to land-use change are largely caused about by deforestation in Brazil. In the Amazon biome, 97% of the emissions in the period 1994-2002 were due to the conversion of forests in agricultural land (Ministry of Science and technology, 2010). One should point that, for the year 2005, only data relative to total liquid emission due to land-use change is available. Because of this, the present work underestimates the emissions resulting from land-use change, since the carbon capture resulting from the maintenance of forests was computed in the liquid emissions, which were allocated to the different productive sectors.

and Retail Trade sectors stand out, presenting high participation in the regional total value added. Regarding the regional participation in the total value added of each sector, the Amazon region once again stands out with its agriculture, especially the Soybean and Cattle sectors.

At last, an important question to be discussed is the role of the external sector. The economic structure of the Amazon region displays activities which are considerably dependent of the external sector as demander of their production. The following sectors should be noted in this sense: Primary Metal Industry and Fabricated Metal Products, Mining, Textiles, Textile Products and Footwear, Soybean, Wood, Furniture and Paper Products. These sectors have in common the fact that they are quite important for the production value in the region and they are intensive in natural resources. Other sectors of the Amazon region which production depends importantly on the exports are: Machinery and Equipment, Refined Petroleum Products, Other Chemical Products and Pharmaceuticals, and Food Products. Nevertheless, one must make a note of caution about the Cattle sector. Part of its production is dedicated to the Food Products sector, which, as noted, exports more than 14% of its production. It is reasonable to assume that some of these sales are coming from cattle raised in the Amazon area and that this applies to the Food Products sector both of Amazon region and the rest of Brazil.

The relevance of the dependence on exports is closely related to the actions to mitigate GHGs emissions. One issue to be addressed by policy makers would be how to handle the issue in order to achieve the goal of reducing emissions. The source of the demand which leads to such emissions is a very important point in this question.

4.2. Generation of output and employment

This subsection shall evaluate output multipliers, besides the effects of new final demands on employment and on value added. It is worth mentioning that the values presented here consider the direct, indirect and income effects of these indicators, and therefore, this analysis is interested in the total values.

4.2.1. Output multipliers

The output multipliers, previously described in this work, indicate how many units of output value are created in the economy as a whole given an increase in final demand for each sector. One interesting point of the interregional approach is the decomposition of these effects for each region. Such results are presented in the following figure.

Figure 2 – Output multipliers of the Amazon region and the rest of Brazil

Source: Research data

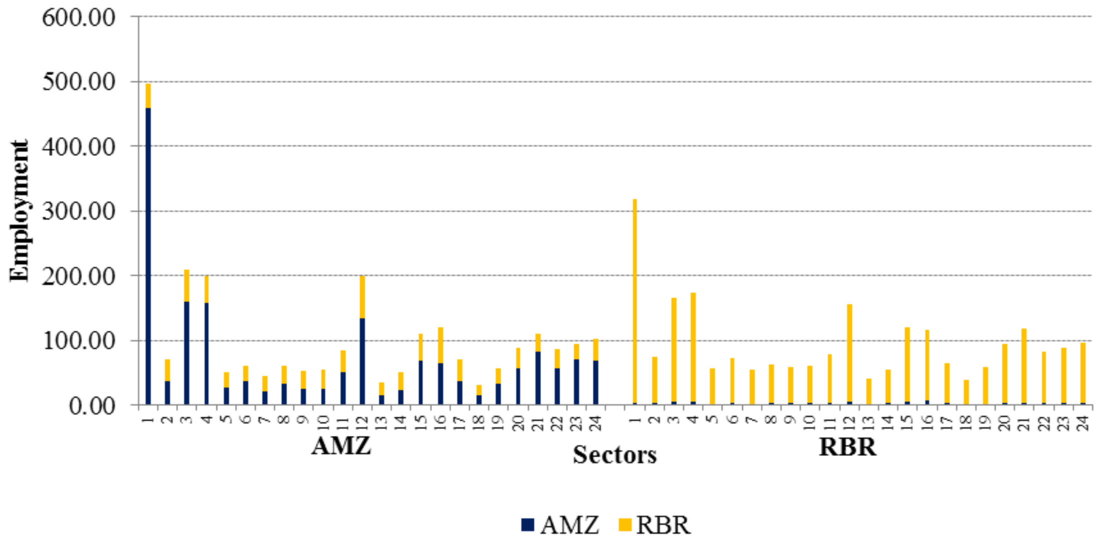
As it can be seen, in general terms there are no major discrepancies in the absolute values of the creation of production across sectors in both regions. The average level of multiplier effects in the rest of Brazil is higher than in Amazon region and, in both regions, the sectors with the highest multipliers are Cattle (number 3) and Food Products (number 16).

Concerning the output multipliers, the major difference between the two regions is seen in the spillover effects. The increase of production proportioned by final demand of sectors of the Amazon is divided, on average, almost equally between the regions, affecting Amazon itself and the rest of the country. On the other hand, the effects of the increase of the final demand of the rest of Brazil area occur mainly in itself, with few repercussions for the Amazon region. This indicates that demand shocks in Amazon region may have significant impacts on its own product, but shocks elsewhere in the country have no major effects on the region. If there was a policy of increasing demand for stimulating the economy in the region, therefore, the targets should be sectors of the Amazon region itself, although there are expressive spillover effects of this increase for the rest of the country (see Guilhoto and Sesso Filho, 2005b, 2005c).

4.2.2. Effects on employment

Regarding employment, the scenario is quite different from that of production, previously treated. The results are presented in the following figure.

Figure 3 – Effects on employment of new final demands of sectors in the Amazon region and in the rest of Brazil



Source: Research data

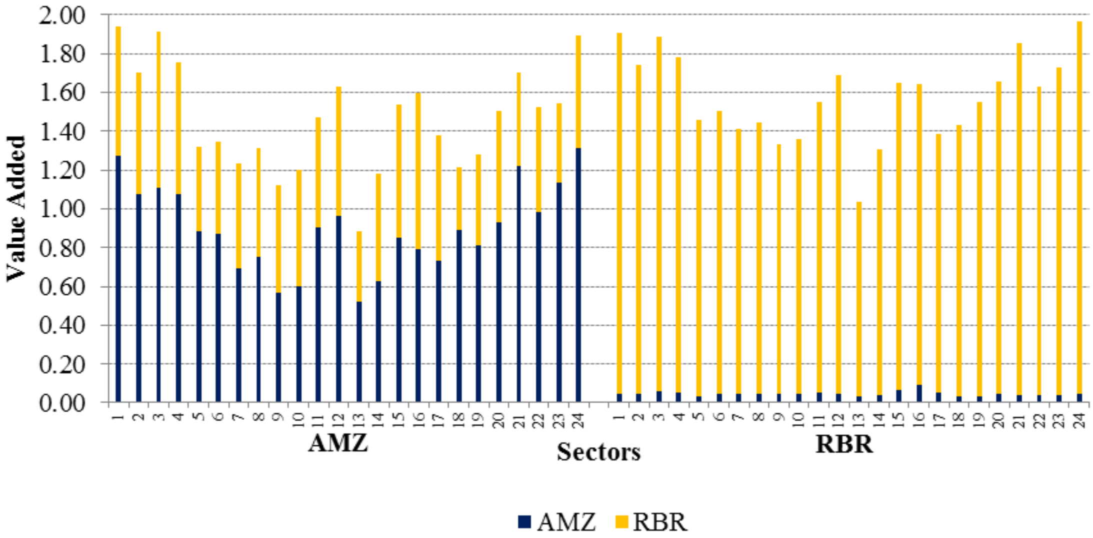
Differently of what was noticed in the case of production multipliers, there are significant discrepancies across the employment effects that each sector provides. There is, however, a general trend that most the jobs created by a sector remain in their own area of origin, although this is slightly more pronounced in the rest of Brazil than in the Amazon. In both regions, the most important sector in terms of generation of employment given by new final demands is Sugarcane (number 1), followed by Cattle (number 3) and Other Activities of Agriculture and Livestock (number 4). Therefore, impacts in the final demand of agricultural sectors cause large effects in the employment of the economy, especially in the Amazon region.

This heterogeneity of the agricultural sectors highlights the question of labor productivity in the Brazilian agriculture, which certainly deserves a more in-depth analysis, as it strongly varies across sectors and regions in the country. While some crops and livestocks in some regions are characterized by intensive utilization of factors and investments in technological developments, as is generally the case of the Soybean sector, large portions of the Brazilian agricultural producers face less favorable conditions which lead to poor labor productivity (see Guilhoto et al., 2007).

4.2.3. Effects on value added

The results found for the generation of value added given by new final demands are more similar to the ones found for production value than those found for employment, as can be seen in the following figure. The importance of analyzing this effect can be explained by the interest dedicated to the GDP growth.

Figure 4 – Effects on value added of new final demands of sectors in the Amazon region and in the rest of Brazil



Source: Research data

In both regions, the effects of the sectors for creation of value added is similar, although here it can be seen more oscillations than in the case of production value. The most prominent sectors in both regions are Sugarcane (number 1), Cattle (number 3) and Public Administration (number 24). However, there is a marked difference between the regions: the increase in value added provided by impacts in the final demand of sectors in Amazon is divided between itself and the rest of the country, while the increase in value added provided by sectors elsewhere in the country focuses primarily on itself, without significant repercussions for the Amazon region.

4.3. Determination of key sectors

As previously mentioned, the determination of key sectors of the economy takes place by means of the use of linkages indices. The present section will analyze the linkages provided by the GHS methodology. For the results of the Hirschman-Rasmussen indices of linkages, see Imori et al (2011).

4.3.1. Results of GHS indices

The already mentioned GHS linkages are different from the HR linkages, since they take into account the magnitude of flows between sectors. The results of these linkages are presented in the table below.

For the Amazon region, considering the magnitude of the economic flows, on the demand side (backward linkages), the main sectors are Food Products and Public Administration, followed by the Electrical and Electronic Equipment, and Construction sectors. On the supply side (forward linkages), the principal sectors are, especially, Other Services, and Wholesale and Retail Trade. Considering both spheres (total GHS linkages), one can consider as key sectors those of Food Products, Wholesale and Retail Trade, Other Services, and Public Administration. The first and last sectors mentioned received this rating due to their quite high demand power. The opposite occurs with the other two, although the discrepancy between its supply and demand powers is not as great as in the case of the other pair of sectors.

Table 2 – GHS Linkages for the sectors of the Amazon region and the rest of Brazil

Sectors	AMZ			RBR		
	Backward	Forward	Total	Backward	Forward	Total
Sugarcane	0.02	0.14	0.08	0.01	0.27	0.14
Soybean	0.29	0.82	0.55	0.09	0.37	0.23
Cattle	0.32	1.68	1.00	0.17	0.44	0.31
Other activities of Agric. and Livestock	0.43	1.26	0.85	0.54	1.18	0.86
Mining	0.62	0.37	0.50	0.35	1.14	0.75
Nonmetallic Mineral Products	-0.04	0.42	0.19	0.08	0.57	0.32
Primary Metal and Fab. Metal Prod.	0.77	0.29	0.53	0.58	1.61	1.10
Machinery and Equipment	0.07	0.03	0.05	0.96	0.29	0.63
Electrical and Electronic Equipments	2.76	0.17	1.46	0.72	0.41	0.56
Transportation Equipment	0.82	0.09	0.46	2.00	0.37	1.18
Wood. Furniture and Paper Products	0.59	0.53	0.56	0.65	1.02	0.84
Ethanol Fuel	0.09	0.04	0.06	0.08	0.14	0.11
Refined Petroleum Products	0.17	0.17	0.17	0.66	1.36	1.01
Other Chem. Prod. and Pharmaceuticals	-0.07	0.34	0.14	0.78	2.10	1.44
Textiles. Textiles Products and Footwear	0.14	0.02	0.08	0.80	0.26	0.53
Food Products	5.60	0.60	3.10	3.61	0.82	2.21
Miscellaneous Manufacturing	0.11	0.08	0.10	0.27	0.9	0.59
Electricity	0.25	1.48	0.86	0.15	1.19	0.67
Gas. Water and Waste Services	0.10	0.45	0.28	0.12	0.40	0.26
Construction	1.81	0.68	1.24	1.90	0.44	1.17
Wholesale and Retail Trade	1.44	3.60	2.52	1.20	2.19	1.69
Transportation	0.67	2.45	1.56	0.94	1.70	1.32
Other Services	1.53	8.13	4.82	3.45	4.70	4.08
Public Administration	5.51	0.15	2.84	3.88	0.13	2.01

Source: Research data

For the rest of Brazil, the results obtained according to the GHS methodology are also quite different from those verified before. Relevant sectors in terms of demand are Food Products, Other Services, and Public Administration. In terms of supply, the Other Services, Wholesale and Retail Trade, and Other Chemical Products and Pharmaceuticals present more importance. Considering both spheres, the key sectors would be Food Products, Other Services and Public Administration.

Comparing the two regions, some important differences stand out. One of them is that the Soybean and the Cattle sectors present greater relevance in the Amazon region than in the rest of Brazil, as displayed by its higher GHS indices, both on demand and supply side. This is also the case of the Public Administration. As one can infer from its GHS backward linkages, the sectors of Electrical and Electronic Equipment, and Food Products, on their turn, have a more expressive role as demanders of inputs in the Amazon region than in the rest of the country. On the other hand, the Other Services sector presents a much higher GHS forward linkage in the Amazon region, what indicates its crucial role as supplier in the regional economy. It is interesting to point out that all the sectors mentioned in the present paragraph have higher total GHS indices in the Amazon region than in the rest of Brazil.

4.4. Relationship with GHGs emissions

According to the procedure previously described, the emissions of GHGs by the Brazilian productive sectors in 2005 are presented in the following table, by region of our interregional input-output model (in thousand tons).

A first important point to note is that CO2 emissions from Amazon are substantially higher than those of the rest of Brazil: in 2005, about 63% of the liquid anthropogenic emissions of CO2 were concentrated in this region. From it, approximately 98% were due to agricultural activities in the region – more specifically, they are results from land-use change in the biome.

In 2005, stood out the expansion of pasture of cattle in the Amazon, which was exclusively responsible for about 36% of Brazilian liquid emissions of CO2. The expansion of agricultural area occupied by soybean was also a major source of CO2 emissions, both in the Amazon region and in other regions of the country. In total, the land-use change due to the expansion of soybean crops accounted for one third of the Brazilian CO2 emissions in 2005. In Amazon, it was responsible for almost 30% of the regional liquid emissions of CO2. One should also emphasize the CO2 emissions due to the expansion of sugarcane crops in other Brazilian regions.

In the rest of Brazil, it is also relevant to indicate the importance of the CO2 emissions corresponding to the Transportation and the Primary Metals and Fabricated Metal Products sectors. In the former, the CO2 emissions are due to the utilization of diesel, gasoline and natural gas in the Brazilian system of road freight transport. Regarding the metallurgic activities, one needs to notice how they are energy intensive in the Brazilian productive structure. Besides this, a large amount of its CO2 emissions are due industrial processes for the production of steel and aluminum.

Concerning the CH4 emissions, almost two thirds of it in Brazil are due to Enteric fermentation in cattle. In this way, the CH4 emissions of the Amazon region will rise as its areas of pasture expand. Furthermore, land-use change was responsible for about 17% of the Brazilian emissions of this gas in 2005. Waste management, in its turn, was responsible for 10% of the total CH4 emissions in the country.

Brazilian N2O emissions are due mainly to agricultural land. Animals kept on pasture and indirect emissions from cattle responded for more than 60% of N2O emissions in Brazil, in 2005. Land-use change, soybean residuals and burning of sugarcane waste were responsible for great part of the remaining emissions of this gas.

Under both metrics for aggregation of the GHGs emissions that were considered in the present work – GWP-100 and GTP-100 – the role of the Amazon region stands out. However, under the GTP-100 metric, which assigns less weight to CH4 and N2O in the global warming process, the participation of the Amazon region in the total of CO2eq emissions in Brazil increases from 54% (under the GWP-100 metric) to 58%, since this region principally outstands in the emissions of CO2.

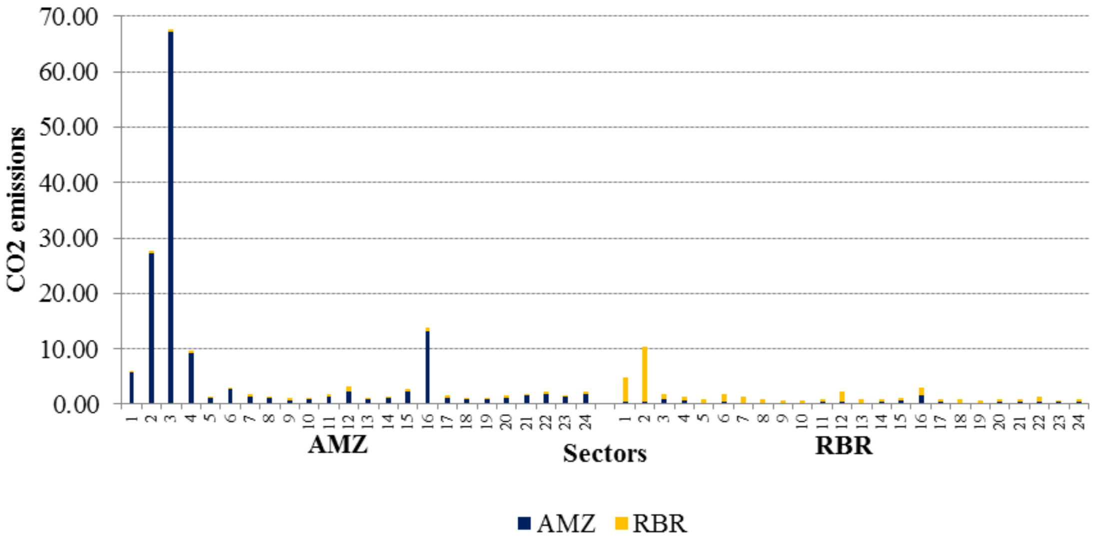
Table 3 – GHGs emissions per sector, Amazon and rest of Brazil, year 2005 (in thousand tons)

		CO2		CH4		N2O		CO2eq - GWP-100		CO2eq - GTP-100	
		AMZ	RBR	AMZ	RBR	AMZ	RBR	AMZ	RBR	AMZ	RBR
1	Sugarcane	2 819.40	49 828.43	14.43	245.38	0.56	9.32	3 297.36	57 872.14	3 043.92	53 573.05
2	Soybean	293 335.36	228 021.31	712.91	552.67	9.10	12.64	311 128.06	243 544.60	299 357.41	234 196.47
3	Cattle	576 378.17	6 400.01	4 005.22	8 776.87	80.22	237.43	685 357.30	264 318.99	618 064.76	114 391.64
4	Other activities of Agriculture and Livestock	107 410.07	9 242.25	480.33	1 043.84	20.55	128.67	123 867.01	71 049.40	115 359.79	49 201.25
5	Mining	1 900.17	19 108.83	27.69	322.31	0.01	0.12	2 485.38	25 913.92	2 041.87	20 752.23
6	Nonmetallic Mineral Products	2 071.66	30 296.34	0.26	4.74	0.02	0.45	2 083.96	30 534.74	2 078.94	30 440.96
7	Primary Metal and Fabricated Metal Prod.	5 581.55	60 022.45	2.96	43.04	0.09	1.24	5 703.93	61 311.97	5 648.76	60 573.60
8	Machinery and Equipment	8.43	1 291.57	0.00	0.00	0.00	0.00	832.30	1 291.57	726.00	1 291.57
9	Electrical and Electronic Equipments	0.00	0.00	0.00	0.00	0.00	0.00	1.78	0.00	1.55	0.00
10	Transportation Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Wood, Furniture and Paper Products	110.11	3 840.89	0.05	1.75	0.01	0.49	115.48	4 028.32	114.12	3 980.88
12	Ethanol Fuel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	Refined Petroleum Products	310.16	22 304.84	0.27	19.23	0.00	0.00	315.78	22 708.72	311.50	22 401.00
14	Other Chemical Prod. and Pharmaceuticals	438.75	26 867.25	0.01	0.49	0.67	21.43	651.83	33 521.38	624.22	32 656.26
15	Textiles, Textiles Products and Footwear	14.96	1 231.04	0.00	0.30	0.00	0.03	15.15	1 246.45	15.08	1 240.52
16	Food Products	393.71	3 479.29	1.89	16.71	0.25	2.19	510.31	4 509.69	470.13	4 154.67
17	Miscellaneous Manufacturing	155.33	6 339.67	0.02	0.78	0.00	0.00	155.73	6 356.07	155.42	6 343.58
18	Electricity	2 507.88	23 478.12	0.14	1.36	0.00	0.00	2 510.92	23 506.58	2 508.60	23 484.90
19	Gas, Water and Waste Services	4.64	105.36	111.43	1 631.57	0.59	13.41	2 527.76	38 525.24	721.27	11 883.73
20	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Wholesale and Retail Trade	167.97	1 786.03	0.11	1.19	0.00	0.04	171.38	1 822.32	169.46	1 801.84
22	Transportation	6 799.38	91 156.88	0.53	7.22	0.10	1.56	6 842.14	91 791.77	6 829.62	91 613.85
23	Other Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Public Administration	168.35	1 570.65	0.00	0.04	0.00	0.01	168.70	1 573.93	168.61	1 573.02
	Total	**1 000 576.06**	**586 371.21**	**5 358.26**	**12 669.49**	**112.19**	**429.02**	**1 148 742.26**	**985 427.81**	**1 058 411.02**	**765 555.03**

Source: Research data

The results of the effects on GHGs emissions of new final demands in the Amazon region and in the rest of Brazil are presented in the following figure. The figures intend to emphasize the spillover effects of emissions resulting from productive activities in both regions of our input-output model.

Figure 5 – Effects on CO2 emissions of new final demands of sectors in the Amazon region and in the rest of Brazil



Source: Research data

As could be expected from the data presented in Table 9, in the Amazon region there is a clear prominence of the generation of CO2 by new final demands of the Cattle sector (number 3), which has a minimum spillover effect to the rest of Brazil. Given a one thousand reais (of 2004) impact in its final demand, the Amazon Cattle sector will cause the increase of the CO2 emissions of the Brazilian economy in nearly 68 thousand tons. 94% of this effect is direct, being mainly a consequence of the land-use change in the Amazon region. The analysis of the CO2 emissions caused by new final demands of the Soybean sector (number 2) is quite similar. Moreover, the Food Products sector (number 16) also features a high effect in CO2 emissions. In this case, however, the indirect effect prevails. This can be expected because of the fact that it is a sector which demands large quantities of inputs from the agricultural sectors.

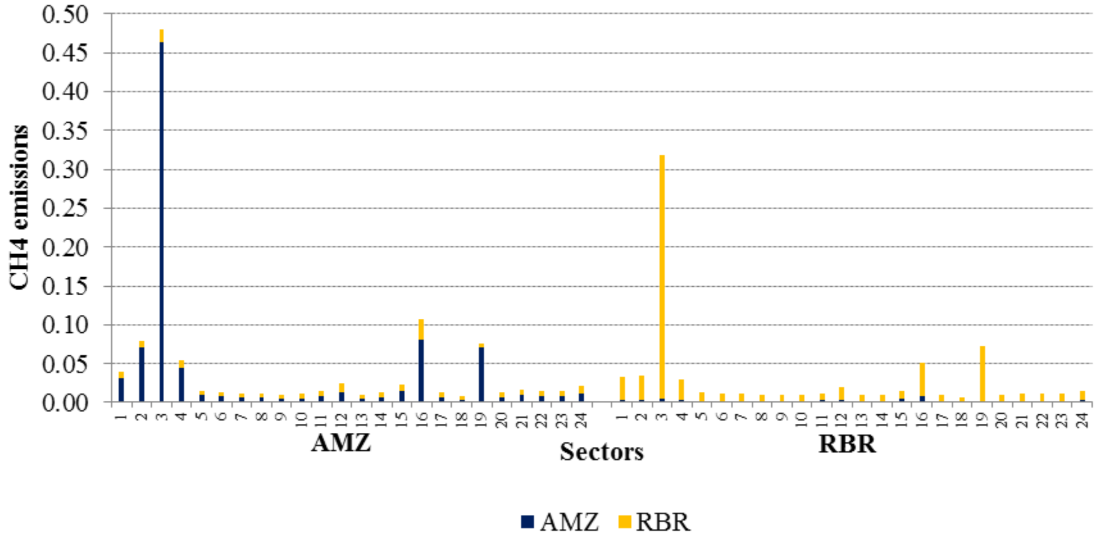
In the rest of Brazil, the CO2 emissions caused by new demands of the Food Products sector (number 16) stand out by its large spillover effect to the Amazon region. The effects on CO2 emissions corresponding to new final demands of agricultural sectors are also outstanding. Although lower than that of the Amazon region, the effects on CO2 emissions corresponding to the Soybean sector (number 2) is the largest one, as Figure 11 presents: for one thousand reais impact in its final demand, the Soybean sector will cause an increase of about 10 thousand tons of CO2 emissions. The Sugarcane sector (number 1) also presents a high CO2 effect, as well its derived industry, the Ethanol Fuel sector (number 12).

This fact highlights the point that, even though the CO2 emissions resulting from the utilization of ethanol in passenger cars[4] are not accounted in the Brazilian Inventory of Anthropogenic Emissions and Removals of Greenhouse Gases and the ethanol distilleries are considered self-sufficient in energy terms (the utilization of sugarcane bagasse as fuel for generating electricity in the distilleries is widespread in Brazil), the final demand for ethanol fuel indeed causes significant emissions of CO2. However, an important aspect has to be considered: the sugarcane crops absorb CO2 during their growth, possibly including not only the emission from ethanol utilization, but also that due to land-use change. This is a point that can be indicated for the land-use change emissions in general and that claims for further studies. The Second Brazilian Inventory considerers the removal of GHGs emissions by crops in 2005,

[4] According to the Ministry of Science and Technology (2010), in 2005, approximately 55% of the licensed passenger cars in Brazil were fueled exclusively by ethanol or could use this fuel in combination with gasoline (flex fuel technology).

but does not consider its temporal dimension, what leads us to overlook the fact that the agricultural plants may remove the emissions caused by the preparation of their land. Thereby, further studies are needed in order to analyze how much the agricultural crops and cultivated grassland can neutralize the land-use change emissions in Brazil.

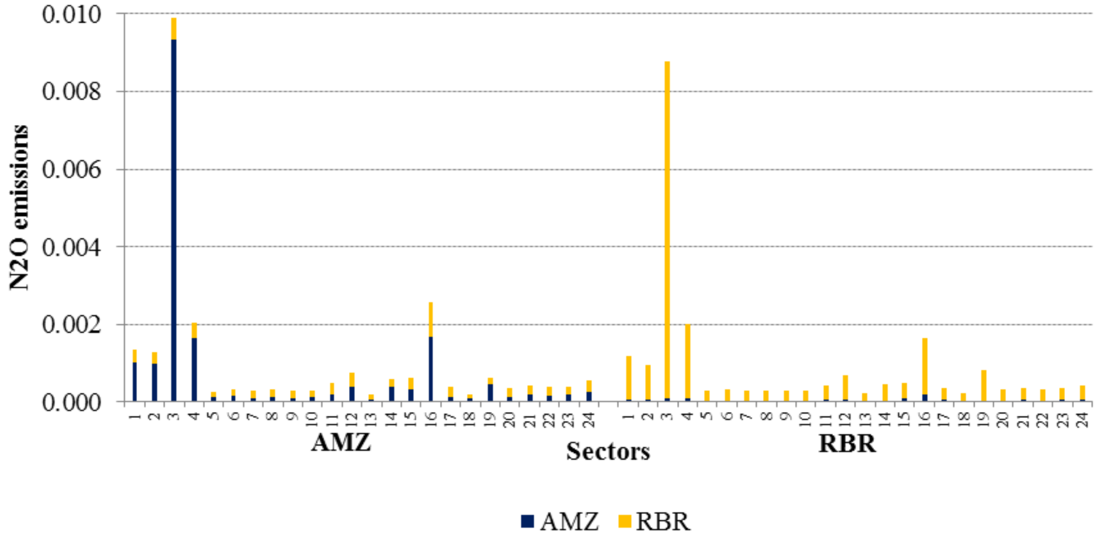
Figure 6 – Effects on CH4 emissions of new final demands of sectors in the Amazon region and in the rest of Brazil



Source: Research data

As could be expected by the nature of CH4, the effects on these emissions caused by new final demands are especially high in the Cattle sector (number 3) of both considered regions. Particularly in the Amazon region, for one thousand reais impact in its final demand, the Cattle sector will cause an increase of near 0.48 thousand tons of CH4 emissions. The Food Producs (number 16) and Gas, Water and Waste Services (number 19) – because of waste management activities – also present high CH4 emissions effects in Brazil as a whole.

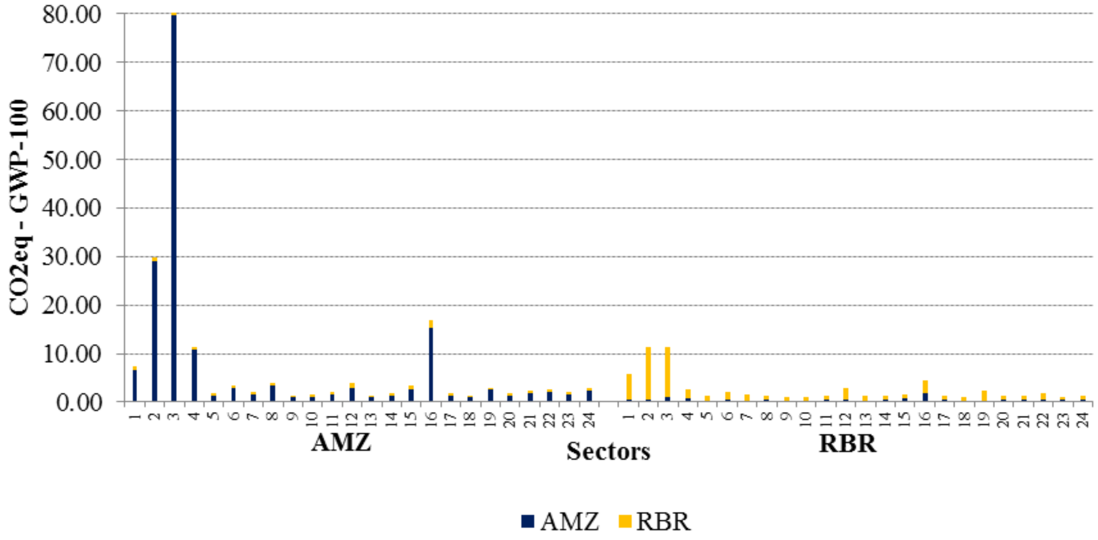
Figure 7 – Effects on N2O emissions of new final demands of sectors in the Amazon region and in the rest of Brazil



Source: Research data

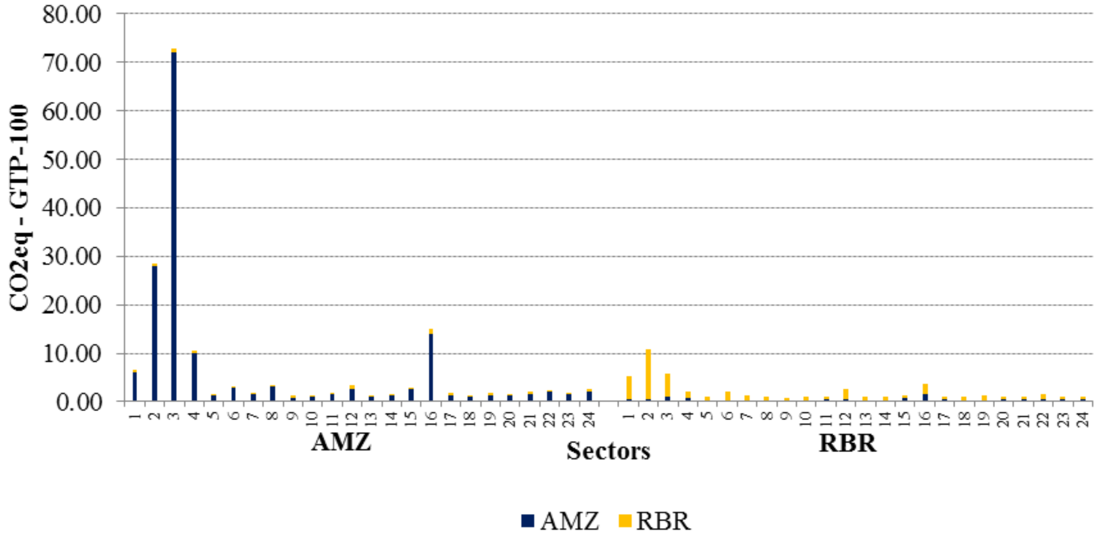
Also in the case of effects of new final demands on N2O emissions, the Cattle sector (number 3) stands out in both regions of our input-output model. In the Amazon region, given a one thousand reais (of 2004) impact in its final demand, the Cattle sector will cause the increase of the N2O emissions of the Brazilian economy in approximately 10 tons.

Figure 8 – Effects on CO2eq of new final demands of sectors in the Amazon region and in the rest of Brazil – GWP-100



Source: Research data

Figure 9 – Effects on CO2eq of new final demands of sectors in the Amazon region and in the rest of Brazil – GTP-100



Source: Research data

Figures 8 and 9 present results of the effects of new final demands on CO2eq emissions under GWP-100 and GTP-100 metrics for the Amazon region. In both cases, the effect corresponding to the Cattle sector (number 3) is largely outstanding – notably under the GWP metric, which, as mentioned before, gives a higher weight to the emissions of CH4.

Finally, these results for the rest of Brazil are also presented in Figures 8 and 9. Under both metrics, the effects of agricultural activities stand out, especially that of the Soybean sector (number 2). However, under the GWP metric, the effect of the Cattle sector (number 3) almost equals that of soybean production.

Summarizing the previous results, one can note that, in the Amazon region, the sector with the highest output and value added effects is also the one with most outstanding GHGs emissions caused by new final demands: the Cattle sector, responsible for 3.4% of product value and 12.4% of employment in the region. Other sectors that have an important role in regional dynamics are Public Administration, Other Services, Food Products and Sugarcane. The latter two also have potential to have strong role in the generation of GHGs. This indicates a possible tradeoff between development policies for the region and environmental preservation: some of the sectors with the greatest effects on the regional economy are also those that most affect the environment through GHGs emissions.

4.5. Contribution to GHGs emissions by final demand component

In the analysis of the GHGs emissions, it is relevant to consider which components of the final demand of each region are more responsible for them, directly and indirectly. The following table presents the contribution of each final demand component of our input-output model to the total CO2eq emissions of the Amazon region and the rest of Brazil, both under the GWP-100 and GTP-100 metrics.

Table 4 – Contribution to CO2eq emissions by final demand component of each region, GWP-100 and GTP-100

Final demand components		GWP-100		GTP-100	
Source region	**Components**	**AMZ**	**RBR**	**AMZ**	**RBR**
AMZ	Exports	16.98%	0.78%	16.60%	0.78%
	Government and non-profit organizations	0.48%	0.21%	0.50%	0.20%
	Households	16.12%	3.25%	16.28%	3.41%
	Gross fixed capital formation and changes in inventories	19.83%	1.03%	19.82%	0.95%
RBR	Exports	6.29%	30.75%	6.27%	28.27%
	Government and non-profit organizations	1.38%	3.84%	1.38%	3.83%
	Households	30.01%	50.68%	30.09%	52.43%
	Gross fixed capital formation and changes in inventories	8.91%	9.46%	9.06%	10.14%
	Total	100.00%	100.00%	100.00%	100.00%

Source: Research data

Concerning the GHGs emissions of the Amazon region, under both metrics, the final demand component with greater contribution is the household consumption from the rest of Brazil – 30% of the CO2eq emissions in the Amazon region are due to productive processes aroused by the final demand of households in other regions of the country. More specifically, near 13% of the emissions in the Amazon region are due to the household consumption of the Food Products sectors in the rest of Brazil. The second largest contribution corresponds to the gross fixed capital formation and changes in inventories in the Amazon region, especially those of the Cattle sector. However, considering the exports of both regions in the model, the table 4 indicates that the external sector is responsible for more than 23% of the emissions of the Amazon region. One should particularly indicate that the exports of the Soybean sector of the own region contribute with more than 10% of the regional CO2eq emissions. Moreover, the exports of Food Products sectors of both regions are directly and indirectly responsible for approximately 9% of the emissions in the Amazon region, especially due to its utilization of Amazon agricultural inputs.

Regarding the rest of Brazil, a first important and distinguishing aspect is that the final demand of the sectors of the Amazon region is responsible for slightly more than 5% of its CO2eq emission, under both metrics. Other important point is that more than 50% of the emissions in the rest of Brazil are due to its household consumption. Also in this region, the domestic demand of the Food Products sector has a major role raising the GHGs emissions, being responsible for more than 22% of them in the rest of Brazil. Besides this, the external sector contributes to the CO2eq emissions here even more than in the Amazon region. Approximately 30% of these emissions can be attributed to exports. Under the GWP-100 metric, both exports of the Soybean and the Food Products sectors are responsible for about 9% of the emission in the region, while under the GTP-100 metric the contribution of the exports of the Soybean sector raises to almost 11% and that of the Food Products sector decreases to 8%.

5. Conclusions

This work aimed to evaluate possible tradeoffs in an effort to reduce GHGs emissions in Brazil, especially in its Amazon region. To demonstrate these dilemmas, an input-output approach was adopted, so that it was possible to identify the most relevant sectors, both economically and in terms of emissions.

In the Amazon region, the most relevant sectors in terms of GHGs emissions multipliers are Cattle, Soybean, Other activities of Agriculture and Livestock, Sugarcane and Food Products. The former four are strongly linked to deforestation, while for the latter such a position is due to its links with the agricultural sectors, as they provide inputs to its activity.

Some points should be highlighted. One of them is that the Soybean sector is highly dependent on its exports – thus, one can consider that most of its GHGs emissions are due to the demand of other countries. This same consideration applies to the Food Products sector, which is also responsible for a considerable part of the total production value of the Amazon region and has high production multipliers, as well as being a key sector according to the GHS index. As a consequence, the present work indicated that approximately 23% of the CO2eq emissions in the Amazon region are due to demands of the external sector. Other significant portion of the GHGs emission in the Amazon region (about 30%) are due to productive processes aroused by the final demand of households in other regions of the country.

These points should be taken into consideration in the formulation of public policies for reducing GHGs emission in the Amazon region. The sectors that most contribute to emissions, mentioned above, also have interesting aspects in order to boost the economy. In this sense, the sector Other activities of Agriculture and Livestock has an important role in terms of employment, as well as the Cattle sector, which presents a high proportion of the jobs in the region, in addition to being relevant in terms of several multiplier effects.

As presented in a previous section of the work, GHGs emissions have been especially linked to regional economic performance in recent times. Usually, this is connected to deforestation in the Amazon rainforest, which is the major source of Brazilian emissions of GHGs. Addressing them through restrictions on the activity of its economy would harm the region, which, as mentioned, is less developed than the rest of Brazil. An economic evaluation of this aspect would involve the consideration of how much the sectors themselves should bear the restrictions and how they should be allocated to the rest of the country and to the export sector.

In any case, a region relatively less developed than the rest of the country could be considered as a priority over the others. The application of restrictions on economic activities, which provide opportunities to promote their development, would not be consistent with this priority. This can be interpreted as one of the greatest – perhaps the central – the dilemma of reducing GHGs emissions in the Amazon region.

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