The economic impact of international agreements for GHG mitigation

Abstract

This paper analyses which countries need to reduce greenhouse gas (GHG) emissions as part of the overall goal of reducing emissions to the ideal level, as defined by the Intergovernmental Panel on Climate Change - IPCC, and which countries will suffer the largest reduction in gross production value (GPV). To identify these countries, the study uses the input-output (IO) and linear programming (LP) methodologies in multi-regional matrices, modelling scenarios of global GHG emission reduction to simulate different international agreements. The database comes from the WIOD headquarters for the year 2009. The results show the largest reduction in GHG and GPV in India and China. In a more ambitious scenario of reduction, the United States increases its responsibility and Russia becomes the country with the largest emissions reduction. The economic impact is largest in countries that have the most intense GHG emissions and in the countries that make up the BRIC. This study allows us to explore the LP-IO methodology, demonstrating the importance of analysing the effect of international agreements and the use of cleaner productive structures.

Keywords: GHG Emissions; International Agreements; Multi-Regional Input-Output; Linear Programming.

1. INTRODUCTION

The process of global climate change is considered a matter of great significance in the 21st century and is one of the most serious externalities due to the severity of the damage it can bring. Among the causes of the phenomenon is the increase in concentrations of greenhouse gases (GHG) in the atmosphere, mainly as a result of economic activities, such as the burning of fossil fuels and changes in land use (IPCC, 2013).

Since the 1980s, there have been international movements that seek to understand and advance the debate on emissions, with effective participation of researchers by the publication of reports to analyse the causes and consequences of the phenomenon. In fact, a set of international agreements has been established for the submission of pollution reduction proposals and targets.

In 2015, the Paris Agreement proposed to keep the global average temperature rise below 2 °C above pre-industrial levels and to seek efforts to limit the temperature rise to 1.5 °C above pre-industrial levels (PARIS AGREEMENT, 2015).

For the temperature rise to stabilize below 2 °C, the Intergovernmental Panel on Climate Change (IPCC) emphasized the need to limit the concentration of CO2eq (equivalent carbon dioxide) in the atmosphere by up to 450 parts per million). To achieve this goal, the global emission of GHG during the 21st century should not exceed, on average, approximately 18 Gt CO2eq/year (billions of tons of GHG expressed in CO2eq per year) (TEAM, PACHAURI & REISINGER, 2007).

According to data from the Word Input-Output Database (WIOD), a project funded by the European Commission and that provides data for 35 sectors from 40 countries and the rest of the world, the global CO2eq emission in 2009[1] was 35.8 Gt CO2eq (WIOD, 2018), virtually twice the volume stipulated by the IPCC.

Thus, the need to reduce overall emissions is significant. Countries need to set ambitious GHG mitigation targets and structure their economies for low pollution production. However, how much do countries need to reduce their emissions to achieve an ideal global emission volume? And what is the impact of this reduction on the economy?

According to WIOD data, in 2009 China emitted the most GHG, followed by the United States and India. Other emerging countries, such as Russia and Brazil, and international powers, such as Japan and Germany, were also among the largest emitters (WIOD, 2018). Therefore, would the reduction of emissions from these countries be enough to reduce global emissions to an ideal level?

GHG mitigation is related to the reduction of the gross production value (GPV) of the country (HRISTU-VARSAKELIS et al., 2009; SAN CRISTÓBAL, 2010; PASCUAL-GONZÁLEZ et al., 2016). Therefore, would the efforts of these countries have an impact on other countries?

In addition, countries have trade relations with several other countries, importing and exporting, in addition to merchandise, GHG emissions (SUH & HUPPES, 2001; WIEBE et al., 2012; ARTO & DIETZENBACHER, 2014; VALE, PEROBELLI & CHIMELI, 2017). Therefore, will the economic impact caused by the mitigation of GHG in one country have an effect on its trading partners?

One way to answer these questions is to apply the linear programming (LP) methodology in a Multi-Regional Input-Output matrix (MRIO) weighted with GHG

[1] Data on GHG emissions from WIOD are available for the years 1995 to 2009. These data were chosen because of the availability of emission values for the economic sectors and countries that represent approximately 78% of global emissions in 2009 In addition, standardization of the data allowed the development of the model proposed in the research.

emissions (expressed in CO_2eq emissions). The MRIO matrix of GHG emissions quantifies the CO_2eq emitted by the sectors of each country and its relation with the other sectors and countries. The LP allows the imposition of restrictions on the MRIO matrix, making it possible to simulate a scenario of global emission reduction targets.

The LP and IO model for GHG emission restriction analysis is found in studies that use an inter-sectoral matrix, where emissions restrictions are carried out in a specific country and the economic impact on the sectors that make up the economy is analysed (HRISTU-VARSAKELIS *et al.*, 2009; 2010; 2012; SAN CRISTÓBAL, 2010; DE SOUZA, RIBEIRO E PEROBELLI, 2016). On the other hand, other studies use the LP and OP model in MRIO matrices, aiming to minimize GHG emissions and maximize gross production value in a global context while observing the countries' responses to the constraints (PASCUAL-GONZÁLEZ *et al.*, 2016).

However, unlike these previous studies, the present research has the objective of restricting the global emission to the desired level to control the increase in temperature and analysing which countries need to reduce their emissions and the economic impact that would be caused by these restrictions. In this way, three scenarios are simulated based on the ideal level of emissions (annual average).

Thus, in addition to this introductory chapter, this work is divided into three other parts. The second part describes the LP and IO methodology used in the research. The database is then displayed. The results and discussions are then presented. Finally, the last part closes the paper presents the conclusions and final considerations.

2. LINEAR PROGRAMMING AND INPUT-OUTPUT

Mathematically, the IO model is composed of a system of linear equations where the production of each sector *i = (1, ..., n)* is the result of the sum of a set of inputs from the other sectors that make up the economy, thus generating a certain quantity of output (DE SOUZA, RIBEIRO e PEROBELLI, 2016).

$$X = (I - A)^{-1} \cdot Y \rightarrow X = B \cdot Y \quad (1)$$

where the matrix B^* is the inverse of Leontief with dimension $n \times n$; X is a vector $n \times 1$ indicating the production of each sector; A is the matrix of technical coefficients with dimension $n \times n$; and Y is a vector $n \times 1$ that indicates final demand. In the Multi-Regional

Input-Output Model (MRIO), the total production of each sector for each region, i.e., the gross value of sectoral production, assumes, as well as the final demand, the shape of a column vector of $n \times p$ elements (MILLER & BLAIR, 2009).

The modelling of GHG emissions with input-output matrices is based on the methodology presented in the study by Wiebe et al. (2012) and is used to measure the quantity, origin and destination of emissions. Based on the concept that CO_2eq emissions from an industry are equivalent to the amount of GHG emissions the industry issues to enable its production, the methodology is based on the emission intensity coefficients of CO_2eq (*c's*).

The *c* corresponds to the quantity of CO_2eq embedded in a product unit of each sector and is calculated as the ratio between the emission of CO_2eq and the gross production value (GPV) of sector *i*. In the case of the MRIO model, *c* is calculated for each sector *i* in country *p* and is expressed as:

$$c_i^p = \frac{Em_i^p}{VBP_i^p} \qquad (2)$$

Thus, each sector of each country presents a *c*. We can formulate a matrix $\hat{E}$ where the diagonal is composed of the values of *c* with the other elements equal to zero.

$$\hat{C} = \begin{bmatrix} c_1^1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & c_i^p \end{bmatrix} \qquad (3)$$

The matrix Ĉ is used in the LP model to formulate the environmental constraint. In the present work, the MRIO matrix is used, which is composed of 35 sectors and 40 countries as well as a region that represents the "Rest of the World".

The LP and IO methodologies are based on works developed by Hristu-Varsakelis et al. (2009, 2010, 2012), San Cristóbal (2010), De Souza, Ribeiro and Perobelli (2016) and Pascual-González et al. (2016). LP-IO optimization models that focus on issues of emission restrictions on pollutant gases concentrate on two problems: (i) maximizing the total gross production value (GPV_T) and (ii) minimizing environmental impacts, i.e., minimizing total GHG emissions (Em_T). In the present research, model (i) is used to maximize the GPV, where the objective function is to maximize the sum of the values of *x*, subject to economic constraints, to meet the final demand values and environmental constraints across countries. The problem is represented as:

$$Max\ \mathrm{VBP}_T = \tau^T \cdot X \qquad (4)$$

$s.t.$:

$$(I - A)X \leq Y \tag{5}$$

$$\hat{C}X \leq T \tag{6}$$

$$X \geq 0 \tag{7}$$

where T is a vector $n \times 1$ of the GHG emission restriction vector and t_j is the sector emissions target j. This target can be defined in various ways for each sector j, or it can be defined as a reduction target for the overall emissions of the country (in the latter case, the environmental restrictions may be reduced to $\sum_{j=1}^{n} c_j x_j \leq \sum_{j=1}^{n} t_j$.

The first restriction concerns final demand, imposing the constraint that the value of final sectoral production should not exceed final demand. The restriction is defined as "less or equal" because in the model there is a GHG emission limit per sector, and as a consequence, a reduction in the supply of goods. Thus, there is no minimum demand to be met, allowing for freedom in the variation of GPV and preventing one sector from surpassing another, preventing a sector from increasing its production beyond its final demand due to the decrease in production in other sectors due to the restriction of emissions.

The second restriction refers to GHG emission limits by sector, by country or globally. As discussed in the introduction on the ideal annual average of CO_2eq emissions to achieve the goal of keeping the global temperature rise below 2 °C, the emission restriction is based on the required amount of global emission reduction for the amount of 18 Gt CO_2eq. As in 2009, according to WIOD data, the global emission was 35.6 Gt CO_2eq, and so the following scenarios are established:

(i) Pessimistic: reduction of 10% in global emissions;

(ii) Moderate: reduction of 30% in global emissions;

(iii) Optimistic: reduction of 50% in global emissions.

Simulating three different global emission reduction scenarios allowed us to progressively analyse the behaviour of countries in the face of GHG mitigation. The optimistic scenario for the ideal amount of emissions is defined as 50% of that issued in 2009, resulting in approximately the volume of emissions proposed (as an annual average) by the IPCC. The third constraint relates to a non-negative, so that the GPV cannot take non-negative values in any of the sectors. As defined in Chapter 4, this is one of the key constraints of a linear programming model. In this way, the parameters and constraints of the IP-PL model are carried out through simulations of three different scenarios and presented below as the main results and analysis.

Among the assumptions used in the LP-IO model of this research, there is no limit on the amount by which each country can reduce its emissions. In this way, it is possible to analyse which countries are subject to the greatest reductions in their emissions for a given global goal.

3. DATA BASE

The input-output matrix used in the research was collected from the World Input-Output Database (WIOD)[2]. This database was constructed from official national accounts information and international trade statistics and comprises a set of annual entry-and-exit tables for 40 countries plus the Rest of the World for the period 1995 to 2014, comprising a total of 35 sectors. In addition, this database provides environmental information, such as land and water use, energy use and greenhouse gas emissions, from various pollutants (DIETZENBACHER *et al.*, 2013; TIMMER, 2012). The data related to the emissions of polluting gases, unlike the input-output matrices, are available for the period from 1995 to 2009. Therefore, the input-output data are used for the last available year, namely, 2009.

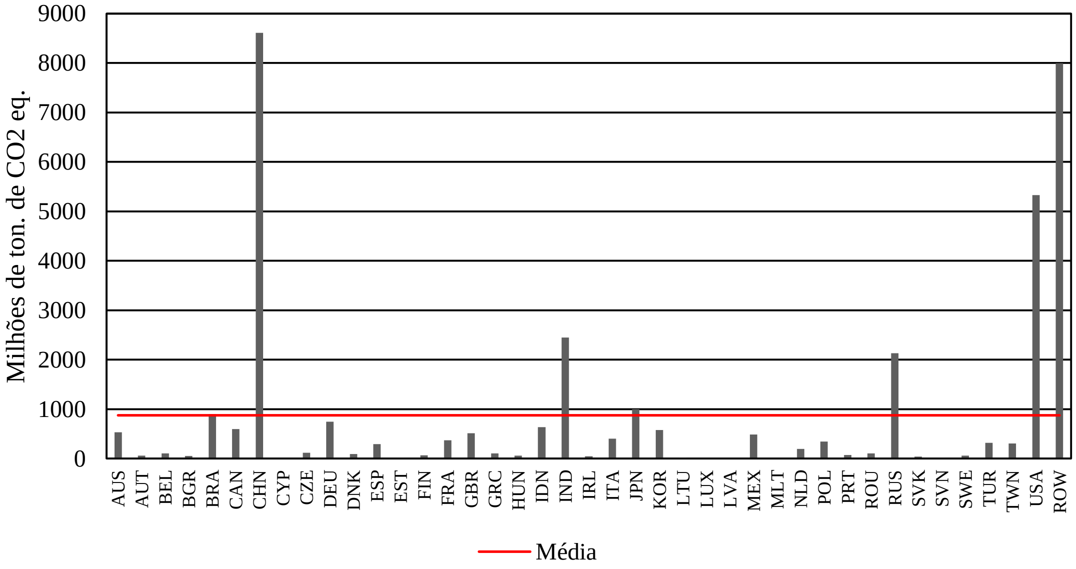
Regarding the GHG data, WIOD only provides information for the emissions of CO_2, CH_4 and N_2O due to missing data related to SF_6, $CFCs$ and $HFCs$. However, Genty *et al.* (2012) state that the last three gases generate a weak impact on global warming, thus this allows research to proceed using only the first three gases. As discussed in Chapter 2, the gases are converted to GWP from specific factors for each gas and after the sum of the conversions, CO_2eq. Based on the Report 5 (AR5) of the IPCC (2014), the conversion factors for the gases are: 1 for CO_2, 28 for CH_4 and 265 forN_2O. In this way, carbon dioxide equivalent is:

$$CO_2eq = 1 \cdot CO_2 + 28 \cdot CH_4 + 265 \cdot N_2O \qquad (8)$$

Finally, the data collected from the emissions of the 35 sectors for the 40 countries plus the ROW are converted and summed, resulting in CO_2eq. Figure 1 shows CO_2eq emissions for the 40 countries plus the "Rest of the World" (ROW) countries that make up the WIOD database.

[2] For a more detailed description of the WIOD database, see Dietzenbacher et al. (2013) and Timmer et al. (2015).

Figure 1. CO_2eq emissions for the 40 most "Rest of the World" in 2009



The red line represents the average emissions of countries, approximately 873.27 million tons of CO_2eq. Among the countries with above-average emissions are China (CHN), the United States (USA), India (IND), Russia (RUS), Japan (JPN) and Brazil (BRA). Germany (DEU) is the European country with the highest volume of emissions, and that volume is close to the average value.

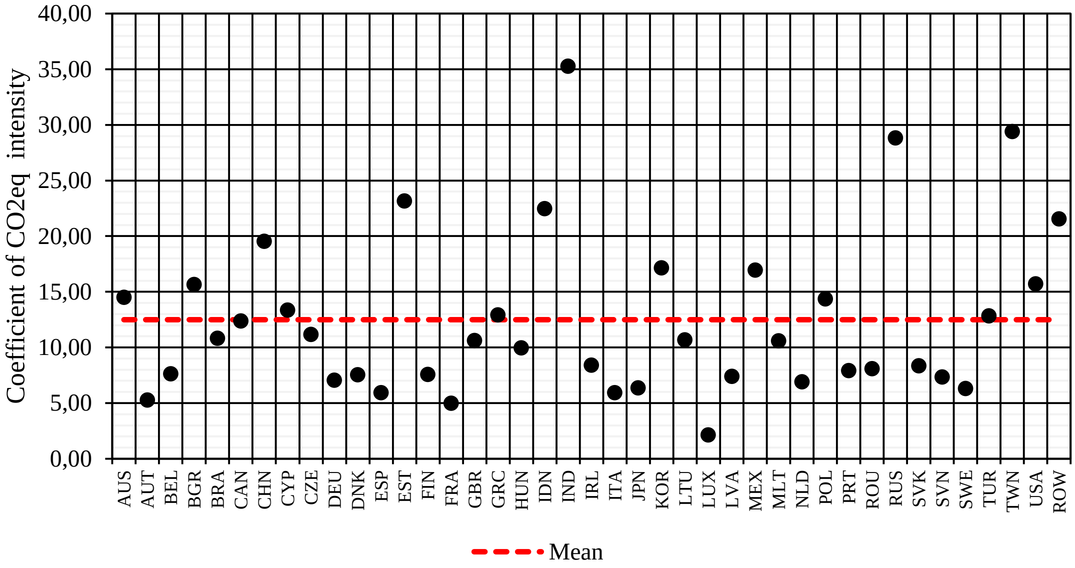
4. RESULTS

4.1 Coefficient of CO_2eq emission intensity

The coefficients of CO_2eq emission intensity (*c*) represent the amount of CO_2eq emitted in relation to the VBP for each sector of the country. With these coefficients, it is possible to analyse the intensity of pollution of each country and each sector, while identifying the main polluting agents.

Figure 1 shows the emission intensity coefficients for the 40 countries plus the "Rest of the World" (ROW) that comprise the WIOD MRIO matrix. Highlighted in red is the average of the coefficients. India (IND), the country that was the largest emitter of CO_2eq in 2009, has the highest coefficient (35.28). That is, India is the country with the highest emission intensity in its economic production. Next is Taiwan (TWN), with a coefficient of 29.41. The country did not show a high volume of emissions in 2009; however, the high value of the coefficient shows the intensity of the pollution of Taiwan.

Figure 1. Coefficient of CO_2eq emissions intensity in 2009



Above the mean, there are still countries among the largest GHG emitters, such as Russia (RUS), China (CHN) and the United States (USA). The latter, even with the highest values of VBP, still has a high coefficient, denoting the high intensity of emissions. In addition to these countries, as in Taiwan (TWN), there are countries with low but highly intensive emissions, such as Estonia (EST), Indonesia (IDN), South Korea (KOR), Mexico (MEX), Bulgaria (BGR) and Poland (POL).

Japan (JPN), the country with the highest GHG emissions in 2009, has a low coefficient value (6.37), which is below the average (12.48). This result shows the low intensity of emissions of the Japanese economy compared to other world powers.

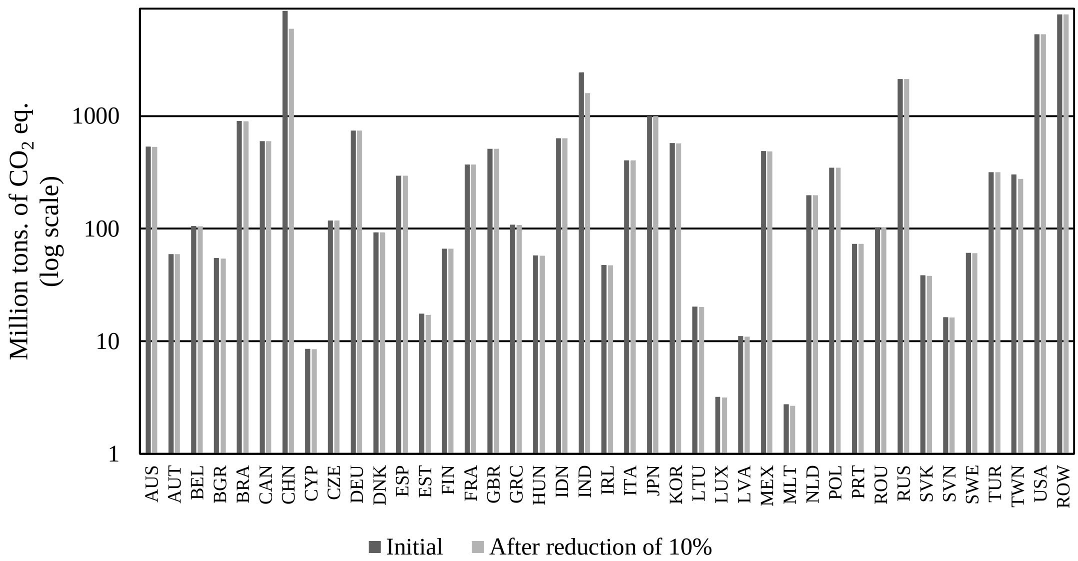
The majority of the European countries are below average, especially the major powers, such as Germany (DEU), the United Kingdom (GBR) and France (FRA). The lowest coefficient, 2.17, is Luxembourg (LUX), a country with low GHG emissions and gross production value.

4.2 Economic impact of reducing GHG emissions

The first scenario simulates the reduction of 10% in the global emission of GHG. To achieve this goal, two countries have the largest reductions in their emission levels: India (IND), with a reduction of 34.82%, China (CHN), with a reduction of 30.87%. Taiwan (TWN) has the third largest reduction in emissions, namely, 9.09%. Given these reductions of the emissions of the three countries, the other countries presented need reductions of less than 5% in order for the overall reduction target to be met.

Therefore, countries that have emitted large amounts of CO2eq in 2009, such as the United States (USA), Russia (RUS) and Germany (DEU), need to reduce their emissions by only 0.04%, 0.25% and 0.1%, respectively, so that the goal is achieved. The emissions variation of all countries can be seen in Figure 3, which represents the initial emissions in 2009 and, after the simulation, represents the 10% reduction in global emissions.

Figure 3. Change in GHG emissions after the imposition of a 10% reduction target in global emissions



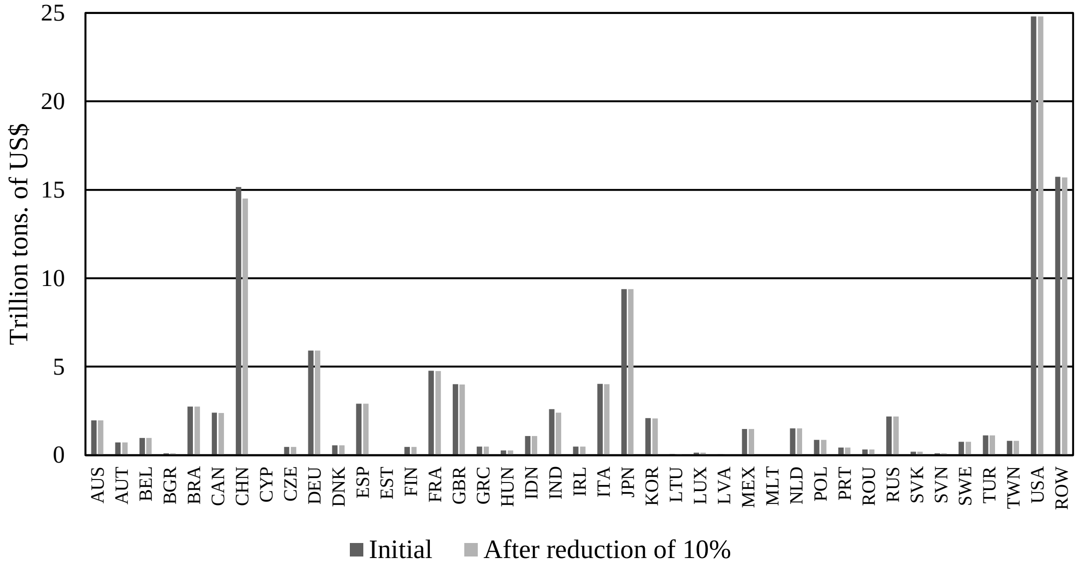
Brazil is among the countries with a low reduction in emissions, with a decrease of 0.12%. Among the European countries, the largest reductions are observed in Malta (MLT), Estonia (EST) and Luxembourg (LUX), with reductions of 3.20%, 2.46% and 1.26%, respectively. The reduction in the magnitude of some European countries is associated with the emission intensity coefficients, where CO2eq/VBP emissions are high, that is, there is a high relative volume of emissions in the country's economic production.

Another indicator analysed after the application of the 10% global emissions restriction scenario is the variation of the VBP, which would be necessary if the country could meet the global target[3]. As shown in Figure 3, India (IND) and China (CHN) show the largest decreases in VBP, 9.68% and 4.62%, respectively. Taiwan (TWN), which showed a relatively lower reduction than its Asian neighbours, with a decrease of 1.08%,

[3] One of the limitations of the PL-IP model is its comparative static and linear relationship between variables, so it presupposes the technology used in the constant economy for the given year. Thus, the only way for a sector, and consequently a country, to reduce its emission is to reduce its VBP and not, for example, by the use of technologies that emit less GHG.

is also among the countries that suffered the greatest reduction in their VBP. The European countries with the largest emission reductions also suffered greater economic impacts, with the GPV of Malta (MLT) and Estonia (EST) decreasing by 2.2% and 1.53%, respectively.

Figure 4. Change in VBP after imposition of a reduction target of 10% in global emissions

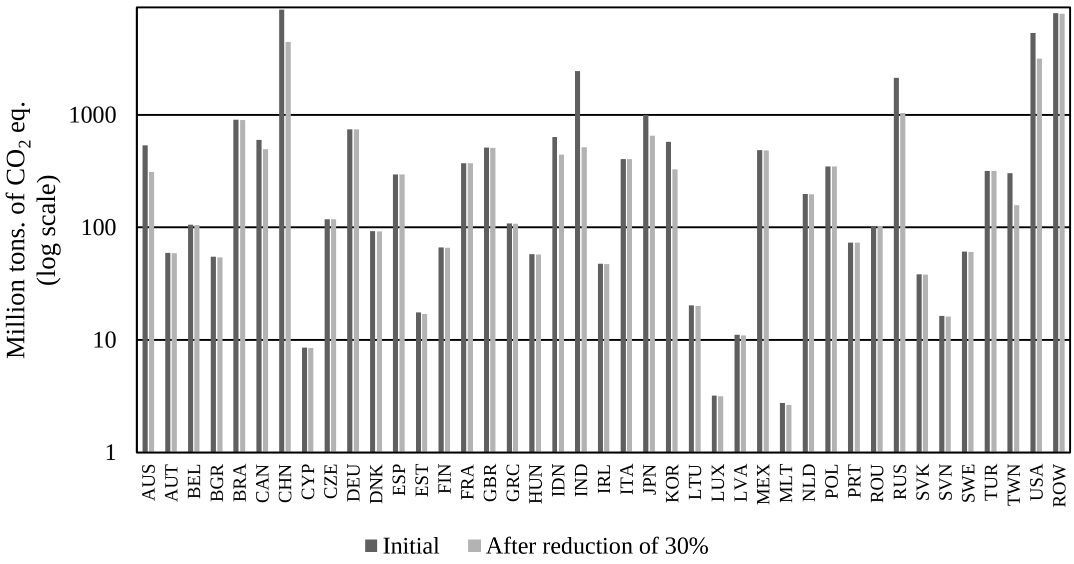


For Brazil (BRA) and Russia (RUS), emission reductions will have a weak impact on their economies, with their VBPs varying negatively by 0.07% and 0.17%, respectively. A small variation is also observed in important global economies, such as the United States, Japan (JPN), Germany (DEU) and France (FRA), with reductions in their GPV levels of 0.03%, 0.11%, 0.1% and 0.06%, respectively. Among the major European economies, the greatest decrease in VBP occurred in the United Kingdom (GBR), which decreased by 0.29%.

The moderate scenario, aiming to reduce global emissions by 30%, results in greater mitigation for India (IND), where the country is expected to reduce emissions by 78.99%. China (CHN) again has a leading role, with a reduction of 48.45%. On the other hand, Russia (RUS), with little responsibility in the pessimistic scenario, has reduced emissions by 51.39%.

A similar result is observed in Japan (JPN), a country with a high volume of emissions in 2009 but with little responsibility in the previous scenario. In the moderate scenario, Japan (JPN) reduces its level of emissions by 34.96%. Figure 4 represents the initial emissions in 2009 and, after that, the simulation of the 30% reduction in global emissions.

Figure 5. Change in GHG emission after the imposition of 30% reduction target on global emissions

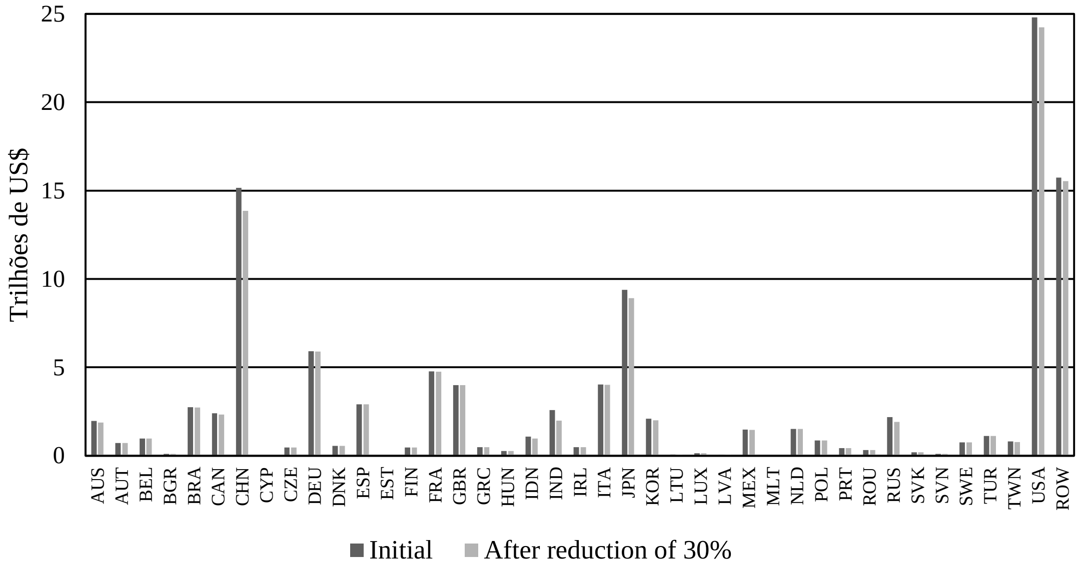


Among the main polluters, the United States (USA) presents a high mitigation, with a reduction of 40.57%. On the other hand, Brazil (BRA) and Germany (DEU), countries among the largest polluters in 2009, presented emissions reductions of 0.38% and 0.29%, respectively.

As emissions reductions increase, a country's GPV is more greatly impacted, particularly in those countries where the responsibility for GHG mitigation has been greatest. Thus, the economic impact is higher in India (IND), with a reduction in GDP of 23.07%, followed by Russia (RUS), with a reduction of 12.58%.

China (CHN), Japan (JPN) and the United States (USA) suffer lower reductions, 8.6%, 4.99% and 1.86%, respectively. Among the largest emitters, Brazil is the country with the lowest reduction, namely, 0.24%. The impact on the gross production figures of the countries after the 30% reduction in global GHG emissions is observed in Figure 6.

Figure 6. Change in VBP after the imposition of 30% reduction target on global emissions



Among the European countries, again the greatest economic impact is observed in Malta (MLT) and Estonia (EST), with reductions of 2.44% and 1.88%, respectively. Germany (DEU), France (FRA) and the United Kingdom (GBR), the main European economies, suffer low reductions compared to other countries, decreasing by 0.29%, 0.15% and 0.42%, respectively.

Indonesia (IDN) and South Korea (KOR) have significant decreases in VBP, with reductions of 10.01% and 4.34%, respectively. In North America, Canada (CAN) has a reduction in economic production of 2.71%, which is higher than under the previous scenario where the economic impact in the United States was lower.

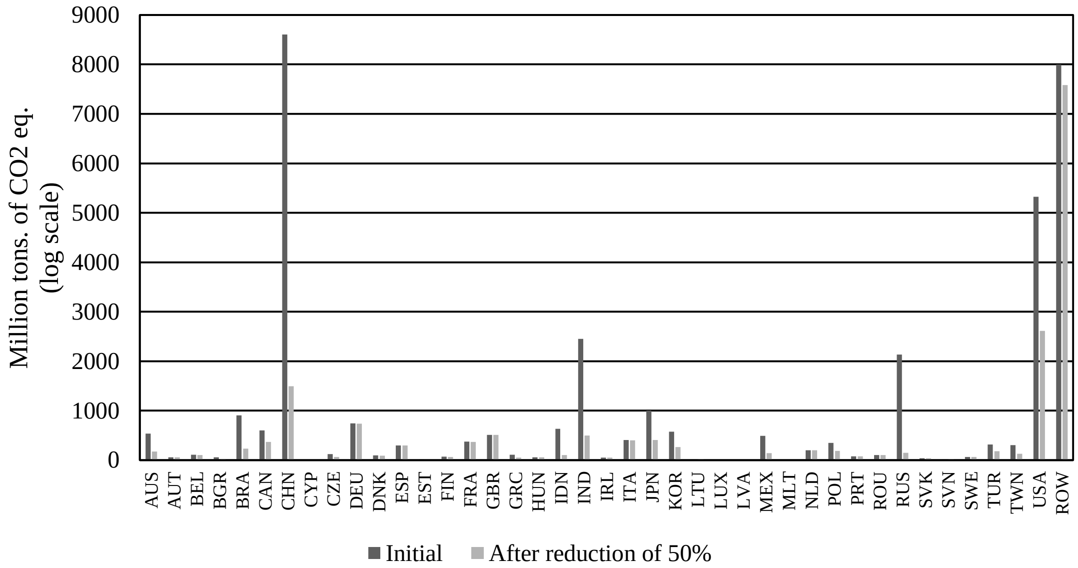
The optimistic scenario is the scenario that most closely approximates the real need to reduce global emissions to maintain a sustainable level of annual emissions and not have the global temperature rise by 2 ºC, as predicted by the IPCC report. In this scenario, the global emission reduction goal is 50%, so the global emission in 2009 of 35.8 Gt is limited to 17.9 Gt.

This scenario highlights the higher level of reductions in the countries with high values in the emission intensity coefficient and in countries considered as emerging economies, especially those that make up the BRIC countries. Russia (RUS) is the country with the largest reduction in emissions, 93.23%, followed by Indonesia (IDN), 83.87%, China (CHN), 82.66% and India (IND), 79,82%. These countries, in addition to their high volume of emissions in 2009, are among those that presented higher values in the emission intensity coefficient.

In the pessimistic and moderate scenarios, Brazil(BRA) presented a small reduction in the level of its emissions, but in the optimistic scenario it has the fifth largest reduction of 74.28%. Even with a below-average emission intensity coefficient, Brazil was among the countries with the highest volume of GHG in 2009. Japan (JPN), also with a below-average coefficient and among the largest emitters of GHG in 2009, shows a reduction on the order of 59.19%.

The United States (USA), the world's leading economy and the second largest GHG emitter in 2009, which resulted in a high coefficient of emission intensity, shows a reduction of 50.97%. Figure 7 shows the initial emissions in 2009 and, after that, the simulation of the 50% reduction in global emissions.

Figure 7. Change in GHG emissions after the imposition of 50% reduction target on global emissions

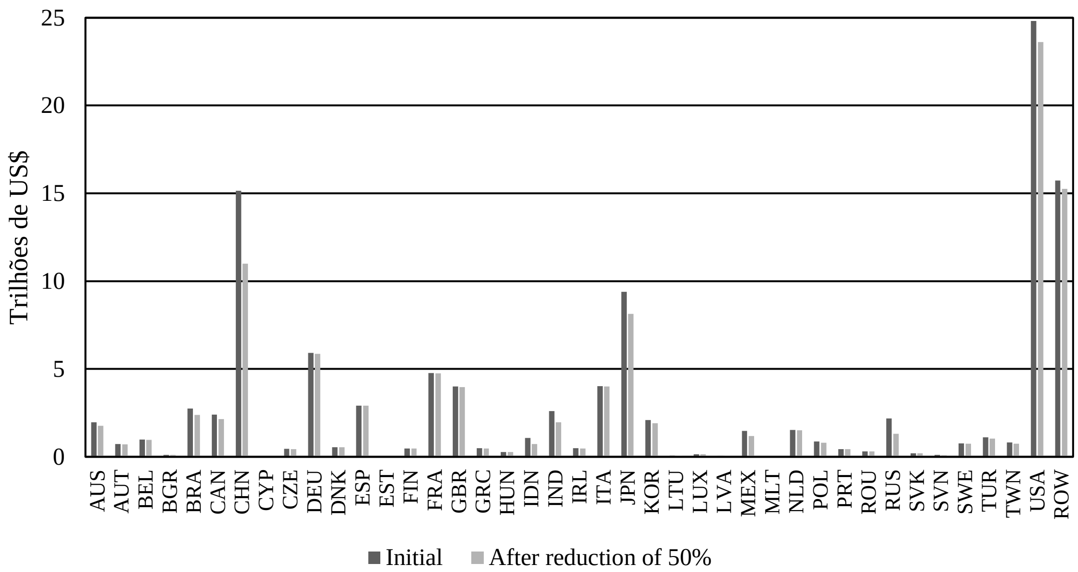


Countries with a high coefficient, but low emissions compared to the others, have a high reduction in CO_2eq volume. This observation is the case for Estonia (EST) and Taiwan (TWN), with a reduction of 70.89% and 58.35%, respectively, in their emissions levels. Among the European countries, the largest reductions, besides Estonia (EST), are Greece (GRC) and Bulgaria (BGR), at 55.04% and 53.67%, respectively. Germany, with the seventh largest volume issued in 2009, reduces its emissions by only 1.04%. Other European powers, such as the United Kingdom (GBR) and France (FRA), also show low reductions, 0.85% and 0.65%, respectively.

The scale of reduction in the level of GHG emissions of the countries required to reach the ideal global emission volume directly impacts their respective economies. Figure 8 shows the VBP variation of all countries in the optimistic scenario. Russia

(RUS), with a 40.12% reduction in VBP, is the country with the greatest economic hardship in the optimistic scenario. In this way, countries with greater volumes of reduction in emissions, suffer greater economic impacts. Indonesia (IDN), has a reduction in GPV on the order of 32,48%, China (CHN) has a reduction of 27.44% and India (IND) has a reduction of 24.02%. Japan (JPN), the third largest economy in 2009, has a reduction in its VBP of 13.45%.

Figure 8. Change in VBP after the imposition of 50% reduction target on global emissions



The economic impact on Brazil (BRA) is approximately a 13.07% reduction in its GPV. As presented by De Souza, Ribeiro and Perobelli (2016), Brazil's main source of emissions is in its primary economic sector, namely, agricultural production, so that the reduction of emissions would directly impact the main economic sector of the country.

In Europe, the greatest impacts are concentrated in countries with the highest emission intensity coefficient, and consequently, those countries would need to reduce the volume of their emissions. Estonia (EST) and Bulgaria (BGR) suffer the largest reductions in the European bloc, 8.88% and 8.11%, respectively. On the other hand, the major powers have a reduction of less than 1%. The GPV of Germany (DEU) is reduced by 0.9%, while that of the United Kingdom (GBR) decreased by 0.77% and that of France (FRA) decreased by 0.48%. The country with the lowest economic impact is in Spain (ESP), with a reduction of only 0.31% in VBP.

5. CONCLUSION

The use of LP-IO in issues involving restriction of GHG emissions, applies a methodology using a national, inter-sectoral matrix to analyse the response of a specific country to a limitation of its emissions (HRISTU-VARSAKELIS et al. (2006). In a cross-sectional analysis of the response of a single country (PASCUAL-GONZÁLEZ et al., 2016) sought to analyse GHG mitigation in the “top-down” approach, i.e., to investigate the need to reduce global emissions and, after simulating global emission reduction scenarios, to analyse the reductions necessary for each country and the impact of these measures.

Thus, the reduction of global emissions to the level determined by the IPCC as ideal, 18 Gt CO_2eq/year so that the worldwide temperature increase stabilizes below 2 °C causes a greater economic impact on emerging countries, especially those that make up the BRICs. Among these countries, Russia is the country that suffers the greatest reduction in its GPV, followed by China, India and Brazil.

The greatest impact occurs because, by stipulating the reduction target needed to reach the ideal level, the overall CO_2eq emissions need to be reduced by 50%. Thus, the major responsibility for reducing emissions falls on countries with high emissions and high-emission intensity, i.e., economies characterized by high GHG emissions in their production.

Great global powers with significant participation in global emissions also need to reduce their emissions. Both the United States and Japan should reduce their emissions by more than 50%. However, the economic impact in emerging countries is significantly higher than to these two world powers, and the difference is even greater when compared with the European powers. Germany, the United Kingdom and France suffer an economic impact of less than 1% reduction in GPV. However, smaller economies with high-emission intensity, such as Greece, Estonia and Malta in Europe, and Taiwan in Asia, show a high level of reduction of both emissions and in VBP.

The reduction in emissions and in the countries' GDP is smaller as the global reduction target becomes less ambitious, but the ratio remains practically the same. Emerging countries and those with the highest emission intensity have the greatest responsibility for reducing their emissions and, consequently, suffer greater economic impact. Meanwhile, European powers have smaller responsibilities in lowering their emissions, which will mean less impact on their economies.

In light of this, during the development of international agreements, such as the Paris Agreement, one must examine not only the need to reduce GHG but also the possible impact that this reduction will have on economies, especially on emerging economies, where the technology employed production generates more pollution. This impact is an important consideration to improve countries' adherence to the targets set in the agreements and, thus, in the joint work of nations to combat climate change.

One of the alternatives is the sharing of information and technologies between countries, seeking the greater use of clean technologies, especially in energy matters. Therefore, one of the objectives of the present work is to bring the issue of the quest for the reduction of GHGs into a global paradigm, a problem that must be approached together. Reducing emissions, thus "slowing down" global warming, are global problems, not just one country's problem.

In addition to seeking to analyse the issue of GHG reduction from a different perspective, the present work also sought to contribute to the development of the PL-IP methodology in environmental issues. The model has its limitations; the analysis is static and does not consider modifications in the technology used in economic production, which limit emissions reduction and thus limit reductions of the VBP. An alternative is the use of the computable general equilibrium models and an international database.

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