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SUGARCANE INDUSTRY EFFECTS ON THE GDP PER CAPITA IN THE CENTER-SOUTH REGION OF BRAZIL

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ABSTRACT

The demand growth for biofuels worldwide led to a significant increase in the Brazilian sugarcane industry from the 2000's. This scenario affected specially the Center-South region of Brazil, which comprises the states of São Paulo, Paraná, Minas Gerais, Mato Grosso do Sul, Mato Grosso, and Goiás, as well as the Federal District of Brasília, because it surpasses all other regions of the country in terms of the production and production facilities. Therefore, the aim of this study is to quantify the sugarcane industry effects on the per capita municipal gross domestic product (GDP) in the Center-South region of Brazil, for the 2000-2012 period. To this end, we estimated two econometric models, using panel data models and quantile regression. The results show that sugarcane industry has an important effect on GDP per capita for the Center-South region municipalities, furthermore the effects are more intensive on the lowest municipalities levels of the per capita GDP, thus being able to provide support for making public policy.

Keywords: Sugarcane industry; panel data models; quantile regression; GDP per capita.

RESUMO

A crescente demanda por energia renovável em um contexto mundial levou a agroindústria canavieira no Brasil a um aumento significativo nos anos 2000. Esse cenário afetou, sobretudo, a região Centro-Sul, que compreende os estados de São Paulo, Minas Gerais, Mato Grosso do Sul, Mato Grosso e Goiás, assim como o Distrito Federal, porquanto tal região representa majoritariamente a produção e o processamento no país. Assim, o objetivo deste estudo é quantificar os efeitos da agroindústria canavieira sobre o PIB *per capita* municipal na região Centro-Sul do Brasil, para o período de 2000 a 2012. Para tanto, foram estimados dois modelos econométricos, modelo de dados em painel e regressão quantílica. Os resultados mostram que a agroindústria canavieira tem um importante efeito no PIB *per capita* dos municípios da região Centro-sul, ademais, sinaliza que os impactos são mais intensos em municípios com baixos níveis do PIB *per capita* municipal, em que tais resultados podem servir de embasamento para políticas públicas desse setor.

Palavras-chave: Agroindústria canavieira; modelo de dados em painel; regressão quantílica; PIB *per capita* municipal.

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INTRODUCTION

Countries seeking to mitigate greenhouse gas emissions – GHG – by introducing ethanol into their energy mix, have begun to pay close attention to the renewable energy sources, including biofuel derived from sugarcane. In the Brazilian case, the demand growth for biofuels worldwide as well as in the internal market, led to a significant increase of sugarcane industry from the 2000's, both in terms of the production expansion as the installation of new production facilities, which included investments by domestic and foreign companies (BACCHI; CALDARELLI, 2015).

The sugarcane production growth in Brazil was accompanied by significant investments in the construction of new ethanol facilities, mainly in the Brazilian Center-South region – São Paulo, Paraná, Minas Gerais, Mato Grosso do Sul, Mato Grosso, and Goiás states, as well as the Federal District of Brasília (TALAMINI et al., 2012; MORAES; ZILBERMAN, 2014). Besides, this growth has also stimulated investments through the production chain.

From 2000 to 2012, the auspicious external scenario for biofuels contributed for pronounced acceleration in the growth of the sugarcane industry in Brazil. The sugar production grew from 16.18 to 38.25 billion of tons per year and the ethanol production raised from 10.59 to 23.23 billion of liters per year. The external trade indicators also show vigorous growth in this period, the exports of sugar and ethanol increased 273.84% and 1304.54%, respectively (UNICA, 2015).

In this context, several studies highlight evidences of the possibility of the economic growth arising from the sector, reflected on job market and income creation, which can generate positive net benefits especially for the low-income Brazilian's population. However, there is no consensus on the scientific literature about this effect for Brazil. Several studies point out the need to offer a comprehensive sustainability assessment regarding biofuels. On the other hand, it is observed in the literature a relatively limited appraisal of the social and wellness aspects related to the growth of biofuel production (GILIO, 2015).

Thus, this study aims to quantify the sugarcane ethanol industry effects on the per capita municipal gross domestic product (GDP), in the Center-South region of Brazil, between 2000 and 2012. To that end, a theoretical model was constructed and estimated using two methodological approaches: panel data models and quantile regression. The panel data model evaluates the mean effects of the sugarcane, sugar and ethanol sector on the GDP per capita takes into account heterogeneity across units. By the other hand, the quantile regression allows to measure these effects on the GDP per capita conditional distribution, considering the different levels of the municipalities GDP per capita – quantiles. So, using the different econometric tools, it was evaluated the mean effects of the ethanol sugar sector on the municipal per capita GDP, and the specific effects in each quantile – 25, 50 and 75 –, that represents different levels of municipalities development.

The time period – 2000 to 2012 – is justified because it represents the most accelerated growth occurred in this sector in Brazil. Furthermore, the Center-South region was chosen because the aforementioned expansion occurred mainly in this region. According to MAPA (2015) and UNICA (2015), in 2012, the Brazilian Center-South region represented 84.58% of the sugarcane harvest in Brazil, above 89% of the sugar production and more than 91% of the ethanol production.

SUGARCANE ETHANOL INDUSTRY IN BRAZIL: AN OVERVIEW

The deregulation of the sugarcane and ethanol sector in Brazil, a gradual process that was not complete until 1999, reorganized the relationship among the actors along the entire production chain. The most important change was in the fact that many of the functions previously exercised by the government became the responsibility of the various stakeholders (MORAES; ZILBERMAN, 2014). Furthermore, many changes occurred in the post-deregulation period contributed for an upward trend in this market in Brazil, such as the international scenario of growing demand for biofuels post-2000, the introduction in Brazil of the flex-fuel vehicles in 2003 and public policies promoting the use of the biofuels, such as blending mandates (TALAMINI et al., 2012).

According to Chagas, Toneto and Azzoni (2012), the main result of the Brazilian institutional and organizational changes that have affected the sugar and ethanol sector in Brazil in 2000's is the importance of the debate about the competitiveness in this sector; greater competitiveness can generate pressure on the area to other activities, such as stock breeding, grain and fruit growing (including soybeans), besides pushing the agricultural frontier into native forests (Figure 1).

As shown in Figure 1, sugarcane area in Brazil has been increasing since early 2000's. Nowadays, Brazil has the largest sugarcane area/production in the world[1], producing about 25 percent of the world production and about half of world exports (FAO, 2015). From the harvest 2000/01 to 2012/13 the sugarcane area in Brazil has expanded 4.87 million of hectares, approximately 99% of growth. It is important to highlight that this expansion is more considerable in the Center-South region of the Brazil which represents approximately 87% of the sugarcane area in Brazil.

[1] Sugarcane is used to produce both sugar and ethanol. On average about 50% is used to produce sugar and 50% to produce ethanol (MORAES; ZILBERMAN, 2014).

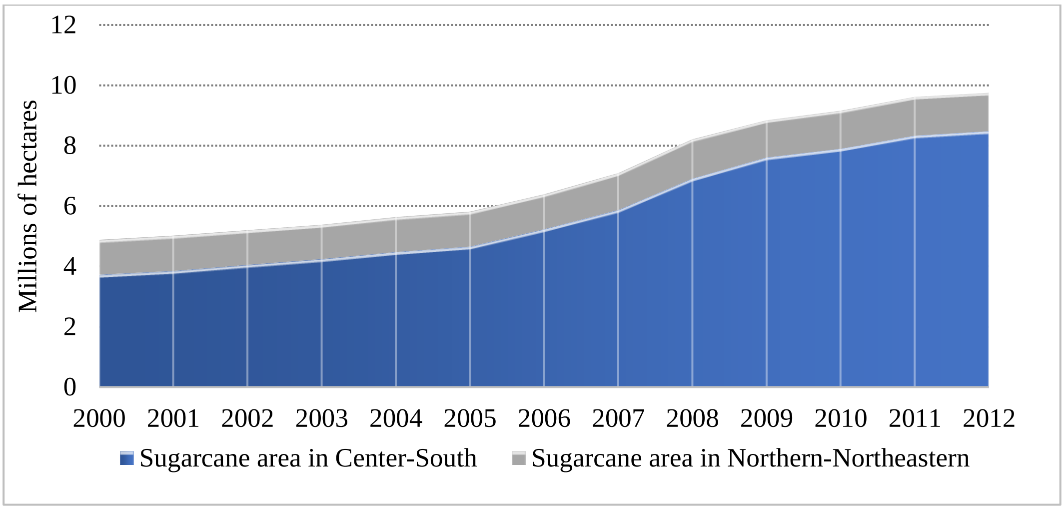

Figure 1. Evolution of sugarcane area in Brazil (millions of hectares) – from harvest 2000/01 to 2012/13

Source: Brazilian Sugarcane Industry Association (UNICA, 2015) and Brazilian Institute of Geography and Statistics (IBGE, 2015).

Figure 2 represents the Brazilian spatial distribution of the sugarcane industry in Brazil, the map indicates where sugarcane is harvested.

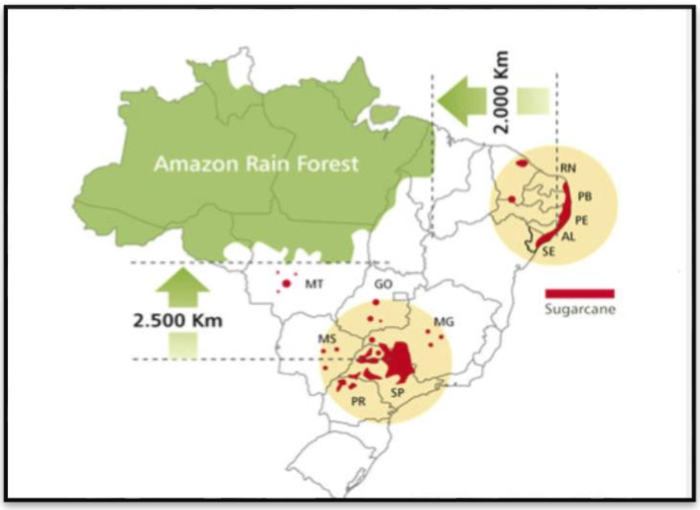

Figure 2. Sugarcane production regions in Brazil

Source: Brazilian Sugarcane Industry Association (UNICA, 2015).

Sugarcane has been currently the largest renewable source of energy in Brazil, with a very important participation in the Brazilian energy matrix (more than 19% in 2010), ethanol is an advanced biofuel that reduces GHG emissions more than 60% compared to gasoline. Besides, several prominent researches have been highlighted the decisive role of the second-generation ethanol and the electric energy production – trough cogeneration – in the mix of global energy (HOFSETZ; SILVA, 2012).

Regards the regional distribution of the sugar and ethanol production, as can be seen in Table 1, the sugar mills and ethanol distilleries are also concentrated in the Brazilian Center-South region. Table 1 shows the evolution of the sugarcane, sugar and ethanol production between the harvests 2000/01 and 2012/13 for Brazil and their regions.

Table 1. Production of sugarcane, sugar and ethanol in Brazil – harvest 2000/01, 2005/06 and 2012/13

		Sugarcane		**Sugar**		**Ethanol**	
Harvest	**Region**	Million tonnes	%	Millions tonnes	%	Billion liters	%
2000/01	Northern/Northeastern	49.72	19.36	3.55	21.94	1.53	14.42
	Center-South	207.10	80.64	12.64	78.06	9.06	85.58
	Nationwide	256.82	100	16.20	100	10.59	100
2005/06	Northern/Northeastern	48.35	12.55	3.81	14.75	1.51	9.54
	Center-South	336.78	87.45	22.02	85.25	14.31	90.46
	Nationwide	385.13	100	25.82	100	15.82	100
2012/13	Northern/Northeastern	55.72	9.47	4.15	10.85	1.86	8.03
	Center-South	532.76	90.53	34.10	89.15	21.36	91.97
	Nationwide	588.47	100	38.25	100	23.23	100

Source: Brazilian Ministry of Agriculture, Animal Husbandry, and Supply (MAPA, 2015) and Brazilian Sugarcane Industry Association (UNICA, 2015).

Between the harvest of 2000/01 and 2012/13 (Table 1), sugarcane production in Brazil increased from 256.82 million tonnes to 588.47 million tonnes (growth of 129.14%), sugar production increased from 16.20 million tonnes to 38.25 million tonnes (growth of 136.11%) and the ethanol production increased from 10.59 billion liters to 23.23 billion liters (growth of 119.36%).

As suggested by Moraes, Bacchi and Caldarelli (2016), Moraes and Zilberman (2014), the observed production increment, especially in the Center-South region (Table 1), was made possible by the recent demand growth for biofuels around the world and the increase in the sugar exports, factors that contributed for considerable investments for the expansion of existing facilities and for the construction of new ones.

Table 2 shows the data related to external trade indicators for sugar and ethanol between 2000 and 2012, for Brazil and Center-South region. As can be seen, Brazilian ethanol exports increased from approximately 0.22 billion liters in 2000 to 3.09 billion liters in 2012, a 1304.54% increase. Although the growth rate is expressive, it is important to emphasize that ethanol exports represented in the harvest 2012/2013 about 15% of the national production. Likewise, between 2000 and 2012, the exports of sugar increased from approximately 0.65 billion tonnes to 2.43 billion tonnes, an increase of 273.84%, representing in harvest 2012/2013 about 70% of the production; the Center-South region represents 92% of ethanol production and 89% of sugar production.

Brazil has an important position in the international market for ethanol; the country possesses all the necessary resources and conditions to continue expanding its domestic ethanol production. The enormous potential for agricultural expansion, enabling it to increase ethanol supply to meet the demand. Apart from that sugarcane fits Brazil's tropical climate and soil conditions and presents a higher energy balance compared to other feedstocks used for ethanol production, such as corn and wheat (HOFSETZ; SILVA, 2012).

Table 2. Brazilian exports of ethanol (billions of liters) and sugar (billions of tons) – from 2000 to 2012

	Ethanol Billion liters		**Sugar** Billion tonnes	
Years	Brazil	Center-South	Brazil	Center-South
2000	0.22	0.18	0.65	0.53
2001	0.34	0.29	1.11	0.90
2002	0.78	0.57	1.33	1.13
2003	0.75	0.45	1.29	1.07
2004	2.40	1.83	1.57	1.31
2005	2.60	2.06	1.81	1.55
2006	3.41	2.96	1.88	1.63
2007	3.53	3.05	1.93	1.71
2008	5.11	4.60	1.94	1.61
2009	3.30	3.02	2.42	2.15
2010	1.90	1.77	2.79	2.51
2011	1.96	1.78	2.53	2.24
2012	3.09	2.90	2.43	2.19

Source: Brazilian Sugarcane Industry Association (UNICA, 2015).

Despite the importance of the socioeconomic effects of the sugarcane, sugar and ethanol sector in Brazil, the literature on this area is scarce and the results are sometimes divergent. It can be seen in the literature a relative shortage of research on the evaluation of socioeconomic impacts of sugarcane ethanol expansion, in contrast to the further exploration of the agronomical and environmental aspects. Besides, the majority of the existent literature on the impacts of the sugarcane industry is related to the State of São Paulo.

Therefore, the empirical analysis developed in this paper, and described in the following sections, seeks to contribute to the empirical evaluation of the effects of the expansion in the sugarcane industry in the Center-South region of Brazil, focusing in the socioeconomic indicators. More particularly, this study will assess the socioeconomic effect through effects on the municipal gross domestic product (GDP) per capita in the Center-South region of Brazil for the 2000 - 2012 period. Besides, we have considered municipalities different levels of development, given the lack of studies with this approach.

METHODOLOGICAL PROCEDURES

We address the issue of the effects of sugarcane industry on GDP per capita of the Brazilian Center-South municipalities in two different methodological approaches. First, we conduct a panel data analysis according to steps proposed by Greene (2008) to measure the mean impacts taking into account differences in behavior across individuals. Second, in order to measure the impacts considering different municipalities' levels of GDP per capita – conditional distribution –, a quantile regression approach is adopted as described by Koenker and Bassett (1978) and Koenker (2005).

Panel data models

Panel data, also known as longitudinal or cross-sectional time series data, is a data set in which the behavior of individuals/units are observed across time. Data sets that combine time series and cross-section are common; these kinds of datasets provide a rich source of information (GREENE, 2008).

This study uses a panel data analysis because it allows measuring the socioeconomic impacts of the sugar and ethanol sector in municipalities across time. According to Stock and Watson (2007), the methodology takes into account heterogeneity across units, and the analysis allows controlling for variables that change over time but not across individuals/units (national policies, federal regulations, international agreements). Therefore, there is a great flexibility in modeling differences across individuals. According to Greene (2008), the basic framework for i units and t periods is a regression model as:

$$y_{it} = x_{it}'\beta + z_i'\alpha + \varepsilon_{it} \quad (1)$$

where there are k regressors in $\boldsymbol{x}_{i\,t}$ and the main objective of the analysis will be consistent and efficient estimation of the partial effects **(β)**,

$$\beta = \frac{\partial E(y_{it}|x_{it})}{\partial x_{it}} \qquad (2)$$

The heterogeneity is $\boldsymbol{z}_i'\boldsymbol{\alpha}$, where $\boldsymbol{z}_i$ contains a set of individual or group specific variable which may be observed or sometimes unobserved – are the set of missing variables. There are different kinds of panel data structures; which depend of the missing variables $\boldsymbol{z}_i$, that is:

i. Pooled regression – if z_i contains only a constant term, there is a common effect (α) – intercept;
ii. Fixed Effects – if the z_i is unobserved and correlated with $x_{i\,t}$;
iii. Random Effects – if the z_i is unobserved and uncorrelated with $x_{i\,t}$.

The Fixed Effects model are used whenever you are only interested in analyzing the impact of variables that vary over time, and the Random Effects model assume that the entity's error term is not correlated with the predictors which allows for time-invariant variables to play a role as explanatory variables. In Random Effects model you need to specify those individual characteristics that may or may not influence the predictor variables (STOCK; WATSON, 2007). Some tests are performed to decide which model fits better, as Hausman, Breusch-Pagan and Chow test (GREENE, 2008).

Quantile regression

Quantile regression, as defined by Koenker and Bassett (1978), is a method for estimating functional relations between variables for all portions of the probability distribution – different quantiles (τ). These models express the quantiles of the conditional distribution as linear functions of the independent variables, therefore quantile regression allows for effects of the independent variables to differ over the quantile.

As described by Koenker (2005), quantile regression models permits many new possibilities for statistical analysis and interpretation of economic data, because this analysis allows comparing how some percentiles may be more affected by certain characteristics than others. This is reflected on the size change of the regression coefficient.

The conditional quantile is denoted by:

$$Q_t(y_{it}|x_{it}) = x_{it}'\beta_\tau + z_i'\alpha(\tau) \qquad (3)$$

For this study, we consider that $\boldsymbol{z}_i$ contains only a constant term.

Furthermore, we could test if the coefficients across different quantiles are equal. For this an *F test* may be performed; additionally, the comparison between quantiles could be obtained by interquantile range – difference between coefficients.

The pseudo R^2 for this kind of regression is obtained as:

$$pseudoR^2 = 1 - \frac{\text{sum of weighted deviations about estimated quantile}}{\text{sum of weighted deviations about raw quantile}} \quad (4)$$

The advantage of using quantile regression to modeling the effects related to the existence of sugarcane industry in the municipality GDP per capita is the possibility to compare these impacts according to the different municipalities' levels of GDP per capita. An important advantage in using quantile regression over mean regression is to consider that the effects of the independent variables may vary over quantiles of the conditional distribution of the dependent variable.

Empirical strategy and data

We build an empirical model of the determinants of municipal GDP per capita. The model was based on the precedent discussion of Moraes, Bacchi and Caldarelli (2016), Bacchi and Caldarelli (2015) and Satolo and Bacchi (2013).

The proposed model can be expressed by the following equation:

$$\text{GDP}_{it} = \alpha_0 + \alpha_1 \text{Du}_{it} + \alpha_2 \text{Part}_{it} + \alpha_3 \text{va\_a}_{it} + \alpha_4 \text{va\_i}_{it} + \alpha_5 \text{income}_{it} + \alpha_6 \text{Dens}_{it} + \varepsilon_{it} \quad (5)$$

where $GDP_{i\,t}$ is the municipal GDP per capita; Du_{it} is a dummy variable (binary) that indicates the presence of sugarcane processing facility in the municipality; $Part_{it}$ is a proportional representation of sugarcane in the municipal area; va_a_{it} means the rate of agriculture on the total value added in the municipality; va_i_{it} is the rate of industry on the total value added; $Income_{it}$ is the total real means income and; $Dens_{it}$ means the Demographic density. Given the empirical strategy, the database employed and respective nomenclature are summarized in the Table 3.

The database contained data from various sources. Data related to GDP per capita (in R$) and population data – used in order to construct the variable density (number of habitants/municipality area) –, were obtained from the IBGE site, Brazilian Institute of Geography and Statistics (IBGE, 2015).

The binary variable indicating the presence/absence of a sugar mill or ethanol plant in a municipality was constructed from data obtained from the Sugarcane Statistical Yearbook, from the sugarcane processing facility registry of the Brazilian Ministry of Agriculture, Animal Husbandry, and Supply, and from the Brazilian Sugarcane Industry Association.

Municipal data related to land use (for sugarcane, temporary crops, and permanent crops) were obtained from the Municipal Agricultural

Research tool and Automated Data Recovery System of the Brazilian Institute of Geography and Statistics (IBGE, 2015).

Table 3. Variables description and labels

Variable	Label
Municipal GDP per capita (in 2012 US$)	*GDP*
Dummy that indicates whether a sugarcane processing facility is in operation in a given municipality (0 = no; 1 = yes)	*Du*
Proportional representation of sugarcane in the municipal area (%)	*Part*
Rate of agriculture on total value added (%)	*va_a*
Rate of industry on total value added (%)	*va_i*
Total real mean income (in 2012 US$)	*Income*
Demographic density (hab/km²)	*Dens*

Source: Authors.

The variables rate of agriculture on total value added and rate of industry on total value added were constructed using IPEADATA information - Institute for Applied Economic Research (IPEA, 2015).

Data related to average incomes were obtained from the Annual Social Information Report issued by the Brazilian Ministry of Labor and Employment (RAIS, 2017).

Results in Brazilian reals were converted to US dollars at the mean commercial exchange rate for 2012.

The analysis was conducted for all municipalities of the Brazilian Center-South region – 2363 municipalities – , which comprises the states of São Paulo, Paraná, Minas Gerais, Mato Grosso do Sul, Mato Grosso, and Goiás, as well as the Federal District of Brasília, for the period of 2000 to 2012.

RESULTS AND DISCUSSION

The results, presented in Figure 3, correspond to the analysis of the GDP per capita and total real mean income evolution comparing municipalities with and without sugarcane processing facilities for the Brazilian Center-South Region (from 2000 to 2012). As can be seen, in general, the set of municipalities with sugarcane processing facilities have better results when compared to the set of other municipalities. The GDP per capita (mean) is 60% higher in the municipalities with sugarcane processing facilities and the total real mean income (mean) is 18% higher.

Within the period analyzed (Figure 3) it is possible to observe that the growth of the GDP per capita and the total real mean income are higher in the municipalities with sugarcane processing facilities. According Satolo and Bacchi (2013) the presence of sugarcane processing facility drives economic growth in municipalities in Brazil. In support of that assertion, various other authors have demonstrated that such facilities not only create jobs directly but also have indirect effects on the local business sector and service industry, therefore when there is the growth of the sugarcane industry, various other sectors of the economy benefit and the growth extends throughout the economy, because of the interactions among sectors (BACCHI; CALDARELLI, 2015; GILIO, 2015).

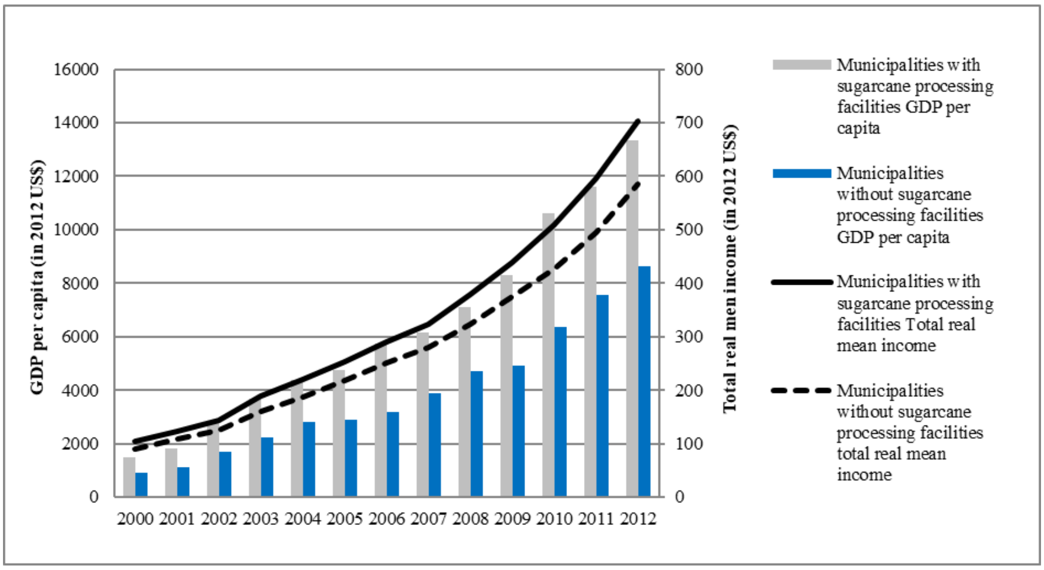

Figure 3. Evolution of the GDP per capita and total real mean income in the Brazilian Center-South region (in 2012 US$) – between 2000 and 2012

Source: Brazilian Institute of Geography and Statistics (IBGE, 2015), Brazilian Sugarcane Industry Association (UNICA, 2015) and Institute for Applied Economic Research (IPEA, 2015).

A similar procedure was done for São Paulo by Walter et al. (2011) for the years 1991 and 2000, but taken into account the set of municipalities with and without sugarcane production. The authors indicated that in municipalities where sugarcane production was relevant, the socioeconomic impacts were positive. In addition, Moraes, Oliveira and Diaz-Chaves (2015), comparing socioeconomic indicators for the sugarcane sector and the overall agricultural sector for Brazil, have found that the sugarcane sector has better results than the agricultural sector, especially on the job market.

In order to measure the socioeconomic effects of the presence of sugar and ethanol production in the Center-South region, the econometric analysis mentioned previously was performed. The results of the panel data model are presented in Table 4. The data base, as summarized in Table 6 (Appendix), suggested that the set of information has heterogeneity across units, because the units (municipalities) are heterogeneous and the standard deviations (*between*) are considerably high. This result is corroborated by the Chow test, which rejects the null hypothesis of the homogeneity between units (Table 4).

The Fixed Effects model coefficients (Table 4) suggest that there is a positive and statistically significant impact between the explanatories variables sugarcane processing facilities (*Du*) and proportional representation of sugarcane in the municipal area (*Part*) and the dependent variable GDP per capita. This result, in the case of variable *Du*, shows that municipalities with the presence of mills and/or distilleries have a GDP per capita 13.34% higher than municipalities that do not have. Whereas, the coefficient for the *part* variable (elasticity of 0.16) – indicates that an increase of 1% in the share of sugarcane in the municipal area results a GDP per capita 0.16% higher; the municipal GDP per capita have been widely influenced by the existence of sugarcane processing facilities (*Du)* than sugarcane cultivation area (*Part*). These results are according to the previous estimates by Bacchi and Caldarelli (2015) and Walter et al. (2011).

Table 4. Effects of the sugarcane ethanol industry on the GDP per capita of the Center-South region– elasticities – using panel data analysis (Fixed Effects)**

Variable*	Coefficients	*t-test*****	P>|*t*|
*Du****	0.13	5.38	0.00
Part	0.16	1.79	0.07
va_a	-0.11	-1.53	0.07
va_i	0.03	1.43	0.13
Income	1.15	7.55	0.00
Dens	-0.70	-17.33	0.00
Consant	8.74	41.90	0.00

F test (18; 28.33) = 31933.01 *p-value* (0.00)
Breusch-Pagan test = 11.00 *p-value* (0.00)
Chow test – F(2,362; 28.33) = 101.00 *p-value* (0.00)
Hausman test = 3,893 *p-value* (0.00)
Wald test for years binaries – F(12; 28.33) = 2158.31 *p-value* (0.00)

*Binaries variables for years were used to estimate the model, but the results were omitted.
** The fixed effects model was chosen based on Chow, Breusch-Pagan and Hausman tests results.
*** Coefficient DU is not directly interpreted as elasticity, must be calculated as $(e^{Du} - 1).100$.
**** Robust option was used for estimative.
Source: Authors.

The estimated model (Table 4) has satisfactory adjustment, the control variables *Du*, *Part*, *va_a*, *Income*, *Dens* and binaries variables for years are statistically significant (individual significance by *t-test* at 10% of significance) and the signs are as expected by the theoretical model – excluding *Dens* variable –, thus the explanatory variables set has a significant influence on dependent variable (GDP per capita). The *F* test indicates that the set of explanatory variables are explaining the variations in GDP; the model is satisfactory fit.

The previous literature about socioeconomic effects of the sugar and ethanol sector in Brazil has pointed that this sector is important to economic growth and economic development (CHAGAS; TONETO; AZZONI, 2012; WALTER et al., 2011; MORAES; ZILBERMAN, 2014; BACCHI; CALDARELLI, 2015; MORAES; OLIVEIRA; DIAZ-CHAVES, 2015; MORAES; BACCHI; CALDARELLI, 2016).

In this sense, Satolo and Bacchi (2013) has stated that the presence of the sugar and ethanol sectors improved the regional economic development for the municipalities of the state of São Paulo in the period analyzed by the authors – from 2000 to 2008. In addition, Moraes, Oliveira and Diaz-Chaves (2015), examining the characteristics of the workforce, pay and working conditions in the sugar and ethanol sector in Brazil, have showed that this sector better off in the performance of the selected indicators than the agricultural sector as a whole in the 2000's.

However, besides these studies are made only considering the State of São Paulo, they have not focused on the differences between municipalities or regions conditional distribution, in the other words, if the impacts are uniform between the different municipalities' levels of economic development – GDP per capita. Therefore, to compare these impacts according to the different municipalities' levels of GDP per capita, a quantile regression is used.

The estimative using quantile regression according to the conditional distribution of the dependent variable – quantiles 0.25, 0.50 and 0.75 – are presented in Table 5. In this point we are interested in better understanding the effects of the sugar and ethanol sectors on different municipalities' levels of GDP per capita.

The results for quantile regression models (Table 5) also present satisfactory adjustment, all the control variables – *Du*, *Part*, *va_a*, *va_i*, *Income* and *Dens* – including the binaries variables for years are statistically significant (individual significance by *t-test* at 1% of significance) and the *pseudo* R^2 for different quantiles are reasonable for this kind of regression. It is also important to observe that coefficients signs and values for quantile regression are not substantially different from the Fixed Effects Model (Table 4).

The results presented on Table 5 corroborate our earlier findings, using panel data analysis – Fixed Effects Model –, in suggesting a closer relation between sugarcane processing facilities and GDP per capita. Concerning to *Du* variable the estimated coefficients – elasticity – are 15.10%, 11.98% and 6.26%, respectively for the quantiles 0.25, 0.50 and 0.75 (significance by *t-test* at 1% of significance). Here, it is important to highlight the fact that municipalities with low and medium levels of GDP per capita can be more positively impacted by sugarcane and ethanol sector than municipalities with higher levels of GDP per capita. Concerning to *Part* variable, the estimated coefficients (Table 5) pointed out that an increase of 1% in the share of sugarcane in the municipal area results a GDP per capita 0.35%, 0.30% and 0.24% higher, respectively for quantiles 0.25, 0.50 and 0.75 (significance by *t-test* at 1% of significance). These findings also corroborate the fact that sugar and ethanol sector, in this case harvest, affect more intensive the municipalities with medium and low levels of GDP per capita.

Table 5. Effects of the sugarcane ethanol industry on the GDP per capita of Center-South region – elasticities – using quantile regression

Quantile	Variable	Coefficients	*t-test****	P>|t|	pseudo R^2
0.25	*Du***	0.14	14.11	0.00	0.55
	Part	0.35	11.96	0.00	
	va_a	-0.26	-34.11	0.00	
	va_i	0.39	46.89	0.00	
	Income	1.10	60.26	0.00	
	Dens	0.04	10.06	0.00	
	Constant	-0.63	-6.11	0.00	
0.50	*Du***	0.11	12.32	0.00	0.52
	Part	0.30	10.52	0.00	
	va_a	-0.16	-22.03	0.00	
	va_i	0.26	31.04	0.00	
	Income	1.31	78.52	0.00	
	Dens	0.00	9.99	0.00	
	Constant	-0.67	6.61	0.00	
0.75	*Du***	0.06	4.94	0.00	0.48
	Part	0.24	6.72	0.00	
	va_a	-0.08	-9.89	0.00	
	va_i	0.18	20.96	0.00	
	Income	1.48	62.22	0.00	
	Dens	-0.04	-9.73	0.00	
	Constant	-0.66	-4.51	0.00	

*Binaries variables for years were used to estimate the model, but the results were omitted.

** Coefficient DU is not directly interpreted as elasticity, must be calculated as $(e^{Du} - 1).100$.

*** Robust option using bootstrap resampling was estimated to correct heteroskedastic errors.

***bootstrapping 100

Source: Authors.

Thus, according to the results, the presence of sugarcane facilities can contribute to the convergence of income about poorer municipalities towards more developed municipalities. These results are confirmed by Table 7 – Appendix –, that shows it is possible reject the null hypothesis that the coefficients of quantiles regression are the same significant at a 10% level of significance, confirming the differential impact between municipalities according to GDP per capita levels.

This result is too important to highlight the impacts of the sugarcane processing industry in the cities of the Center-South region, thus contributing to formulation of public policies for this sector, especially in cities with low and medium GDP per capita.

CONCLUSIONS

This research focuses on quantify and evaluate the effects of the sugarcane, sugar and ethanol sector on the GDP per capita in the Center-south region of Brazil, for the period between 2000 and 2012.

Our findings have evidenced that the sugarcane industry – facilities – has positive socioeconomic effects in the aforementioned region of Brazil – increases in the municipal GDP per capita. The results suggest that the sugarcane industry has an impact in the GDP per capita higher than sugarcane cultivation expansion.

In contrast to previous studies about socioeconomic impacts of the sugarcane, sugar and ethanol sector in Brazil, this study contributes to evaluate the impacts for center-south region of Brazil, while the majority of studies have considered São Paulo, furthermore this study consider a period longer than the previous studies have considered and taking into account different municipalities' levels of GDP per capita, using quantile regression.

The main contribution of this study, relative to previous studies, is to highlight how the large-scale production of sugarcane industry in Brazil has made a positive contribution to the development of host municipalities – income; as evidenced by increases in the municipal GDP per capita. The results are higher in municipalities with low levels of GDP per capita.

Hence, the results of this study could be an important base to policy makers distinguish that the main impacts of the sugarcane industry in Brazil is widely influenced by the existence of the sugarcane processing facilities.

It is expected that this article promote reflection on recent changes in the energy policy in effect in Brazil and how the ethanol industry could contributes for the biofuels production – renewable fuel supply – and for economic development. Therefore, it is pivotal the implementation of adequate public policies. In this regard, policy examples include a degree of control over the expansion of sugarcane production, support of the development of second-generation technologies and support to promote diversification, such as encouraging the development of biorefinaries.

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APPENDIX I

Table 6 – Summary of the variables

Variables		Mean	Standard deviation	Min	Max	Observations
GDP	*overall*	8475.91	10633.96	387.81	285619.20	N=30719
	Between		7626.40	1803.93	117118.60	n=2363
	Within		7412.27	-97780.56	208358.80	T=13
Part	*overall*	55.94	13.43	0.00	92.00	N=30719
	Between		12.71	0.00	88.00	n=2363
	Within		4.34	-4.77	74.59	T=13
va_a	*overall*	25.89	16.82	0.00	89.22	N=30719
	Between		16.12	0.00	83.60	n=2363
	Within		4.82	-6.13	70.26	T=13
va_i	*overall*	18.00	14.35	0.76	93.15	N=30719
	Between		13.78	1.47	90.46	n=2363
	Within		4.04	-19.38	67.92	T=13
Income	*overall*	579.69	354.83	0.00	4528.96	N=30719
	Between		141.53	334.41	1661.04	n=2363
	Within		325.39	-892.13	4231.69	T=13
Dens	*overall*	118.88	659.94	0.18	13023.09	N=30719
	Between		659.06	0.28	12443.42	n=2363
	Within		36.45	-1133.49	1524.84	T=13

Source: Authors.

Table 7 - Joint *F-test* for equality of different quantiles

Hypothesis	*Du* variable	*Part* variable	Regression
test $H_0[q.25 = q.50 = .q75]$	$F(2,30700)$ = 18.47 $Prob > F$ =0.00	$F(2,30700)$ = 2.79 $Prob > F$ =0.06	$F(2,30700)$=34.39 $Prob > F$ =0.00
test H_0 $[q.25 = q.50]$	$F(1,30700)$ = 8.23 $Prob > F$ =0.00	$F(1,30700)$ = 3.07 $Prob > F$ =0.07	$F(1,30700)$ = 28.79 $Prob > F$ =0.00
test H_0 $[q.50 = q.75]$	$F(1,30700)$ = 22.25 $Prob > F$ =0.00	$F(1,30700)$ = 2.94 $Prob > F$ =0.08	$F(1,30700)$ = 23.45 $Prob > F$ =0.00
test H_0 $[q.25 = q.75]$	$F(1,30700)$ = 36.43 $Prob > F$ =0.00	$F(1,30700)$ = 5.56 $Prob > F$ =0.01	$F(1,30700)$ = 59.61 $Prob > F$ =0.00

Source: Authors.