Paris agreement on climate change and the possible impacts on Brazilian meat and dairy sectors

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PARIS AGREEMENT ON CLIMATE CHANGE AND THE POSSIBLE IMPACTS ON BRAZILIAN MEAT AND DAIRY SECTORS

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Abstract: This study analyzes the impacts of reducing GHG emissions on the Meat and Dairy sectors. For this purpose, the Brazilian targets for the reduction of GHG emissions ratified in the Paris Agreement in 2015 are considered as starting points. To achieve this goal, General Equilibrium Model (GTAP) is used, which allows the inclusion of carbon taxes and the construction of alternative scenarios using GWP and GTP as GHG emissions measures. Four scenarios are analyzed. Scenario 1 applies carbon taxes upon Meat & Dairy sector and no carbon taxes on the other Brazilian sectors. Scenario 2 simulates only carbon taxes upon the Energy sector and Scenario 3 equal carbon taxes on all sectors (20$, 40$ and 60$ per tons of CO2). Scenario 4 considers the application of carbon taxes to the Meat & Dairy, Grains & Crops lower than to the Energy and Industry & Services sectors. For all scenarios is analyzed the main effects on sector emissions but also on production, trade and the Brazilian GPD. In general terms, the results show that: the Scenario 3 may be the most appropriate when we use the GTP measures to estimate GHG emissions. In this case, the reduction in GDP are not as intense as when are used GWP, though the exportation of the Beef and Dairy are also expected to drop. The fourth Scenario seems to be the most adequate in terms of cost distribution among the various economic sectors in Brazil, only when the GWP is considered.

Keywords: meat and dairy, carbon taxes, GHG emissions, GTAP.

1- Introduction

Over the last decade Brazil has experienced an important economic growth in both agriculture and food processing maintaining a leading position in international trade. According to the FAO, Brazilian beef, pork and chicken meat exportation had grown 99%, 45% and 23%, respectively, from 2006 to 2015 (Hubbard, Alvim and Garrod, 2017).

For instance, this performance has potential to reinforce the negative externalities from the meat production and trade, increasing the Greenhouse Gas (GHG) emissions. It is important to emphasize that beef, pork and chicken production in Brazil has a strength connection with the three axes of the Paris Agreement: GHG emissions, deforestation and energy generation from biomass. As an example of this, meat and dairy sectors accounts 29% of the Brazilian GHG emissions (SEEG, 2019). Similarly, grain production (mainly soy and corn as the basis of animal feed) is often associated with the deforestation, animal and biofuel production (Margulis, 2003; Ferreira Filho et al, 2015; Carvalho, Domingues and Horridge, 2017).

Therefore, this paper aims to analyze the possible impacts of reducing GHG emissions on the Meat and Dairy sectors. For this purpose, the Brazilian targets for the reduction of GHG emissions ratified in the Paris Agreement in 2015 are considered as

starting points. Some studies have analyzed this topic (Fernandez and Daigneault, 2016; Henderson, 2018; Gurgel, Paltsev and Breviglieri, 2019), using carbon taxes, land use and no deforestation. Differently from the others, this paper consider two diverse indicators of GHG emission as Global Warming Potential[1] (GWP) and Global Temperature Potential[2] (GTP) to analyze the effects of the environmental policies on Brazilian Meat and Dairy sectors.

The paper also shows the importance of gradually increasing the goals and the instruments of environmental policy after 2020, since the significant decrease of GHG emissions in Brazil has been mostly from the reduction of deforestation (Cerrado and Amazon forest) and from the increase reforestation areas until 2018 (MCTI, 2014, IPEA, 2019; SEEG, 2019).

Although the GWP is the standard indicator defined in the Paris Agreement, the present study considers as well the GTP to analyze the different effects of carbon taxes on the meat and dairy sectors, and likewise upon the other sectors of the Brazilian economy. As a result, it is possible to gather a broader set of strategies and instruments that seek to make compatible, not only the goals of the Paris Agreement with Brazilian environmental policies, but moreover with economic and agricultural policies in Brazil.

To achieve this aim a General Equilibrium model (GTAP) are used. This model make possible to simulate alternative scenarios and to estimate the impacts of the Paris Agreement on Meat and Dairy sectors, including also other main Brazilian sectors. The scenarios considered different environmental policies assembled in two groups: Economic instruments (carbon taxes) and Command and Control instruments (regulation), see also Meijla, et al, 2006; Rutheford, 2010; Carvalho, Domingues and Horridge, 2017; Gurgel, Paltsev and Breviglieri, 2019.

As main results, it is expected to observe the effects on Brazilian Meat and Dairy carbon emissions and trade. In addition, it shall be possible to evaluate the different effects on other sector of Brazilian economy for alternative environmental policy scenarios.

2- Paris Agreement and Carbon Emissions in Brazil

The 21th Conference of the Parties (COP21), as also known as the Paris Climate Change Agreement, was signed by 195 countries at United Nations Framework Convention on Climate Change (UNFCCC) in 2015. As a strategy to strengthen mitigation actions and to foresee precautionary arrangements against climate change, the Paris Agreement sets the following targets for signatory countries (article 2), (IPCC, 2015; CEBDS, 2017):

(i) Holding the increase in the global average temperature between 1.5 and 2°C above pre-industrial levels, reducing the risks and impacts of climate change.

[1] Global Warming Potential (GWP) of a GHG emission is defined as the time-integrated radiative forcing of an emission pulse of gas, divided by the corresponding time-integrated radiative forcing of an emission pulse of CO2 of equal mass. In this case, the methane is equal to 28 for the equal CO2 mass. Otherwise, the temperature change will be nearly seven time higher for the emission pulse of CO2 than the emission pulse of CH4 (Persson et al, 2015, p.1-2)

[2] Global Temperature Potential (GTP) of a GHG is defined as the temperature impact at a future impact at a future point in time due to an emission pulse of the gas, divide by the corresponding temperature change from an emission pulse of CO2 of equal mass. The methane emission is equal 4 for the equal mass of CO2 (Persson et al, 2015, p.1-2).

(ii) Increasing the ability to adapt to the impacts of climate change and foster climate resilience, in a manner that does not threaten food production;

(iii) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

In order to achieve these goals by the signatory countries, it is necessary to define and apply a set of environmental policies with goals to be achieved. Brazil has committed itself to a set of actions which aims to reduce gas emissions and to manage environmental problems. The actions are organized in three axes that summarize Brazil's commitments (CEBDS, 2017):

(i) Considering the 2005 greenhouse gas emission levels, reduce by 37% until 2025 and 43% until 2030.

(ii) Restore 12 million hectares of forests.

(iii) Increase the share of biomass energy to 18% of the energy matrix by 2030.

The main gas emissions indicator for Intergovernmental Panel on Climate Change (IPCC) and considered in the Paris Agreement target assessment is the GWP. However, as this indicator penalizes emissions from countries with a higher methane weight from production (as Meat and Dairy sectors), some researches are already suggesting the use of GTP instead of GWP. The differences between the two indicators is significant and may affect the strategies of Brazil in conducting environmental policies to mitigate GHG emissions (Johansson, 2012; Persson et al, 2015).

As the data from SEEG (2019) in Table 1, the largest GHG emitter is from Deforestation, followed by the Energy and Meat & Dairy sectors considering GWP and GTP indicators in 2018. For both indicators, Brazil has already met the Paris Agreement target for 2030. Even though there are significant decreases on deforestation in Brazil until 2018, all other sectors have remained increasing GHG emission from 2005 to 2018.

The differences between GWP and GTP emissions are greater in the sectors that release a higher proportion of methane in total GHG, as the Meat & Dairy sector, the Grains & Crops and the Industry & Services. However for the Energy sector and Carbon Sequestration, the differences between the two measures are small due to low methane emission in these categories.

Table 1 also shows a relevant decrease in terms GWP (GTP) for Deforestation activities, reducing 60.0% (60.1), respectively. Otherwise the sectors linked with the Brazilian urban regions maintained the increase of GHG. For this reason, the Energy and the Industry & Services have increased the emissions in 28.0% (29.4%) and 29.2% (18.2%) for GWP and GTP, respectively. Also in agriculture sector the emissions have increased for the Meat & Dairy and Grains & Crops in 2.2% (3.0%) and 55.2% (72.3%) between 2005 and 2018. As a result of the reduction in the Deforestation and of the increase in the Carbon Sequestration, Brazil has realized a substantial cut in the total GHG emission by 44.4% (53.9%) until 2018, overcoming the increase of GHG emissions from the other sectors.

On average, animal world production is estimated to account for 15% of GHG emissions, 80% of which originate from ruminant animal systems (Persson et al, 2015). But in Brazil, animal production represents 29% of GWP emissions, 94% of which is

related to the production of ruminants in 2018 (SEEG, 2019). This behavior of sectorial emissions reflects in the profile of the Brazilian Economy, which has an important participation of agriculture and the food sector in total GDP and international trade.

Table 1. GWP and GTP Emission from all Sectors (tons) and growth (%) 2005-18 – Brazil

Sectors	2005		2018		% 2005-18	
	GWP (t.)	GTP (t.)	GWP (t.)	GTP (t.)	GWP	GTP
Meat & Dairy	400,022,781	114,435,703	408,675,212	117,924,190	2.2	3.0
Deforestation**	2,068,426,095	1,989,495,796	827,043,560	794,106,885	-60.0	-60.1
Grains & Crops	94,537,522	48,417,779	146,699,271	83,439,144	55.2	72.3
Industry & Services*	115,122,063	78,806,916	148,787,577	93,671,081	29.2	18.9
Energy	331,843,307	315,180,572	424,803,865	407,694,211	28.0	29.4
Carbon Sequestration	-446,394,750	-446,394,750	-529,451,505	-529,451,505	18.6	18.6
Total	2,563,557,019	2,099,942,016	1,426,557,980	967,384,005	-44.4	-53.9

* Industrial processes + solid waste.

** Change in land use + forest waste.

Source: SEEG, 2019.

In terms of environmental policies, Brazil's main efforts have been focused on the recovery of degraded areas and reforestation from 2005 to 2018. The deforestation has decreased substantially the GHG emission in this period due to the recovery of degraded areas in the Amazon, Cerrado, Atlantida and Pantanal biome in the same period (see table 2 and also MCTI, 2014; IPEA, 2019). These results are due to a successful environmental policy that occurred with the implementation of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm, 2004) and the Action Plan for the Prevention and Control of Deforestation and Burnings in the Cerrado (PPCerrado, 2010).

Brazil has also implemented the ABC Plan and RenovaBio as ways to reduce emissions from agriculture and energy use, though with lesser effectiveness on the reduction of gas emissions. The ABC Plan aims to adopt sustainable production technologies with potential to reduce GHG emissions in the agricultural sector (Brazil, 2012). On the other hand, the National Biofuels Policy (RenovaBio) seeks to strengthen the production of biofuels and expand the internal energy supply (IPEA, 2019). Although relevant, these two actions had few effects in reducing GHG gas emissions, according to Tables 1 and 2.

Table 2 presents the Meat & Dairy sector disaggregated for different chain segments (farm and industry). Although the Meat and Dairy industry is responsible for the lower percentage of carbon emissions in the total of Meat & Dairy sector, it has maintained a faster growth in terms of carbon emissions. On the farm level, the milk production are responsible for the second major share of the GHG total emissions, and only this segment has appointed a decrease in terms of emissions, reducing GWP and GTP in 24.0% and 22.1%. This occurred due to the intensification of milk production and the adhesion of these family producers to new technologies that increase productivity, the recovery of degraded areas and the reduction of GHG emissions in production, following the ABC Plan.

Table 2. GWP and GTP Emission from Meat & Dairy Sectors (t.) and variation (%), 2005-18 - Brazil

	2005		2018		% 2005-18	
	GWP	GTP	GWP	GTP	GWP	GTP
Chicken	7,815,078	5,004,364	11,236,822	7,225,561	43.8	44.4
Milk	54,102,309	18,529,030	41,105,908	14,431,737	-24.0	-22.1
Beef	325,425,607	86,358,396	339,650,400	90,593,409	3.8	3.9
Pork	9,649,793	4,111,057	12,178,750	5,030,150	26.2	22.4
Meat-Milk (Total Farm)	*396,992,787*	*114,002,848*	*404,171,880*	*117,280,857*	*1.3*	*2.1*
LET - Chicken	202,925	28,989	385,101	55,014	89.8	89.8
LET - Milk	1,669,276	238,468	2,336,424	333,775	39.9	39.9
LET - Beef	857,541	122,506	1,177,814	168,259	37.3	37.3
LET - Pork	300,252	42,893	603,992	86,285	101,2	101,2
Meat-Milk (Total Industry)	*3,029,994*	*432,856*	*4,503,332*	*643,333*	*48.6*	*48.6*
Total Meat and Dairy	400,022,781	114,435,703	408,675,212	117,924,190	2.2	3.0

Source: SEEG, 2019.

In an opposite trend, the production of beef, chicken and pork emissions continue to grow over the same period. The beef producers are responsible for the major share of GHG emission, though they are responsible for a minor growth in GHG total emission in both indicators (Table 2).

The next step is to present in the main aspects to be considered in the General Equilibrium model, GTAP.

3- Method and data

GTAP is an applied General Equilibrium multiregional model that assumes constant returns to scale and perfect competition in production and consumption activities. The GTAP global economy can be explained by analyzing an arbitrary region and its relationships with other regions, by imposing equilibrium conditions between global agents. In each region there are (j) industries using (i) primary factors and (i) intermediate inputs, both locally produced and imported (Hertel, 1997). The aggregations of regions, sectors and primary factors are shown in Table 3. The initial equilibrium is characterized by the economy in 2011, according to the GTAP 9 database. In the aggregation of regions, countries are assembled following criteria of trade partners and spatial proximity.

Table 3. Regions, sectors and primary factors in the GTAP model

Regions	Sectors	Primary Factors
Africa (AFR)	Grains & Crops (GACO)	Capital
Argentina (ARG)	Cattle production (BECA)	Land
Brazil (BRA)	Chicken and pork production (CIPO)	Natural Resources
China (CHN)	Raw Milk production (RMIL)	Skilled Labor
East Asia (EAS)	Forestry (FORE)	Unskilled Labor
EU-25 (EUR)	Beef - industry (BEEF)	
North America (NAM)	Chicken and pork - industry (CHPO)	
Oceania (OCE)	Dairy-industry (DAIR)	
Rest of the Word (RW)	Industry & Services (INSE)	

Russia (RUS)	Energy (ENER)	
South Asia (SAS)		
Southeast Asia (STA)		
United States (USA)		

Source: GTAP 9.

In this study, the impact of the sector carbon-based taxation (Economic Instruments) upon production, trade and GWP and GTP emissions indicators is assessed. Table 4 presents the alternative scenarios in a summarized form. Overall, the scenarios in the table describe a set of environmental policies that aim to reduce GHG emissions in Brazil. In general, the scenarios described below seek to incorporate two environmental policy instruments: economic instruments and command and control instruments.

Table 4. Descriptions of Alternative Scenarios by different Carbon Taxes (COP21)

Scenarios	Description	Deforestation	Mitigation on agricultural sector in Brazil	Mitigation on other sectors in Brazil
(1) COP21-MEAT	Carbon taxes apply to the Brazilian Meat & Dairy sectors. (Econ. Instr.)	Same level of carbon sequestration of BAE. (Flexible Command and Control Instruments).	YES (20, 40, 60 $/t)	NO
(2) COP21-ENIS	Carbon taxes applied to the Brazilian Energy sector. (Economic Instruments).	Same level of carbon sequestration of BAE. (Flexible Command and Control Instruments).	NO	YES (20, 40, 60 $/t)
(3) COP21-All Sectors	Carbon taxes applied to all sectors in Brazil.	Same level of carbon sequestration of BAE. (Flexible Command and Control Instruments).	YES (20, 40, 60 $/t)	YES (20, 40, 60 $/t)
(4) COP21-MD^{-}	Carbon taxes: lower taxes to Meat & Dairy sector.	Same level of carbon sequestration of BAE. (Flexible Command and Control Instruments).	YES (20, 40 $/t)	YES (40, 60 $/t)

The four scenarios consider only the application of different carbon taxes (Economic Instruments) in the Brazilian sectors, keeping the same level of carbon sequestration from the BAE (Flexible Command and Control Instruments), and considering constant the other agricultural and environmental policies. Scenario 1 reflects the application of carbon taxes upon Meat & Dairy sector and no carbon taxes on the other sectors in Brazil. Scenario 2 considers only carbon taxes upon the Energy

sector and scenario 3 simulate equal carbon taxes on all sectors (20$, 40$ and 60$ per t. of CO2), though no carbon taxes to the forestry sector. Scenario 4 considers the application of carbon taxes to the Meat & Dairy, Grains & Crops lower than to the Energy and Industry & Services sectors, measuring the economic effects on production, trade and GHG emissions (Feijó and Porto Jr, 2009; Gurgel and Paltsev, 2014; Gurgel, Paltsev and Breviglieri, 2019).

From the simulation of these scenarios will be analyzed the impacts on the Meat & Dairy production, the change on trade, flows and GHG emissions (GWP and GTP). Regarding the environmental aspect, two points must be considered to calculate the Brazilian GHG emissions using GWP and GTP indicators (see also Röös et al, 2013): first, the total emission in production is obtained by multiplying the production value for each sector by its corresponding GWP or GTP coefficient. These result shows the total emission for each sector in different alternative scenarios. For instance, the total carbon emission, GWP and GTP, it is the sum of the total carbon emissions in the production (Tourinho, Seroa da Motta and Alves, 2003).

In the present study, the GTAP equivalent shock value which is equivalent to pricing the GHG emissions, it's calculate as the percentage ratio between the value of carbon emissions (tons of carbon emissions multiplied by the price of carbon emissions per ton) by the production value of each sector. As previously mentioned, total emissions are estimated as GWP and GTP. The prices for carbon emissions are $ 20 / t, $ 40 / t and $ 60 / t, as observed in the studies by Tol (2019), Henderson et al (2018) and Lucena et al (2016). Finally, the production value for each sector analyzed was obtained from the GTAP 9 database.

3.1 Closure and Channel Effects

This study discusses the economic and environmental effects of the carbon taxes. Economic theory suggests that raising the price of normal goods and services through the use of a tax reduces its own demand. Pigou (1920) proposed the use of taxes to internalize negative externalities and showed that a direct tax on polluting activity is the most efficient tax instrument for reducing environmental damage.

Similarly the effect of an environmental tax on carbon emissions in productive activities will depend on the implementation approach, the economic structure, the consumer preferences and the other socio-political factors. In these simulations, short-term closing is considered. Also it is applied carbon taxes based on origin emissions or upon production level, which makes possible to identify the different effects on production and trade in different economic sectors.

From producer sectors point of view, Command and Control instruments make possible to reduce or even replace gasoline and diesel by biofuels. The same instruments also make possible to reduce deforestation and/or encourage reforestation in degraded areas. However, these environmental instruments are not so effective in reducing methane emissions in the animal production.

For Fraser (2013), the government revenue increases more in the cases of applied emission taxes to production and to export than in the applied carbon taxes to consumers and to import goods. Within the scope of GTAP, this argument suggests that

countries that export carbon-intensive commodities, such as Brazil, cause three possible types of effects, such as:

(i) *Pigou's well-being*: there is an efficiency gain associated with the decrease in the consumption of the polluting good in relation to the marginal external cost of pollution and the change in the price of the polluting good.

(ii) *Tax interaction*: environmental policies increase the price of polluting products in relation to household leisure and creating market distortions.

(iii) *Revenue feedback*: when environmental tax revenue is recycled through cuts in (other) marginal tax rates, this reduces the distortion caused by pre-existing taxes, improving the level of well-being.

The next section presents the results considering the alternative scenarios defined in this section. Initially, the effects of tariffs and their effects on changes in carbon emissions are shown. Later, the impacts of these carbon tariffs on meat and dairy exports and on Brazil's GDP are assessed.

4- Results

The GTAP model is used to simulate the economic impacts of sector emissions restrictions in a stylized way. For this purpose, the adoption of economic instruments was defined exogenously. The aim is to measure the impact of carbon taxes on the net carbon emissions of the sectors (section 4.1), and on GDP and trade (section 4.2). For achieve this results are also considered two different carbon-equivalence measures, GWP and GTP. The sector "Meat and Dairy" are disaggregated in three groups: Beef, Pork & Chicken and Dairy. This lets possible to analyze in details the different impacts and the sensibility of the results comparing GWP and GTP.

For this reason, the next section presents the results of the simulations for six sector groups (Meat, Pork and Chicken, Grains & Crops, Energy, Forestry and Industry & Services). The effects on macroeconomic aggregates, exports and gross production are presented only for the agricultural sectors.

4.1 Emissions

Initially, the results about the effects of carbon rates on emissions from the Meat & Dairy, Grains & Crops, Energy and Industry & Services sectors are presented at Table 5.

Table 5. Variations (%) in GWP and GTP emissions by sectors in all scenarios

Scenario	Beef		Pork & Chicken		Dairy		Grains & Crops		Energy		Forestry		Ind. & Serv.		Total	
	GWP	GTP	GWP	GTP	GWP	GTP	GWP	GTP	GWP	GTP	GWP	GTP	GWP	GTP	GWP	GTP
1-20	-11.9	-2.7	1.7	1.6	-1.4	-0.3	0.7	0.2	0.6	0.1	-0.1	0.0	0.1	0.0	-2.4	-0.2
1-40	-24.5	-6.0	1.0	0.9	-3.0	-0.9	1.6	0.4	1.3	0.3	-0.2	-0.1	0.2	0.1	-5.0	-0.4
1-60	-37.1	-9.3	0.3	0.1	-4.6	-1.4	2.4	0.6	2.0	0.5	-0.3	-0.1	0.3	0.1	-7.6	-0.6
2-20	0.5	0.5	2.3	2.2	0.0	0.0	0.8	0.8	-6.8	-6.6	0.1	0.1	0.2	0.2	-1.7	-2.5
2-40	1.1	1.1	4.8	4.6	0.1	0.1	1.8	1.7	-14.5	-14.0	0.2	0.2	0.4	0.4	-3.7	-5.2
2-60	1.7	1.7	7.3	7.0	0.1	0.1	2.7	2.6	-22.1	-21.3	0.2	0.2	0.6	0.1	-5.6	-8.0
3-20	-12.0	-3.0	0.9	0.3	-1.5	-0.4	-1.1	-1.1	-7.7	-8.1	0.3	0.3	0.5	0.4	-4.6	-3.2
3-40	-23.7	-5.5	4.1	2.7	-3.0	-0.9	-0.5	-0.6	-14.2	-15.0	0.2	0.4	0.8	0.6	-9.1	-6.1
3-60	-35.3	-8.1	7.1	5.2	-4.5	-1.4	0.1	0.0	-20.6	-21.9	0.2	0.4	1.1	0.8	-13.5	-9.0
4-20/40	-11.2	-2.4	3.9	2.7	-9.2	-0.4	0.2	-0.2	-15.1	-15.5	0.3	0.4	0.7	0.6	-6.7	-6.0
4-20/60	-10.6	-1.9	6.9	4.9	-1.3	-0.4	1.1	1.7	-22.5	-22.9	0.4	0.4	0.8	0.7	-8.4	-8.7
4-40/60	-23.0	-4.9	7.0	5.1	-2.9	-0.9	0.6	0.3	-21.6	-22.4	0.3	0.4	1.0	0.8	-10.9	-8.8

Source: research results.

In Table 5, it is possible to identify how the different strategies of pricing the GHG emissions generate different effects on each sector and on total in Brazil. As expected, the carbon taxes applied to GWP emissions have greater impacts than GTP on the activities that have higher methane emissions.

Even after the same carbon tariff is applied to each of the segments of Meat & Dairy, there is a substitution effect between the production of beef and dairy with the production of poultry and pork. This results in a more intense reduction in activities related to cattle and dairy farming (Pigou's well-being effect), and increases the emissions from other meats, such as chicken and pork. As a result of these changes, there is a net reduction in GHG emissions.

As an example of this, in Scenario 1 the carbon tariffs are the same for all segments of Meat and Dairy (Beef, Pork & Chicken and Dairy), but the observed effects have different intensities according to the indicator (GWP or GTP) and their link with the other economic sectors in Brazil. This occurs because in the structure of the GTAP, the sectors affected directly by the shock are those that present the greatest variation. However, the way these sectors are linked with the others in the economic system trigger indirect effects. For all alternatives in this scenario, it is possible to observe a more significant reduction in the production of beef and milk, than in the chicken & pork and the other sectors.

For these sectors, the production of Beef (Dairy) decreased between 11.9% and 37.1% (1.4% and 4.6%) considering GWP and between 2.7% and 9.3% (0.3% and 1.4%) for GTP. The production of Pork and Chicken, even with carbon taxes, has increased due to a change in relative prices in the Meat & Dairy market. Due to the growth of this sector, the model shows an increase in the production of Grains & Crops and in the Energy sector, resulting in a higher emissions for these last two groups.

For the Brazilian economy as a whole in scenario 1, there is a reduction in carbon emissions considering GWP, from 2.4% to 7.6%, while for GTP, from 0.2 to 0.6%. Reductions in GHG emissions in terms of GTP are less sensitive to changes in tariffs when compared to GWP. As discussed earlier, this is mainly due to Brazilian GHG standards with a higher share of Methane.

In the second scenario, the emission pricing policy was simulated only for the energy sector. In this case, two important issues related to the GTAP model must be considered in this analysis. First, there is a proportional relationship between sector emissions and the average energy use for each industry. Second, the production of the energy sector assumes a CES function of energy and added value (Narayanan & Walmsley, 2008). Due to this proportional relationship and the reduced participation of methane in the total emissions of the energy sector, the results are very similar for both GHG measures.

As mentioned before, the changes in GHG in terms of GWP and GTP are similar due to the imposition of equal tariffs only on the Energy sector in Brazil. As a result, there is a reduction in emissions of GWP between 6.8% and 22.1% and of GTP between 6.6% and 21.3%. In the Brazilian economy as a whole, the scenarios 2 show a reduction in GWP between 1.7% and 5.6% and in GTP between 2.5% and 8.0%. For the Meat & Dairy sector, Chicken & Pork emissions are the ones that present a more significant increase in GHG emissions for both indicators.

In scenario 3 are simulated carbon taxes on emissions for all sectors of the economy, and considering the same amount per ton of GHG. The carbon taxes in this scenario mainly discourages the emissions from Energy, and Beef & Dairy sectors for both indicators, GWP and GTP. In an opposite way, even with the equivalent carbon tax, there is an incentive to increase GHG emissions from Pork & Chickens, due to the substitution effect between Pork & Chickens and Beef production.

The emissions from the Energy sector reduce between 7.7% and 20.6% to GWP, and between 8.1% and 21.9% to GTP. For the Beef sector occurs a reduction in GWP emissions between 12.0% and 35.3% and a decreased in GTP between 3.0 and 8.1%. Although with a smaller decrease, the Dairy sector GWP emission falls between 1.5% and 3.5%, and the GTP emission between 0.4% and 1.4%.

The third scenario also shows the difference between the indicators used (GWP and GTP) regarding the sensitivity of different measures in the process of pricing carbon emissions for the different segments of the economy. In most of the cases, the variations measured in GWP are greater than the variations in terms of GTP. As a result, the carbon tax effects on GHG emissions using GWP has a more intense impact on activities related to Beef and Dairy, mainly because these activities are higher emitters of methane.

In the case of GHG emissions measured in GWP, the simulations from Scenario 3 show a reduction between 4.6% and 13.5% for the entire Brazilian economy, while for GTP the variations are between 3.2% and 9.0%. When compared the results between the two indicators, it is possible to observe that there is a smaller variations in emissions in favor of GTP for most of the sectors. For both indicators, the sectors most impacted by the application of the carbon tariff are the Energy and the Meat & Dairy sectors. In the case of the Energy sector, there are no important differences between GWP and GTP. However, in the case of the Meat & Dairy sector, the variations are smaller in the case of GTP. Considering equal applied carbon taxes seems be more appropriate GTP than GWP, because it does not penalize with greater intensity a relevant sector of the Brazilian economy.

The fourth scenario simulates different tariffs between sectors of the Brazilian economy. The central idea is to penalize less the agricultural activity that has notably lower profitability and greater risk than the other economic activities. For this, three forms of collection are defined: in the first option of Scenario 4 (4-20/40), $20/t are applied to carbon emissions for Meat & Dairy and Grains & Crops sector and, $40/ t for Energy and Industry & Services sectors. Similarly, the two other alternatives (4-20/40) and (4-40/60) consider lower carbon taxes to the agricultural sectors and, higher taxes to Energy and Industry & Services sectors.

The different carbon taxes cause unlike effects to the sectors and to the economy as a whole when compared with the previous scenarios. Specifically for the Meat and Dairy sectors, the decrease in GHG emissions are smaller when compared with scenarios 1 and 3 for the same carbon taxes. As a result of the substitution effects, the Pork and Chicken increases the production and emission of GHG, assuming the same carbon tax level and comparing with the alternative scenarios.

In the fourth scenario, Pork & Chicken emissions has a greater variations in GHG emissions than all previous scenarios, considering the same carbon tax applied to this sector. As for Dairy production activities, there was a more significant reduction than in

the previous scenarios. In the Energy sector, the changes were more negative and intense than in the previous scenarios, for the same applied carbon tax. In general, the results for the Brazilian economy indicate that GHG emissions would reduce between 6.7% and 10.9% for GWP and 6.0% and 8.8% for GTP.

In the Scenarios 1 and 2 only tariffs are applied for the Meat and Milk sector and for the Energy sector, respectively. In the case of Scenario 1, the tariffs on emissions are applied only to the Meat & Dairy sector, this pricing simulation results in lower emissions, but also an intense reduction in the production of Beef and Dairy. The Scenarios 2 has potential to create a greater inequalities between the rural and the urban areas in Brazil. On the other hand, in Scenario 2 where tariffs are applied only to the Energy sector, there is an increase in the production of Meat & Dairy and in its GHG emissions, which is also undesirable.

The Scenarios 3 seem more appropriate when we use GTP as an indicator of GHG emissions, especially because this indicator has a lower weight for methane emissions, which are characteristic in the Beef and Dairy production. The use of GTP, unlike GWP, allows a less marked reduction in production and in emissions on the Beef and Dairy sector, which allows applied an equal carbon tax for all sectors. Scenarios 4 seem to be more appropriate when are used GWP as an indicator for GHG emissions. In this case, the lower carbon tax for the agricultural sectors than for the other sectors allows to compensate the negative impacts on the production and emissions of these segments caused by the greater weight of the methane emissions existing in the GWP.

In the next section, the different scenarios are analyzed, evaluating the effects of carbon taxes on Meat & Dairy exportation and on the Brazilian GDP.

4.2 Economic impacts

This section describes the results from the simulations in terms of changes in Brazilian exports and GDP. Table 6 presents results for three important sectors of Brazilian international trade (Beef, Pork & Chicken and Dairy). The variations in terms of exportation and GDP to the Brazilian economy are presented at the table 6. The last two columns indicate the results for GDP variation considering GWP and GTP. For all scenarios, the impacts of these two sorts of carbon equivalence measure are presented.

In table 6, the first scenario simulates carbon taxes only on the Meat & Dairy sectors. The effects on exports in Scenario 1 are concentrated mainly in these segments. As a result, the Beef sector has the most negative impact on exports, followed by the Dairy sector. The Beef exports when considered GWP reduce from 73.9% to 230.2% and, for GTP they reduce from 16.5% to 57.9%. In the case of GWP, Brazil changes from Beef Exporter to Importer in Scenario 1-60.

For the Dairy sector, exports also decrease between 16.8% and 57.8% for GWP and between 3.6% and 18.1% for GTP in Scenario 1. However, Brazil is not a traditional Dairy exporter, like Beef exports, which Brazil is the largest exporter in the international market (Hubbard, Alvim and Garrod, 2017). As a result of this pattern from the BAU scenario, after applying carbon taxes in Scenario 1 it is possible to observe the greatest losses on the Beef sector in international market.

The total Brazilian exportations increase from 1.5% to 4.4% for GWP and, from 0.4% to 1.2%, considering GTP. Scenario 1 has the smallest variations for GDP, from -0.3% to -0.8% for GWP and, from -0.1% to -0.3% for GTP. However, as previously mentioned, this scenario presents the negative aspect of pricing only the Meat & Dairy segment, changing the relative prices in the Brazilian economy and reducing the production, the exportation and the emissions for just one sector.

Table 6. Variations (%) on Exports and GDP in GWP and GTP in all scenarios

Scenario	Exports								GDP	
	Beef		Pork & Chicken		Dairy		Total			
	GWP	GTP	GWP	GTP	GWP	GTP	GWP	GTP	GWP	GTP
1-20	-73.9	-16.5	3.9	3.7	-16.8	-3.6	1.5	0.4	-0.3	-0.1
1-40	-152.1	-37.1	2.6	2.0	-37.3	-10.9	3.0	0.8	-0.5	-0.1
1-60	-230.2	-57.9	1.3	0.5	-57.8	-18.1	4.4	1.2	-0.8	-0.2
2-20	5.1	4.9	5.5	5.4	5.5	5.3	2.4	2.3	-0.9	-0.8
2-40	10.4	10.4	11.3	11.3	11.1	11.1	4.9	4.9	-1.8	-1.8
2-60	16.5	16.7	17.9	18.2	17.6	17.9	7.7	7.8	-2.8	-2.8
3-20	-74.9	-15.9	2.3	0.6	-18.2	-5.3	-1.0	-2.4	-0.3	0.0
3-40	-144.2	-32.2	10.3	6.7	-29.6	-6.0	4.1	1.1	-1.8	-1.2
3-60	-213.8	-45.8	18.1	12.9	-41.2	-5.7	9.1	4.6	-3.3	-2.3
4-20/40	-68.5	-13.3	9.7	6.6	-10.9	-0.4	2.4	0.2	-1.4	-0.9
4-20/60	-61.5	-8.5	16.9	12.1	-3.9	5.0	5.6	3.0	-2.5	-1.9
4-40/60	-137.6	-26.75	17.4	12.7	-22.5	-0.11	7.3	3.7	-2.9	-2.1

Source: research results.

The results for the second scenario consider the emission charging on the Energy sector. In general, this scenario has an increase in Brazilian exportation on the Meat & Dairy sector as well as on total. In this scenario, there is a significant reduction in GDP between 0.8% and 2.8% for both, GWP and GTP. On the one hand, this scenario promotes a reduction in emissions from energy generation, on the other hand, it rises production, exports and emissions from as Meat and Dairy sectors. This last aspect has a determining role for the beef cattle production on Brazilian deforestation. The results reinforce the idea that the greater production of beef is associated with greater deforestation and bigger emissions from the forestry sector.

In Scenarios 3, equal tariffs on carbon emissions are applied for all sectors. In this scenario are also observed the biggest reductions in Beef and Dairy exportation and the biggest increases in Pork & Chicken exportation for both indicators, GWP and GTP. The Beef exportation decreases between 74.9% and 213.8% for GWP and, between 15.9% and 45.8% for GTP. Although with a less intensity, Dairy exportation decreased between 18.2% and 41.2% for GWP and between 5.3% and 6.0% for GTP. As can be seen, the negative effects on Beef and Dairy exportation are relatively more intense than those observed in other scenarios. On the other hand, Pork & Chicken exportations have increased between 2.3% and 18.1% for GWP and, between 0.6% and 12.9% for GTP. Again, these different trends among Beef and the Pork & Chicken exportation are due to the substitution effect on meat production.

For the Brazilian economy, this is one of the scenarios that foresees the greatest reductions in GDP, which can be reduced by up to 3.3% for GWP and up to 2.3% for GTP. Despite a significant drop in Beef and Dairy exportation and a predicted drop in GDP for this scenario, total Brazilian exportation in Scenario 3 have growth up to 9.1% for GWP and up to 4.6% for the GTP. This scenario indicates that an equal carbon tax on the emissions from all segments may negatively affect strategic sectors in terms of exportation, such as Beef and Dairy products.

In the fourth scenario, the pricing for GHG emissions is simulated by applying lower tariffs for the agricultural sector than for the Energy and Industry & Services sectors. This alternative scenario is proposed to minimize the effect of carbon taxes on Meat and Milk segments, especially when is used the GWP as a reference for total emissions.

The Beef exportations decrease between 68.5% and 137.6% for GWP in Scenario 4, although they have decreased less than in Scenarios 1 and 3. Likewise, Dairy exportation decreases between 3.9 and 22.5%, seeing only GWP emissions. Similar to Scenario 3, the exportation of Pork & Chicken sector and, also the total exportation have increased in Scenario 4, though with a smaller variation in this scenario. As a result of this dissimilar charge between sectors, GDP in this scenario has a smaller decrease than in Scenario 3, dropping from 1.4% to 2.9% in the fourth scenario for the GWP.

Considering the results from tables 5 and 6, it is possible to observe the disadvantages of only charging the emissions from one sector of the economy. In Scenario 1 and 2, despite providing reductions in carbon emissions, it increases the differences in income generation between the analyzed sectors of the Brazilian economy, as it charges for emissions from only one segment.

From tables 5 and 6 it is also possible to observe that Scenario 3 may be the most appropriate when we use the GTP measure to estimate emissions. In this case, the reduction in GDP are not as intense as when are used GWP, though the exportation of the Beef and Dairy are also expected to drop. As discussed earlier, the Scenario 4 is a combination of different carbon taxes by sectors, seeking to minimize the effects of GWP on the most intensive activities in methane emissions. Considering only the GWP alternative, the fourth scenario seems to be the most adequate in terms of cost distribution among the various economic sectors in Brazil. Although it presents a significant reduction in Beef and Dairy exportation and in the Brazilian GDP, it apparently redistributes this cost of carbon emissions among the different sectors in a more balanced way than Scenario 3 for GWP.

In the next section are presented the main conclusions of this research and the contributions, which are related to a reduction on carbon emissions, applying carbon taxes to GHG emissions.

5- Final remarks

This article analyzes the effects of applying carbon taxes on strategic sectors of the Brazilian economy, emphasizing the changes in the Meat and Dairy exportation and in the GHG emissions, using GWP and GTP. To identify the effects of this charge on carbon emissions, it was adopted a strategy to compare different environmental policies and these effects on production and trade, evaluating the degree of effectiveness in reducing emissions.

In the context of climate policies, the article contributes to widening the discussion and presenting different strategies to reduce carbon emissions in Brazil. Although, until 2018 Brazil has already achieved the goals in the Paris Agreement, hardly with the consistent increase in meat exports, this emission pattern will be maintained.

The increase in production and exportation of meat, particularly beef in Brazil, has increased pressure on forest areas to be converted into pasture. In this sense, the present study presents a broad set of economic instruments, complementary to the Command and Control instruments, which has the potential to allow a sustainable reduction of carbon emissions in the medium and long term.

Brazil as a signatory to the Paris Agreement since 2015, uses the GWP as a GHG measure for sector emissions, defining its environmental policies and pursuing the targets for reducing GHG emissions set out in the Paris Agreement. However, as discussed in the results, the GWP penalizes more the sectors that emit a higher proportion of methane than others, which associated with a policy of charging emissions, severely harms the production and exports of beef.

The article also shows that the use of GTP measures for carbon taxes can be an alternative strategy to minimize the effects of local environmental policies for charging emissions, reducing the negative impact on Beef production and on exportation. Another alternative also analyzed, although less effective from the point of view of the meat sector, it is to keep charging for GHG emissions using GWP, although with lower tariffs for the agricultural sector.

The adoption of more strict measures to reduce GHG emissions has the potential to place Brazil in a prominent position in the global scenario as a proactive country in the global warming mitigation. However, as discussed early in this study, it is important that Brazil applies environmental policy instruments for all sectors of the economy, without making unfeasible strategic sectors in Brazil, such as beef cattle.

Finally, the appropriate debate on the use of diverse instruments of environmental policies may to allow Brazil to reduce its GHG emissions and minimize jointly the negative aspects upon production, exports and economic growth. For this reason, it is important cooperative action between policies makers from different areas as economic, trade, agricultural and social.

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