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ECONOMIC DEVELOPMENT'S IMPACT ON CO2 EMISSIONS: AN APPLICATION OF THE KUZNETS ENVIRONMENTAL CURVE FOR MATO GROSSO DO SUL

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ABSTRACT

Productive activities are recurrent causes of externalities, and the literature is controversial as to the real impact that these activities generate on the environment, sometimes informing about negative externalities, or reporting on positive externalities. The present study analyzes the impact of economic development on carbon dioxide (CO2) emissions in Mato Grosso do Sul (MS), covering the period between 2002 and 2016. In order to carry out the analyzes, five sectors were investigated: agriculture, energy, land use change and use, industrial processes and residues, all related to GDP *per capita* of linear and quadratic format, according to Kuznets theory, as sources of economic development. The research was exploratory, unpublished and based on econometric models. The empirical results indicate that, during the period evaluated, the impacts of economic development were negative in the total carbon dioxide emissions for Mato Grosso do Sul. The econometric model of residues presented the best significance, being controversial about the results in countries developed;

for the other models, the sectors presented the "U" format; and the land use and change sector introduced the Kuznets' ("U" inverted) environmental curve theory. When compared to the industrialized Brazilian states, Mato Grosso do Sul is incipient in its economic performance; However, when analyzing the environmental sustainability trajectory, as measured by CO2 emissions, the MS presents better empirically verified numbers.

Keywords: Economic Development; Environment; Economy; Econometrics; Econometric Modeling.

IMPACTO DO DESENVOLVIMENTO ECONÔMICO NAS EMISSÕES DE CO2: UMA APLICAÇÃO DA CURVA AMBIENTAL DE KUZNETS PARA O MATO GROSSO DO SUL

RESUMO

As atividades produtivas são recorrentes causadoras de externalidades, e a literatura é controversa quanto ao real impacto que tais atividades geram ao meio ambiente, ora informando sobre externalidades negativas, ora noticiando acerca de externalidades positivas. O presente estudo analisa o impacto do desenvolvimento econômico nas emissões de dióxido de carbono (CO_2) no Mato Grosso do Sul (MS), compreendendo o período entre 2002 e 2016. Para a realização das análises, cinco setores foram investigados: agropecuária, energia, mudança e uso da terra, processos industriais e resíduos, todos relacionados com PIB (Produto Interno Bruto) per Capita de formato linear e quadrático, conforme teoria de Kuznets, como fontes de desenvolvimento econômico. A pesquisa foi exploratória, inédita e baseada em modelos econométricos. Os resultados empíricos indicam que, ao longo do período avaliado, os impactos do desenvolvimento econômico foram negativos nas emissões de dióxido de carbono totais para o Mato Grosso do Sul. O modelo econométrico de resíduos apresentou a melhor significância, sendo controverso quanto aos resultados em países desenvolvidos; para os demais modelos, os setores apresentaram o formato de "U"; e o setor de mudança e uso da terra apresentou a teoria da curva ambiental de Kuznets ("U" invertido). Quando comparado aos estados brasileiros industrializados, o Mato Grosso do Sul se mostra incipiente em seu desempenho econômico; porém, ao analisar a trajetória da sustentabilidade ambiental, medida pelas emissões de CO_2, o MS apresenta melhores números empiricamente constatados.

Palavras-chave: *Desenvolvimento Econômico; Meio Ambiente; Economia; Econometria; Modelagem Econométrica.*

INTRODUCTION

Environmental sustainability and economic growth are extensive sources of research and deepening of debates within society, the academy and the development of public policies.

Environmental problems are numerous, and degradation can be caused by the increase in factors such as industrialization, transportation, population, poverty, soil erosion, congestion/traffic, exploitation of open access resources whose property rights are poorly defined, and pollutants/ residues that affect economic growth (BORHAN et al, 2012). The effects of population growth are visible over time, leading to increased environmental pollution and contributing to negative externalities related to human well-being, both in increasing social and health costs and in productivity.

The 1997 Kyoto Protocol was adopted at the third Conference of the Parties[1] (COP 3) and is recognized as a community-led government framework to reduce emissions of greenhouse gases (GHGs), among which carbon dioxide is the largest representative. Among the goals of that protocol were the reduction of 5% in GHG emissions, compared to 1990 for developed countries. The latest evolution of that first try for an agreement materialized in COP21 held in France in 2015 with the drafting of the Paris Agreement, through which 195 countries agreed to parameterize their voluntary targets $_{CO2}$ emission reduction by restricting in less than 1. 5 ^{0} C the planet's temperature increase by 2100 (MCTIC, UN ENVIRONMENT, 2017).

Since the 1970s, *per capita* emissions of carbon dioxide in Brazil have advanced by an average of 1. 6% per year. In the 1990s, the emission rate included the indicator called Land Use Change and Forest, which enables the stratification of the sectors responsible for CO2 emissions. According to the Greenhouse Gas Emission Estimate System[2], from this

1 "The Conference of the Parties (COP) is the supreme body of the United Nations Framework Convention on Climate Change (UNFCCC), which annually brings together the participating countries at global conferences. Their decisions, collective and consensual, can only be taken if they are accepted unanimously by the Parties, being sovereign and valid for all the signatory countries. Its purpose is to regularly keep under review and make the necessary decisions to promote the effective implementation of the Convention and any legal instruments that the COP may adopt" (MMA, 2017).

2 SEEG "is an initiative of the Climate Observatory, which includes the production of annual estimates of greenhouse gas (GHG) emissions in Brazil, analytical documents on the evolution of emissions, and a web portal for making available simple and clear of the methods and data generated in the system. Estimates of Greenhouse Gas Emissions are generated according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC), based on data from the Brazilian Inventories of Anthropogenic Greenhouse Gas Emissions and Removals, prepared by the Ministry of Science, Technology and (MCTI) and data obtained from government reports, institutes, research centers, sector entities and non-governmental organizations" (SEEG, 2017).

indicator, it is possible to observe the implications of agribusiness in the composition of carbon dioxide emissions. In 2013, Brazil had an emission rate of 2. 4 tons of CO2 per inhabitant, and in the following year, considering its absolute numbers (approximately 501 Kt), the country reached the tenth place among the largest emitters of carbon dioxide in the world (SEEG, 2017).

The present study investigates the relationship between economic development and CO2 emissions in the state of Mato Grosso do Sul between 2002 and 2016. The choice for such an empirical field was based on the fact that the mentioned unit of the federation reflects an important position within the Brazilian economic matrix - with emphasis on agribusiness - activity with a strong impact on local development and the environment - 70% of the Brazilian wetland, a peculiar area with the largest continental wetland of the planet (UNESCO, 2000)[3]. On the other hand, the historical framework is justified because it has a reference frame to Rio + 10, which took place in 2002 (in which a balance was taken of advances and new demands after Rio-92) and 2016, as the most recent base year available, with economic data obtained in the databases of the Central Bank of Brazil (BACEN). Considering the parameter of analysis for the present research, the mapping of the carbon dioxide emissions was adopted, followed by the reasoning that, according to Greenpeace (2009), this balance would represent a relevant indicator of the economic development.

In order to examine the impact of economic development on the particular analyzed, the GDP *per capita* and *per capita* GDP squared were used. To compose the data of the CO2 time series in Mato Grosso do Sul, the carbon dioxide emissions were divided by sector by means of the elaboration of an econometric model of analysis, applying modeling with linear method (*OLS*) for each of the five distinct sectors: energy, agriculture, land use change, waste and industrial processes.

In order to achieve the aforementioned objectives, this work is organized from this introduction, which presented an overview of the research scenario; then Section 1 (Analytical Design) is presented, which shows the diagnostic structure, with examples of similar research, developed worldwide. In section 2 (Analysis of CO2 emissions in Brazil

3 "The *United Nations Educational, Scientific and Cultural Organization* (UNESCO) in Brazil is a national office in the Latin American region. Its main objective is to assist the formulation and operationalization of public policies that are in line with the strategies agreed between the Member States of UNESCO. Its activities are carried out through technical cooperation projects in partnership with various governmental bodies and sectors of civil society, as their purposes contribute to public policies that are in line with sustainable development "(UNESCO, 2018).

and Mato Grosso do Sul), a survey was made to narrow the understanding of CO2 emissions in Brazil and the relation with GDP *per capita:* emission of CO2 in the State of Mato Grosso do Sul and the relation with GDP *per capita;* and the emission of GHG in the field activities. Then, in section 3 (Data Analysis and Results), the models used and results of the analyzes are presented respectively, while in its Final Considerations, this study brings a summary conclusion about the research theme.

The present econometric analysis is expected to contribute to the available literature on externalities between economy and environmental degradation, modifying and extending conventional models, including additional sectors and variables.

2 ANALYTICAL DELINEATION

The development of nations depends on economic and productive results with the ability to align growth with sustainable, especially environmental, processes. In the agricultural sector, there is a wide discussion about production, impacts and productivity, since there is a close relationship between economy and production, which is consolidated by the cyclical composition of the larger the production, the greater the degree of economic strengthening, due to the increase in productivity (IPEA, 2014). In agriculture, one must consider the possibility that the adoption of more efficient strategies could reflect in the maximization of productivity and, consequently, generate an increase in economic development.

Studies that relate the countries' economic development and their alignment with the levels of carbon dioxide (CO2) emissions can be divided into two moments: in the first, there was a strong positive correlation between the levels of growth of the National Product (GNP or GNP) and carbon dioxide emissions. This suggested that, in order to grow the country, the necessary condition would be related to the increase in the emission of said gas.

In that first phase of analysis, the studies established relationships between the possible conditioning factors of CO_2 emissions and their notableness in relation to environmental degradation. Among these studies, we highlight the studies Kraft and Kraft (1978), which verified that the production composes a unidirectional causality correlated to the energy consumption and, consequently, emission of carbon dioxide, in the United States between 1947 and 1974. Their analysis is in line with studies

such as that of Ghosh (2010), which observed, in India, the nexus causality between CO_2 emissions and economic development. In Africa, Akinlo (2008) followed this composition, allocating the analysis between energy consumption and economic development. Central America was studied by Apergis and Payne (2009), also indicating the links between energy consumption and economic development. Canada was analyzed by Ghali and El-Sakka (2004), the composition of relations between energy use and production. In Europe, more specifically in France, Ang (2007) pointed to similar compositions. There are still studies that consider different factors, such as income, and, as an example of such research, Coondoo and Dinda (2008) verified the composition between income and carbon dioxide emissions. Lee, in his studies (2005; 2006), demonstrated the relationship between energy consumption and production by Gross Domestic Product indices of the G-11 countries. Shaari et al. (2017) used linear and non-linear econometric models to measure the effects of Research & Development (R & D) on CO2 emissions. For the empirical studies cited, the hypothesis is assumed that the economic development damages the environment, and it is necessary to carefully understand this nexus for the construction of mitigating strategies capable of meeting the economic and environmental needs.

Secondly, on the other hand, the research has pointed to the following considerations: the technological development of a country allows economic advance, without this necessarily reflecting the increase of carbon dioxide emissions, reversing the correlation previously described. The indications in the second study suggest that CO_2 and economic development are not necessarily mutually dependent events. Zhang and Cheng (2009) have shown in China the links between energy consumption, carbon emissions and economic development. Tiwari (2011), in India, examined causality in the dynamics of energy consumption, CO_2 emissions and economic growth, concluding about the need for a greater effort to exploit the use of renewable energies, generating productivity without delaying economic development and reducing CO_2 emissions. Corroborating assimilation, the International Energy Agency (IEA, 2016) confirmed the decoupling of global emissions and growth, noting that global emissions of energy-related carbon dioxide, the largest source of man-made emissions of greenhouse gases, remained stable in 2014 and 2015. These data show the trend of untying economic development as one of the main contributors to global warming.

Identifying the stage of technological development in a country or region may provide evidence to infer the greater or lesser correlation between the economy and the raising of carbon levels in the atmosphere.

3 ANALYSIS OF CO2 EMISSIONS IN BRAZIL AND MATO GROSSO DO SUL

Under the *Nationally Determined Contribution (iNDC*)[4], Brazil signed the climate treaty, committing itself to a reduction of 37% in CO2 emissions by 2025 and 43% by 2030, compared to 2005 emissions (MMA, 2016). To this end, commitments can be made to guarantee 45% of renewable sources in the energy matrix, with a 23% increase in renewable sources for electricity supply and the ambition to eradicate illegal deforestation (MMA, 2015). The Brazilian government has also pointed to a 41. 1% reduction in GHG emissions between 2005 and 2012. And, according to government information, the main action to reach this value lies in an aggressive policy to control deforestation in the Legal Amazon, which encompasses the establishment of agricultural frontiers, encompassing demarcation and obedience in environmental protection areas, using the land use and forest change indicator (MMA, 2015). In this sense, and according to Kässmayer and Neto (2016)[5], the Paris Agreement, ratified by Brazil in 2016, represents the beginning of a new paradigm of sustainability: the climate paradigm, whose aim is to harmonize climate policy with sustainable development in all sectors.

The contributions of production, agribusiness and CO2 emissions make up a larger group of objectives related to the environmental sciences. The volume of research is large, addressing: the relations between the factors of production and agribusiness, production and CO2 emissions, as well as agribusiness and carbon dioxide emissions. These studies focus mainly on an isolated analysis of the factors, while the purpose of this paper is to analyze the factors composing an interrelationship between them.

Brazil presents itself as one of the great forces of the world market, reaching to compose leadership indicators in several sectors of production, as is the case of agribusiness, in which are products such as soy, corn, meats, among others. Assuming characteristics of developing countries,

4 http://www. mma. gov. br/images/arquivo/80108/BRASIL%20iNDC%20english%20FINAL. pdf

5 https://www12. senado. leg. br/publicacoes/estudos-legislativos/tipos-de-estudos/textos-para-discussao/td215

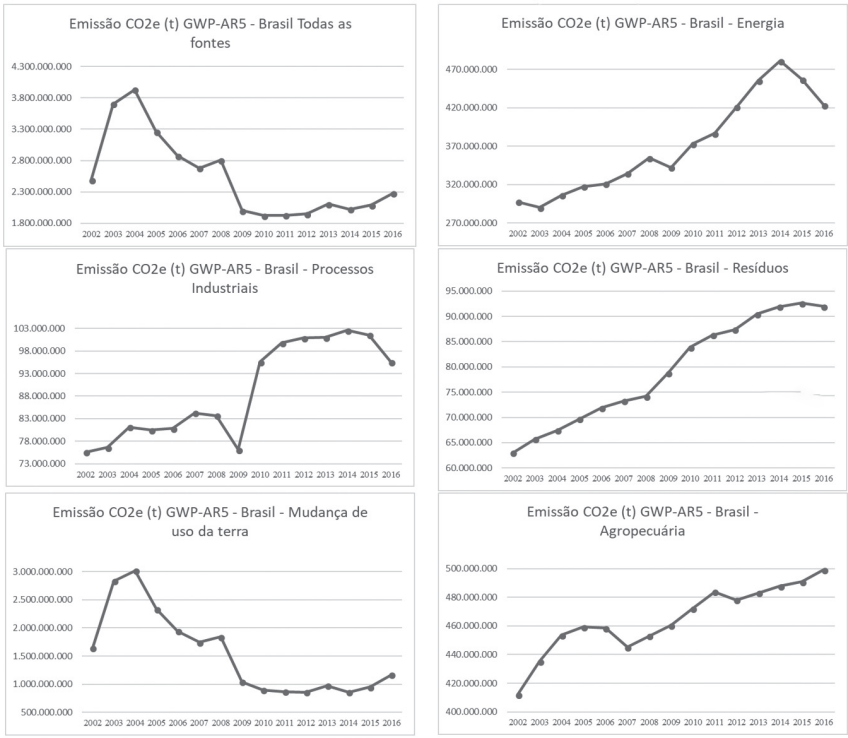
absolute increases in numbers of people, consumption, and pressure on frontiers, which are imposed by the globalized economy, are observed (GASQUES et al., 2014). This very specific composition conditions a cross-sectional study, between a certain historical frame, through which results and observations of the relation of the variables must be collected specifically for Brazil.

However, since Brazil is a developing country and, therefore, having its technological framework in the same situation, would it be possible for the country to meet the objectives of the climate agreements, as was the Paris Agreement? Could the same scenario be replicated in the state of Mato Grosso do Sul? In order to answer such questions, the GHG emissions levels and their comparison with the Gross Domestic Product *per capita* will be described, both at national and state levels. The period chosen began in 2002, due to Rio + 10, a relevant landmark for sustainable development, ending the historical series in the year closest to the realization of the present study, that is, generating analyzes based on the most recent data available. Therefore, data on CO2 emissions and GDP *per capita* in Brazil cover Gross Domestic Product and emissions until December 2016, while data available for Mato Grosso do Sul's GDP *per capita* have data updated up to December 2015.

3. 1 CO2 emissions in Brazil and the ratio of GDP *per capita*

Graphs showing the behavior of total carbon dioxide emissions in Brazil, from 2002 to 2016, are presented below.

Table 1: Total CO2 Emissions in Brazil by Sector (2002-2016)



Source: SEEG (2017).

Table 1 contains the CO2 emission curve in Brazil, aggregating all sources, or sectors of the economy. It is evident that after a rapid growth period, which covers the period between 2002 and 2004, there is a consistent downward trend in the emission until its relative stability, between the years 2010 and 2012. At the end of that year, there is an upward movement, representing an increase in the amount of tons of CO2 in the atmosphere by the end of the series in 2016. Even so, the figures recorded between 2010 and 2016 are well below those recorded during the previous decade.

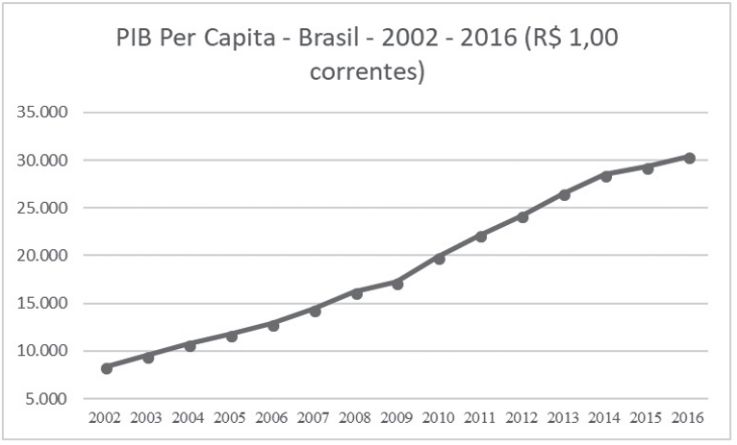
When confronted, the data indicate that only Agribusiness and Land Use Change were the sectors that influenced the increase of emissions during the whole period considered, while the other sectors - Energy, Industrial Processes and Waste - followed the movement of high only between the years of 2010 and 2014. That said, it is valid to conclude

that the first two sources cited - Agribusiness and Land Use Change - determined the inflection of the downward trend, notably from 2014. So, if overall emissions fell between 2002 and 2016, there is some upward pressure in the final three years of the series.

However, it is prudent to consider that the 2013-2016 period is still too short to confirm an actual trend reversal - which can be assessed in subsequent studies. Only the agriculture and livestock sector presented growth in carbon dioxide emissions during the whole historical frame.

The GDP *per capita*, whose movement is indicated in Table 2, was invariably up in all the historical moment considered.

Table 2: GDP *per capita* in Brazil, from 2002 to 2015



Source: SGS (2018).

The conclusion is that, although there was economic development registered in Brazil by the indicator that shows the wealth produced, divided among the population of the country, the reduction in the emission of the main GHG was registered - allowing to establish an inversely proportional relation between generation of wealth and discharge of CO2 gas into the atmosphere.

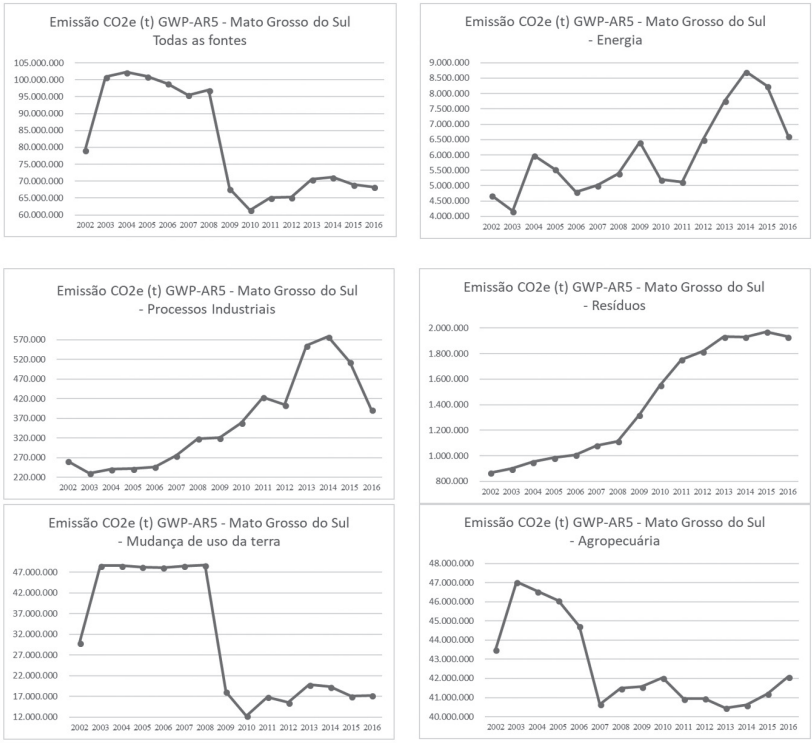
3.2 CO2 EMISSIONS IN MATO GROSSO DO SUL AND THE RELATION WITH GDP *PER CAPITA*

The state of Mato Grosso do Sul, supported by State Law 4,555/2014[6] (STATE OF MATO GROSSO DO SUL) assumed a voluntary reduction in greenhouse gas emissions of 20% by 2020 compared to the 2005 GHG emissions. To achieve this goal, the legislator has designated several strategies, including this federation unit in the Climate Change Program (PROCLIMA), which involves a series of state actions and commitments to mitigate greenhouse gas emissions. One of these actions is Terra Boa, whose goal is to recover two million hectares of degraded areas in Mato Grosso do Sul, equivalent to 13% of the commitment (15 million hectares) assumed by Brazil at COP 21 (IMASUL/2016).

In a continuous act, the Neutral Carbon State Project was an integral part of PROCLIMA, carried out by the State Secretariat for Environment and Economic Development (SEMADE), whose purpose is to generate the methodological bases for a low carbon economy in Mato Grosso do Sul, developing and adapting technologies to reduce and mitigate greenhouse gas emissions in various sectors of the state economy (SEMADE/2016).
As with the conjectures about the possibilities for Brazil to achieve what was proposed by the international agreements signed, it is also necessary to evaluate the potential for the MS to meet its own climate-related goals, and the following graphs show how this unit of the federation in the course of the same historical cut of the presented data for Brazil. The graphical inference about the behavior of GHG emissions CO2 in the state of Mato Grosso do Sul sought to identify the degree of adherence between the scenario of this place and that of the country. This time, the movements described in Table 3, below, are considered.

6 State Law No. 4,555, dated July 15, 2014, established the State Policy on Climate Change (PEMC) within the territory of the State of Mato Grosso do Sul

Table 3: Total CO2 emissions in Mato Grosso do Sul by Sector (2002-2016).



Source: SEEG, 2017.

The general framework points to a direct equivalence between the growth in gas emissions in MS and in Brazil between 2002 and 2004. Since then, while there has been rapid decline in the country between 2004 and 2007, Mato Grosso do Sul recorded steadily high rates until 2008. From that year, a strong decline began, culminating with the lowest level of the entire series in 2010.

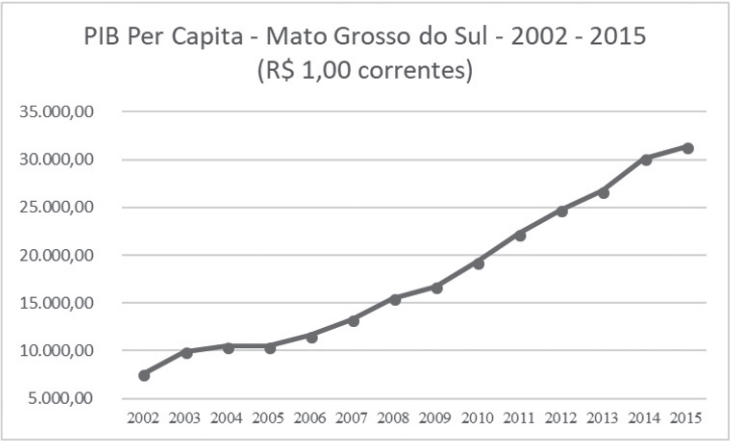
The discharge of CO2 in the state of MS operated contrary to what occurred in Brazil among the rest of the records: if, from 2010 to 2014, there was an increase in local emissions, a lower emission movement began from the latter until the end of the series, in 2016.

When considering all sources of CO2 emissions in the MS, it is noted that the sectors of energy, industrial processes, waste and land use

change behave similarly to the national movement, with small variations between annual records - but preserving the general movement. Emphasis is given to emissions behavior in agriculture: the upward curve is quite clear in Brazil; already in MS, the general picture is of a fall, with inflection for the growth noticed only from 2013.

The same behavior is registered for GDP *per capita,* which in the state of Mato Grosso do Sul shows a clear adherence to the movement of this indicator at the national level (Table 4).

Table 4: Gross Domestic Product *per capita* in Mato Grosso do Sul, from 2002 to 2015



Source: SGS (2018).

The data presented so far indicate that there is a coincident economic development in Brazil and the state of Mato Grosso do Sul, with the congruence of declining behavior in the emission of carbon dioxide in the atmosphere. However, the question arises as to the possible reasons for higher CO2 emissions in activities related to agriculture and land use change - which will be discussed below.

3.3 GHG EMISSION IN FIELD ACTIVITIES

The first phase of this study sought to understand the dynamics of GHG emissions, based on available inventories and their relation with land

use changes and agricultural activities in Brazil and Mato Grosso do Sul. Current inventories are based on global and national standards, emission factors that are not fully adapted to certain characteristics of the state, and some emission factors are probably overestimating GHG emissions.

What may explain the increase in GHG emissions in field activities is that the conversion of forest, enclosed and field areas to agricultural or pasture areas decreases the organic matter content in tropical and subtropical soils due to the short and long term consequences disorders caused by periods of tillage operations associated with low levels of addition of organic material (SARTORI et al., 2006). The process of carbon loss from the soil to the atmosphere is called soil CO2 emission (FCO2), or soil respiration, resulting from microbial activity and respiration of the roots, being considered the second largest source of carbon dioxide to the atmosphere, second only to the oceans. Soil respiration is determined by a set of factors, such as soil temperature and humidity (EPRON et al., 2004). In the CO2 emission process, in particular the transport of the gas from the soil to the surface is governed by the diffusion equation, which in turn is influenced in the first order by changes in soil temperature and humidity (KANG et al., 2003).

In 2014, the 7. 74 million hectares of trees planted in Brazil were responsible for the stock of approximately 1. 69 billion tons of carbon dioxide (tCO2), representing an increase of 1. 2% over 2013. Eucalyptus plantations occupy 5. 56 million hectares of trees planted in Brazil, representing 71. 9% of the total, located mainly in the states of Minas Gerais (25. 2%), São Paulo (17. 6%) and Mato Grosso do Sul 14. 5% or 803,699 hectares (IBÁ, 2015). According to some studies, eucalyptus has a greater potential to store atmospheric carbon in the aerial biomass and in the soil, mainly when associated with pasture or annual crops, and especially in the conversion of degraded lands to productive land and renewable energy sources (LA SCALA et al., 2012).

The change in land use caused by the conversion of forests into pasture or in agricultural areas modifies the coverage and consequently the carbon content in the soil. The equilibrium between the carbon retained and the lost carbon in the soil is affected by the change in land use until a new "equilibrium" is taken up (GUO; GIFFORD, 2002).

A set of measures to contain deforestation in Brazil, mainly in the Amazon, reduced, in the 23 years between 1990 and 2012, 56% of the total emissions of tons of carbon equivalent (tCO2 e). In 1990, gross emissions

corresponded to 1. 25 billion tons of CO2, reaching, in 2004, a peak of two billion tons CO2 e. In the following years, it began a deforestation reduction process, which reduced emissions by half in 2007, reaching 1. 07 billion t CO2 e. The process continued decline and, in 2013, emissions from land use changes reached their lowest level with 0. 54 billion tonnes CO2 and (SEEG, 2015).

Previous studies can confirm the potential for carbon emission reduction associated with no-till. In the Report on Technical Synthesis, Land Use, Land Use Change and Forestry, carried out in 2010, it was already predicted that in the low carbon scenario, 100% of cotton, rice, beans, maize and soybean production would be converted into no-tillage, al jumping highlighted in 2015. There was an immediate drop, confirmed on the chart shortly after 2009. The report further conceptualizes the use of the no -tillage system as a guarantor of three basic actions for the sustainability of the system: planting should be done continuously in a direct manner, without the traditional soil rotation; crops capable of leaving high quality straw were used to keep the soil covered with residues every year; and, finally, the use of crop rotation in summer and winter would be necessary to break cycles of pests and diseases and improve soil nutrient recycling.

4 ANALYSIS OF DATA AND RESULTS

The present research qualifies as quantitative, exploratory, with empirical analysis, using econometric approach, following the procedures of Ang (2007), Gosh (2010), Borhan, Ahmed and Hitam (2011) and Shaari et al. (2017).

The data evaluated in this work were obtained from secondary sources, allocated in time series, and cover the period between 2002 and 2016. For specific data on carbon dioxide emissions, the SEEG database, generated from guidelines of the Intergovernmental Panel on Climate Change, was used. The economic data were obtained in the databases of the Central Bank of Brazil (BACEN).

4. 1 ESTIMATION METHOD

For empirical analysis, econometric modeling was defined as a methodological procedure, and the method for estimation was Ordinary Least Squares (OLS). Based on five theoretical models, the objective is

to analyze the relationship between economic growth variables and CO2 emissions. The explanatory (independent) variables were GDP *per capita* and GDP *per capita* squared; to analyze the inverted "U" theory, all data were log linearized. As for carbon dioxide emissions, there were five distinct sectors: energy, agriculture, land use change, waste and industrial processes

The quality and adjustments of the values obtained in the regression are measured with the index "R $^{2"}$ (R *squared*). The coefficient of determination, called R^2, is a measure of adjustment of a generalized linear statistical model, such as linear regression, in relation to the observed values. R^2 varies between 0 and 1, indicating, in percentage, how much the model can explain the observed values. The higher the R^2, the more explanatory the model; that is, the better the model, the more it fits the sample (GUJARATI, 2011).

4. 2 Theoretical Models

4. 2. 1 Model 1

$$CO2terra_t = \beta_0 + \beta_1 PIBpc_t + \beta_2 PIBpc_t^2 + \varepsilon_t$$

On which are the emission data of the land use change sector, and the explanatory variables are Total Gross Domestic Product (GDP), GDP *per capita* (GDPpc), GDP of agribusiness (PIBAgro) and planted area (Area) in hectares. The "" are the angular coefficients of linear regression and is the random error.

4. 2. 2 Model 2

$$CO2resíduo_t = \beta_0 + \beta_1 PIBpc_t + \beta_2 PIBpc_t^2 + \varepsilon_t$$

Onwhich " Are the waste sector emission data. The explanatory variables for economic growth are the same in the five models.

4. 2. 3 Model 3

$$CO2indústria_t = \beta_0 + \beta_1 PIBpc_t + \beta_2 PIBpc_t^2 + \varepsilon_t$$

" is the dependent variable that characterizes data on carbon

dioxide emissions by the industrial processes sector.

4. 2. 4 Model 4

$$CO2agronegócio_t = \beta_0 + \beta_1 PIBpc_t + \beta_2 PIBpc_t^2 + \varepsilon_t$$

is the dependent variable that characterizes data on carbon dioxide emissions by the agribusiness sector.

4. 2. 5 Model 5

$$CO2energia_t = \beta_0 + \beta_1 PIBpc_t + \beta_2 PIBpc_t^2 + \varepsilon_t$$

is the dependent variable that characterizes data on carbon dioxide emissions by the energy sector.

With the theoretical construction of the models, this empirical study used the software "*R*[7]" to estimate the predicted values, from linear regression.

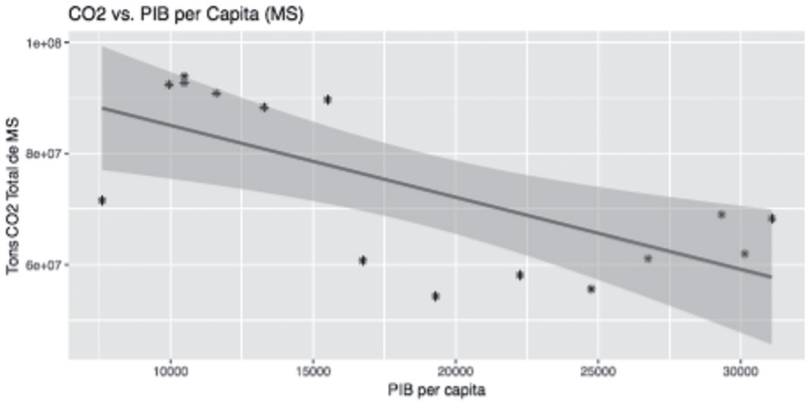
4. 3 Results

The studies applied in the area of economic growth and CO2 emissions deal with econometric models based on the Kuznets curve, which analyze the marginal variation of pollution in the productivity and income of the population. As in Akinlo (2008), Zhang & Cheng (2009), Ghosh (2010), Borhan et al. (2012) and Shaari et al. (2017). In this research, we used linear regression of five distinct models, one for each economic sector.

A simple correlation between total CO2 emissions and GDP for Mato Grosso do Sul between 2002 and 2016 is shown in Figure 1.

7 R version 3. 4. 3 (2017-11-30) -- "Kite-EatingTree", Copyright (C) 2017 The R Foundation for StatisticalComputing. https://www. r-project. org/

Graph 1: Linear correlation between GDP *per capita* and Total CO2 Emissions in MS (2002 to 2016)



Source: BACEN and SEEG (2017).

The linear correlation between GDP growth and CO2 emissions in Mato Grosso do Sul shows an inverse relationship, since, as the economy grows, emissions decrease, in contrast to the studies of developed countries such as China, USA and France (Ang, 2008; Ghosh, 2010). This correlation brings initial evidence of clean energy production (use of hydroelectric plants), as well as the adoption of advanced technologies to increase productivity in the national agriculture[8] [8].

In Asia, Borhan et al (2012) and Shaari et al (2017) show evidence that there is a positive correlation between economic growth and CO2 emissions, especially in the energy generation sector.

In order to achieve this result, the models presented in Table 1, which show the results of the estimations of the five proposed models, were estimated, including the economic sectors that emit carbon dioxide carbon.

8 See: GASQUES, J. G. ; CONCEIÇÃO, J. C. P. R. Transformações estruturais da agricultura e produtividade total dos fatores. Text for Discussion n. 768. Brasília: Ipea, 2000.

Table 1: Results of Estimates of Econometric Models

	Dependent variable:				
	Energia	Agro	ProcInd	Res	Mut
	(1)	(2)	(3)	(4)	(5)
PIBpc	−5.217	−3.638	−4.829	−4.439*	5.925
	(4.205)	(2.080)	(3.719)	(2.221)	(11.361)
Pibpc2	0.287	0.187	0.281	0.262**	−0.354
	(0.217)	(0.107)	(0.192)	(0.114)	(0.585)
Constant	39.083*	35.069***	33.088*	32.286**	−7.026
	(20.372)	(10.076)	(18.018)	(10.758)	(55.039)
Observations	15	15	15	15	15
R^2	0.656	0.205	0.872	0.954	0.625
Adjusted R^2	0.599	0.072	0.851	0.946	0.562
Residual Std. Error (df = 12)	0.137	0.068	0.121	0.072	0.370
F Statistic (df = 2; 12)	11.446***	1.544	40.831***	123.849***	10.000***
Note:					*p<0.1; **p<0.05; ***p<0.01

The econometric analysis of the results of Table 1 allows, in the peculiar case of the waste sector, to perceive it as the only model that presented statistical significance, however, contrary to the Kuznets Curve in the scenario of Mato Grosso do Sul. evidence that increased *per capita income* decreases CO2 emissions, and, in the quadratic form, emissions increase, forming the "U" trajectory. The model has a good fit with R^2 of 0. 954. The empirical result shows that there is an optimal level of income for the lowest level of carbon dioxide emissions.

The models and data present empirical evidence of deceleration of CO2 emissions in the state of Mato Grosso do Sul resulting from the measures already adopted and a growing economic development, with the probable use of more sustainable technologies to increase productivity and power generation.

FINAL CONSIDERATIONS

The present study was motivated by the research question about the existence or not of economic development in Brazil and the state of Mato Grosso do Sul, with the maintenance of sustainability baselines relevant to global documents and agreements. The answer could indicate

the greater or lesser alignment of Brazil and the state under analysis with the parameters of sustainable development practiced in the world, indicating the productive potential for local development.

In order for this question to be answered, it was decided to follow the recommendations of recent studies that could relate indicators of economic development to those of impacts on the environment. The choice was based on the volume of carbon dioxide emission - a major greenhouse gas - and its comparison with GDP *per capita* - a relevant measure of economic progress by measuring the average production and distribution of wealth in one place. As a historical frame, it was defined that the period should range from an important sustainable development framework - which would impose stricter control measures on the emission of pollutants - until the date of the most recent data available at the time of this study.

In the end, it was verified that, both Brazil and the state of Mato Grosso do Sul, during the period under consideration, they performed economic development associated to the low relative emission of carbon dioxide. However, the analysis of the data leaves a great open question: would Brazil, in general, and the state of Mato Grosso do Sul, in particular, be endowed with such technical and technological development that would allow them to achieve economic growth with low emission of carbon dioxide, or is there any other exceptionality that would allow such a correction? This can be a topic of exploration for further research.

The present study also suggests that, in order to mitigate CO2 emissions and reduce the contribution of agriculture to greenhouse gas emissions, the most efficient strategies would be to reduce the burning of fossil fuels, minimize deforestation and soil, planting of species favorable to the rapid incorporation of surplus carbon - such as eucalyptus, for example - achieving, finally, the maximization of carbon sequestration, even in the most intensive productive activities, a fact present in the unit of the federation studied.

REFERENCES

AKINLO, A.E. Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries. In: Energy Economics, Elsevier, vol. 30(5), pages 2391-2400, 2008. Disponível em: <https://www.sciencedirect.com/science/article/pii/S014098830800025X>. Acesso em: 06.mai.2018.

ANG, J.B. CO_2 emissions, energy consumption, and output in France. In: Energy policy. Vol.35, pages. 4772-4778, 2007. Disponível em: <https://www.sciencedirect.com/science/article/pii/S0301421507001498>. Acesso em: 02.mai.2018.

APERGIS, N.; PAYNE, J. Energy consumption and economic growth in Central America: Evidence from a panel cointegration and error correction model. In: EconPapers, Economics at yourf inger tips. 2009. Disponível em: <https://econpapers.repec.org/article/eeeeneeco/v_3a31_3ay_3a2009_3ai_3a2_3ap_3a211-216.htm>. Acesso em: 02.mai.2018.

BANCO CENTRAL DO BRASIL (BACEN)

BANCO INTERNACIONAL PARA RECONSTRUÇÃO E DESENVOLVIMENTO/BANCO MUNDIAL. Estudo de baixo carbono para o Brasil. Relatório de Síntese Técnica. Uso da Terra, Mudanças do uso da Terra e Florestas. 2010. Disponivel em: <http://siteresources.worldbank.org/BRAZILINPOREXTN/Resources/3817166-1276778791019/UsoTerra_Final_Portugue.pdf>. Acesso em: 11.maio.2018.

BORHAN, H.; AHMED, E.M.; HITAM, M. The Impactof CO_2onEconomicGrowth in Asean 8. In: SciVerseScienceDirect, 2012. Disponível em: <https://ac.els- cdn.com/S1877042812004156/1-s2.0-S1877042812004156-main.pdf?_tid=d59356d3-ae00-4861-be2d-142dbfb47533&acdnat=1525228406_616b3e920fae1a9fb346576903aebd88>. Acesso em: 01.maio.2018.

Chien-Chiang Lee. The CausalityRelationshipbetween Energy Consumptionand GDP in G-11 Countries Revisited. Energy Policy, 34, no. 4. UK: Elsevier, 2006.

Chien-Chiang Lee. The CausalityRelationshipbetween Energy Consumptionand GDP in G-11 Countries Revisited. Energy Policy, 34, no. 4. UK: Elsevier, 2006.

COONDOO, D.; DINDA, S. Carbondioxideemissionandincome: A temporal analysisof cross-country distgributionalpatterns. In: ScienceDirect, Elsevier, 2008. Disponível em: <https://pt.scribd.com/document/242572213/Coondoo-and-Dinda-2008-pdf>. Acesso em: 03.mai.2018.

EPRON, D.; NOUVELLON, Y.; ROUPSARD, O.; MOUVONDY, W.; MABIALA, A.; SAINT-ANDRÉ, L.; JOFFRE, R. JOURDAN, C.; BONNEFOND J. M.; BERBIGIER, P.; HAMEL, O. Spatialand temporal variationsofsoilrespiration in a Eucalyptus plantation in Congo. Forest Ecologyand Management, Amsterdam, v. 202, n. 1-3, p. 149-160, 2004.

ESTADO DE MATO GROSSO DO SUL. Lei nº 4.555, de 15 de julho de 2014. Disponível em <http://aacpdappls.net.ms.gov.br/appls/legislacao/secoge/govato.nsf/448b683bce4ca84704256c0b00651e9d/c8e1c43dcb65a53104257d170051d5b1?OpenDocument>. Acesso em 14.mai.2018.

GASQUES, J.G.; BASTOS, E.T.; VALDES,G.; BACCHI, M.R.P.; Produtividade da agricultura. Resultados para o Brasil e estados selecionados. In Revista de Política Agrícola. Ano XXIII, n°3, jul./ago./set.2014. Disponível em: https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1003973/1/Produtividadedaagricultura.pdf. Acesso em: 08.abr.2018.

GHALI, K.H.; EL-SAKKA, M. Energy use and output growthin Canada: a multivariatecointegrationanalysis. In: EconPapers, Economicsatyourfingertips, 2004. Disponível em: <https://www.sciencedirect.com/science/article/pii/S0140988303000562>. Acesso em: 02.maio.2018.

GUJARATI E PORTER; Análise de Regressão Linear Múltipla . Instituto de Ensino e Pesquisa. Capítulo 7 e 8, 2011.

GUO L. B; GIFFORD, R. M. Soilcarbon stocks andland use change: a meta analysis. Global ChangeBiology, Chichester, v. 8, p. 345-360, 2002.

INDÚSTRIA BRASILEIRA DE ÁRVORES - IBÁ. Anuario estatístico da IBA: ano base 2014- 2015, 2015. 80 p

INFOAGRO. Balanço anual do agronegócio sul-mato-grossense 2013/2014. Campo Grande, MS: SENAR/MS; FAMASUL, 2015. 494 p.

INSTITUTO DE PESQUISA ECONÔMICA APLICADA (IPEA), Desafio

do desenvolvimento. Revista de informações e debates do Instituo de Pesquisa Econômica Aplicada. Ano 10, ed.78, 16/01/2014. Disponivel em: http://www.ipea.gov.br/desafios/index.php?option=com_content&view=article&id=2973:catid=28&Itemid=23. Acesso em 20.mar.2018.

INTERNATIONAL ENERGY AGENCY (IEA). Decouplingof global emissionsandeconomicgrowthconfirmed. 2016. Disponível em: https://www.iea.org/newsroom/news/2016/march/decoupling-of-global-emissions-and-economic-growth-confirmed.html. Acesso em: 05.abr.2018.

KANG, S.; DOH, S.; LEE, D.; LEE, D.; JIN, V.L. & KIMBALL, J. Topographic and climatic controls on soil respiration in six temperate mixed-hardwoodforestslopes, Korea. Global Change Biology, Chichester, v. 9, p.1.427-1.437, 2003.

KASSNAYER, K.; NETO, H. J. F. A entrada em vigor do Acordo de Paris: o que muda para o Brasil? Textos para Discussão. Núcleo de Estudos e Pesquisa da Consultoria Legislativa. Senado Federal. Vol.215, 2016. Disponível em: <https://www12.senado.leg.br/publicacoes/estudos-legislativos/tipos-de-estudos/textos-para-discussao/td215> . Acesso em 04.maio.2018.

KRAFT, J; KRAFT, A. On the Relationship between Energy and GNP. In: Journal of Energy and Development, Ed.3, pg. 401-403, 1978.

LA SCALA, N.; DE FIGUEIREDO E. B., PANOSSO A. R. A review on soil carbonic cumulation due to the management change of major Brazilian agricultural activities. Brazilian Journal of Biology, São Carlos, v. 72, n.3, p. 775-785, 2012.

LEE, C.C. Energy consumption and GDP in developing countries: A cointegrated panel analysis. In: Energy Economics, 2005. Disponível em: <https://econpapers.repec.org/article/eeeeneeco/v_3a27_3ay_3a2005_3ai_3a3_3ap_3a415-427.htm>. Acesso em: 03.maio.2018.

LEE, C.C. The Causality Relationship between Energy Consumption and GDP in G-11 Countries Revisited. Energy Policy, 34, no. 4. UK: Elsevier, 2006. Disponível em: https://www.sciencedirect.com/science/article/pii/S030142150500128X. Acesso em: 07.maio.2018.

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E

COMUNICAÇÕES (MCTIC) E ONU MEIO AMBIENTE. Trajetórias de mitigação e instrumentos de políticas públicas para alcance das metas brasileiras no Acordo de Paris. Pag. 15, Brasilia/DF, 2017. Disponível em: http://sirene.mcti.gov.br/documents/1686653/2098519/Trajetorias-Ebook-b_final.pdf/29c11698-b71d-4009-850c-a162090e1108. Acesso em 07.naio.2018.

MINISTÉRIO DO MEIO AMBIENTE (MMA), REPÚBLICA FEDERATIVA DO BRASIL PRETENDIDA, CONTRIBUIÇÃO NACIONALMENTE DETERMINADA PARA CONSECUÇÃO DO OBJETIVO DA CONVENÇÃO-QUADRO DAS NAÇÕES UNIDAS SOBRE MUDANÇA DO CLIMA, 2016. Disponível em: <http://www.mma.gov.br/images/arquivo/80108/BRASIL%20iNDC%20portugues%20FINAL.pdf> . Acesso em: 04.mao.2018.

ORGANIZAÇÃO DAS NAÇÕES UNIDAS (ONU). Disponível em: <https://nacoesunidas.org/?s=cop+3>. Acesso em: 01.maio.2018.

ORGANIZAÇÃO DAS NAÇÕES UNIDAS PARA EDUCAÇÃO, CIÊNCIA E A CULTURA (UNESCO). Biosphere Reserve Information – The Pantanal Biosphere Reserve. MAB – Man and Biosphere Programme. Biosphere Reserves Directory, 2000. Disponível em: <http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?code=bra+03&mode=all>. Acesso em: 02.maio.2018.

Relatório anual GREENPEACE, 2009. Disponível em: <http://www.greenpeace.org/brasil/Global/brasil/report/anual/2009.pdf> Acesso em: 02.maio.2018.

SARTORI, F.; LAL, R.; EBINGER, M. H.; PARRISH, D. J. Potential soil carbon sequestration and CO_2 offset by dedicated energy crops in the USA. Critical Reviews in PlantSciences, New York, v. 25, n. 5, p. 441-472, 2006.

SGS – Sistema Gerador de Séries Históricas. Banco Central do Brasil. Disponível em <https://www3.bcb.gov.br/sgspub/localizarseries/localizarSeries.do?method=prepararTelaLocalizarSeries>. Acesso em: 14.mai.2018.

SHAARI, M.S.; RAZAK, N.A.A.; BASRI, B.H.; The effects of electricity consumption and economic growth on Carbon Dioxide emission. In: International Journal of Energy Economics and Policy, vol. 7, 2017. Disponível em: < http://econjournals.com/index.php/ijeep/article/

view/5279>. Acesso em: 03.maio.2018.

SIGA-MS. Sistema de Informação Geográfica do Agronegócio de Mato Grosso do Sul. 2016. Disponível em: <http://www.sigaweb.org/ms/sistema>. Acesso em: 01.abr.2018.

Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG). Disponível em: http://plataforma.seeg.eco.br/total_emission. Acesso em: 01.maio.2018.

TIWARI, A.K., Energy consumption, CO_2 emissions and economic growth: A revist of the evidence from India. In: Applied Econometrics and International Development. Vol.11-2, 2011. Diposnivel em: http://www.usc.es/economet/journals1/aeid/aeid11212.pdf. Acesso em: 07.mar.2018.

ZHANG, X.P.; CHENG,X.M.; Energy consumption, carbono emissions, and economic growth in China. In: Econ Papers, Economics at your fingertips. Vol.68, 2009. Disponível em: https://econpapers.repec.org/article/eeeecolec/v_3a68_3ay_3a2009_3ai_3a10_3ap_3a2706-2712.htm. Acesso em: 02.maio.2018.