Sugarcane Industry in Brazil: Different Impacts for Distinct Municipalities Development Patterns

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Abstract The increased demand for ethanol in Brazil and the international interest in alternative energy sources and less environmentally harmful fuels stimulated a significant growth in Brazilian sugarcane, sugar and ethanol production, with the expansion of sugarcane agricultural area and new processing units of ethanol and sugar. This Chapter assesses the socioeconomic impacts of this recent sugarcane industry expansion over five years, from 2005 through 2009. For this purpose, a panel data analysis was developed considering socioeconomic impacts on different levels of municipalities' development. The results suggested that sugarcane, sugar and ethanol production can improve socioeconomic indicators, mainly in municipalities that have low and medium level of development, besides the environmental ethanol benefits widely discussed in the literature. These findings indicate that public policies for the sector should consider socioeconomic aspects, both in Brazil as in other developing nations.

Keywords Brazil sugarcane industry · Sugarcane ethanol · Socioeconomic impacts · Quantile regression

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1 Introduction

In the post 2000 period, several factors led to an increase in the production of biofuels in countries with productive potential, as Brazil, United States and some European Union countries. Looking at the Brazilian context, where ethanol[1] is made from sugarcane, the production expansion was spurred mainly by the introduction in 2003 of flexible-fuel vehicles (capable of running on any arbitrary combination of gasoline and ethanol), which increased the demand for hydrous ethanol.[2] In addition, the increased international interest in alternative energy sources and less environmentally harmful fuels created expectations of biofuel demand growth around the world, and Brazil could offer a large share of ethanol supply. This context led to a significant increase in the Brazilian production of sugarcane and ethanol, held both by the expansion of the plants already existing in the country, as the installation of new plants ("greenfield" projects), which included investments by domestic capital and foreign companies.[3]

In effect, the sugarcane industry[4] production increased considerably [24, 36]. Between the harvests of 2001–02 and 2012–13, Brazilian sugarcane production rose from 293 to 588 Mt, sugar production from 19 to 38 Mt, and ethanol production increased from 11 million m^3 to 23 million m^3 [37]. According FAO, actually Brazil is the largest sugarcane producer in the world, followed by India, Thailand and Australia; the largest sugar producer and exporter, besides it is the world's the second-largest ethanol producer [11].

This accelerated growth of sugarcane industry verified in Brazil, concomitantly with the increase in corn ethanol production in the United States and the growth

[1] Brazil produces two types of fuel ethanol: anhydrous ethanol, which is mixed with gasoline; and hydrous ethanol, which can be used in flex-fuel automobiles and in automobiles that run exclusively on fuel ethanol (hereafter referred to as "ethanol-powered automobiles").

[2] According to statistics from the Brazilian National Association of Automobile Manufacturers (ANFAVEA), by June of 2005 flex-fuel vehicles already accounted for more than half of all light commercial Otto-cycle vehicles licensed in Brazil. That proportion is in 2014 an impressive 90%, flex-fuel vehicles accounting for over 50% of the national vehicle fleet [24].

[3] Between 2007 and 2009, there were at least seven major transactions involving national processing facilities and international groups, such as: French group Louis Dreyfus Commodities and the Brazilian company Santelisa Vale; Spanish group Abengoa Bioenergy (a subsidiary of Abengoa S.A.) purchased a number of sugarcane processing facilities; the Bermudan company Bunge Limited acquired the Brazilian sugarcane-processing conglomerate Grupo Moema; Shree Renuka Sugars, India's largest sugar refiner, purchased the Brazilian sugar and ethanol producing company Vale do Ivaí, then acquiring the majority share of another such company (Equipav); the largest Brazilian producer of sugarcane, sugar, and ethanol, the Cosan group, became even larger after purchasing the Grupo Nova América, which incorporated an additional milling capacity of approximately 11 million tons; Cosan group later announced a joint venture with Shell International Petroleum Company in 2009. In the 2011–12 harvest, the sugarcane processing capacity of the Cosan group was over 65 million tons. In 2010, there were at least 10 transactions involving the purchase of sugar and ethanol producing facilities in Brazil. For more details see [24].

[4] In Brazil the great majority of productive unit produce both sugar and ethanol from sugarcane, and the available statistics usually are presently jointly for these two sectors. Sugarcane industry in this study refers to three sectors: sugarcane production, sugar plants and ethanol plants.

expectations for the production of biofuels in several EU countries, have raised questions about economic, social and environmental aspects arising from this process. Most of the debate is focused in agricultural land competition between biofuels and food production, known in the literature as food versus fuel debate, besides environmental and social issues that have gained importance in the scientific literature and also for policy makers.

Besides the growth verified in Brazil, several countries began in mid-2000 to promote biofuels through public policies aimed at their adoption, given the potential for mitigation of greenhouse gases of some biofuels compared to fossil fuels. By early 2012, public policies promoting the use of biofuels (production subsidies, transport fuel-tax exemptions, share in total transport fuel obligations), as well as blending mandates, were in place at the national level in at least 46 countries and at the regional level in 26 states and provinces [28]. In addition, fuel-tax exemptions and production subsidies have now been put in place in at least 19 countries [28].

In this context, several studies have highlighted evidences of the possibility of economic growth arising from the sector, reflected on jobs and income creation, which can generate positive net benefits especially for the low-income Brazilian's population [15, 23, 29]. However, there is no consensus on the scientific literature about the impacts led by the production and consumption of agricultural fuels, and several authors have argued about the potential of the negative consequences [12, 13, 21, 33].

Several studies point out the need to offer a comprehensive sustainability assessment regarding biofuels, however it is observed in the literature a relatively limited appraisal on the social and wellness aspects related the growth of biofuel production. As stressed by Talamini et al., environmental, agronomic and technological dimensions were the three primarily discussed areas about sugarcane industry [35]. Chagas et al. also highlighted that socioeconomics impacts are less discussed in the literature and it is verified that the results often presents divergent results [4].

Thus, this study aims to assess the socioeconomic impacts of the expansion of Brazilian sugarcane, sugar and ethanol production in municipalities of the biggest sugarcane producer state (São Paulo), for the period 2005–2009. Socioeconomic impacts were evaluated through use of the Federation of the State of Rio de Janeiro Industries' (FIRJAN) Municipal Development Index (IFDM) as a proxy for the Human Development Index (HDI).

Two empirical approaches are used in this research. First, to measure the mean impacts, a panel data analysis is implemented. Secondly, a quantile regression approach is used in order to measure the socioeconomic impacts considering different municipalities' levels of development [17]. The main innovation of this study is the assessment of the impacts considering the different patterns of development of the municipalities.

2 Literature Review

It is noticed when analyzing the literature about the socioeconomic impacts related to the expansion of sugarcane crops and biofuel production the prevalence of studies related to the impacts on the labor market and rural workers. According to Carvalho and Marin, this recurrence may be justified by the fact that the promotion of access to work constitutes a major mechanism of social inclusion, generally associated with agro energy policies [4].

The jobs created by the sector's presence are those ones directly related to the production of sugarcane, sugar and ethanol sectors (sugarcane industry) as well those ones generated due the interactions of these sectors with other sectors of the economy, whether as a purchaser of the inputs needed for production, as a supplier of products for indirect use, or as a supplier of products for direct use (by the final consumers of sugar and ethanol). However, in the scientific literature about the impacts of sugarcane, sugar and ethanol sectors it is noted a greater attention to jobs creating by the direct way.

Moraes conducts a descriptive analysis of the Brazilian National Household Sample Survey (PNAD) and Annual Social Information Report (RAIS) highlighting the growth of number of employees and formalization of work within the sector [23]. This study indicates that between 2000 and 2005, considering the three sectors of sugarcane industry (sugarcane, sugar and ethanol), there was a significant increase of 52.9% in the number of employees, which increased from 642,848 in 2000 to 982,604 in 2005 [23]. Coelho et al. highlight the low cost of creating a job in the sugarcane agribusiness with respect to chemical and petrochemical industry [6]. According to these authors, a new job in the chemical and petrochemical industry can cost up twenty times more and the employment rate per unit of energy produced is up to 152 times higher in the ethanol agro industry compared with the oil industry (or fossil fuel) [6].

Regards economic development, several authors point out that the expansion of the sugarcane, sugar and ethanol production can contribute for the economic development in rural areas, which usually presents worse socioeconomic indicators compared to urban or industrial areas.

In the literature about the theme, the presence of the sugarcane mills is reported as a key driver of endogenous growth in the municipalities [32]. In addition, to the direct relationship arising from job generation, some authors reports the effects on local business or services, urbanization, income, population expansion and growth of municipal tax collection [5, 22, 26, 29, 32].

Regarding the aspect of aggregate income, studies about the sector's expansion in general are convergent in affirming the positive impacts (some of small magnitude) of the sector's presence. Oliveira et al. assessed whether the expansion of sugarcane in the Midwest of the State of Minas Gerais, which intensified after 2006, has contributed to higher growth in GDP per capita of the municipalities of this Brazilian State [26]. This study reports that in the municipalities evaluated from 1999 to 2008 period, the growth was 39.94% where it occurs with the presence of the sugarcane

industry, while the average of GDP growth was 22.49% for the Midwest of Minas Gerais, and 29.1% for the state as a whole [26]. However, these data must be evaluated carefully, as that study does not include other regional factors that may bias the analysis.

Among the studies of quasi-experimental approach, Deuss used a propensity score matching (PSM) method to evaluate the effect of the expansion of the sugarcane industry (treatment effect) on the brazilian economic development at the municipality level in Brazil as a whole and in the main sugarcane producing regions, the North-Northeast (NE) and the Center-South (CS) [7]. As a result, the author found a positive GDP per capita effect, especially in the South Central region (except São Paulo) and Northeast. That study did not find a significant effect on economic growth in the State of São Paulo [7].

Satolo and Bacchi analyzed the impact of sugarcane and ethanol expansion in the state of São Paulo, assessing their impact on GDP per capita of different municipalities [29]. Through a spatial dynamic panel data model, the study shows that there is a positive spatial time dependence on the level of per capita GDP and on its distribution [29]. The authors found that the effect of the expansion of sugarcane industry is positive on GDP per capita if this expansion occurs in an area of up to 23% of the municipalities' agricultural areas, replacing crops or pasture areas [29]. This study, by aggregating spatial analysis, also evaluates a positive impact on the sugarcane industry's presence on the nearby municipalities, although it was a small effect. This spillover effect can be explained by migratory attraction and increased own local income, which can increase demand for goods and services consumed locally, multiplying the positive effect on income.

Bacchi and Caldarelli undertook a panel data analysis in order to identify the positive externalities related to the expansion of the sugarcane industry by evaluating the Municipal Development FIRJAN Index (IFDM). These authors present evidence that the expansion of the sugarcane industry in the state of São Paulo generated positive effects on employment and income, but there was no significant positive impacts on health and education indexes. Nevertheless, the authors didn't analyze the differences between less developed municipalities and more developed ones [2].

In addition to these aspects, Shikida and Souza argued that the presence of plants and sugarcane plantations contributes to smooth the evasion of rural people of the municipalities, which may occur with the decrease of family farming areas [32].

In contrast with benefits evaluated in these studies, Sawyer points out a possible effect of concentration of income, driven by the expansion of a culture over large areas [30]. The author argues that both in the case of manual harvesting sugarcane, with working conditions often precarious, as the mechanized, extinguishing jobs, there may be this negative impact locally [30].

With respect to reduction of regional inequalities, Schaffel and Rovere estimate that the expansion of the sugarcane industry has had little influence [31]. This fact is justified, according to the authors, because the production of ethanol and sugar are concentrated mostly in São Paulo, state with high level of development. However the authors point out that the expansion into new areas is still in the beginning, and there are no several impact studies [31].

Chagas, Toneto-Jr and Azzoni sought to identify the effects that the production of sugarcane has on the social indicators of the producing regions using municipal Human Development Index (HDI) as a summary indicator of local social conditions [8]. Through the spatial propensity score matching method, these authors concluded that the sugarcane industry's presence in the evaluated municipalities is not relevant to determining their social conditions, for better or for worse [5].

In different case studies it is also reported the precariousness of jobs created, the risks to health of rural workers and poor housing conditions of immigrant workers, which suggests the occurrence of negative impacts at the local level [12, 21].

The findings of the literature review indicates a predominance of the case studies analysis, which are important for the analysis and understanding of particular realities in detail, but are limited in characterizing the impacts of the sugarcane industry expansion in a more comprehensive and broader way, due particular institutional, economic and social characteristics of different municipalities, regions or countries.

It is also interesting to observe the divergent results between qualitative and quantitative analysis found in the literature review, especially under different geographical levels. The quantitative approach studies; using econometric methods, general equilibrium or critical analysis of data, tend to have a more positive outlook when compared to the case studies.

Despite the importance of the cited studies and apparent contradictions in the results, it can be seen in the literature a relative shortage of research on evaluation and assessment of social impacts of sugarcane ethanol expansion, in contrast to the further investigation of the environmental and agronomic aspects.

Therefore, the empirical analysis developed and described in the following sections of this chapter seeks to contribute to the evaluation of the relationship between the expansion of the sugarcane industry and socioeconomic development patterns, analyzing the effects of the recent sugarcane expansion and the presence of plants on producing municipalities of the State of São Paulo, the main Brazilian producer state.

More particularly, this study assesses the socioeconomic effect through the Municipal Development FIRJAN Index (IFDM), a summary index that annually reports the socioeconomic development of municipalities [10]. The period of analysis is 2005–2009, and the emphasis of this empirical study is on analyzing socioeconomics impacts considering municipalities different' levels of development, given the lack of studies with this approach.

3 Methodological Procedures

We address the issue of the effects of sugarcane expansion on socioeconomic development of São Paulo municipalities' in two different methodological approaches. First, we conduct a panel data analysis according to steps proposed by Greene [14] to measure the mean impacts, taking into account differences in behavior across individuals. Second, in order to measure the socioeconomic impacts considering

different municipalities' levels of development, a quantile regression approach is adopted [17].

3.1 Panel Data Analysis and Quantile Regression

Panel data, also known as longitudinal or cross-sectional time series data, is a data set in which the behavior of individuals/units is observed across time. Data sets that combine time series and cross-section are common; these kinds of datasets provide a rich source of information [14].

This study uses a panel data analysis because it allows measuring the socioeconomic impacts of the sugarcane industry in municipalities across time. According to Maddala, the methodology takes into account heterogeneity across units, the analysis allows to control for variables that change over time but not across individuals/units (national policies, federal regulations, international agreements) [19]. So, there is a great flexibility in modeling differences across individuals.

The basic framework for i units and t periods is a regression model [14, 19]:

$$y_{it} = x'_{it}\beta + z'_i\alpha + \varepsilon_{it}, \tag{1}$$

where there are k regressors in x_{it} and the main objective of the analysis will be consistent and efficient estimation of the partial effects (β),

$$\beta = \partial E[y_{it}|x_{it}]/\partial x_{it}. \tag{2}$$

The heterogeneity is $z'_i\alpha$ where 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 on the missing variables z_i, that is:

- **Pooled regression** – if z_i contains only a constant term, there is a common α;
- **Fixed Effects** – if the z_i is unobserved and correlated with x_{it};
- **Random Effects** – if the z_i is unobserved and uncorrelated with x_{it}.

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 you need to specify those individual characteristics that may or may not influence the predictor variables [34]. Some tests are performed to decide which model fits better and shall be estimate, as Hausman, Breusch and Pagan and Chow test.[5]

[5]For more details see [26, 32, 34].

Quantile regression, as Koenker and Basset defines it, is a method for estimating functional relations between variables for all portions of the probability distribution – different quantiles (τ) [17].

As described by Koenker, quantile regression models present many new possibilities for statistical analysis and interpretation of economic data, mainly because this analysis allows comparing how some percentiles may be more affected by certain characteristics than other quantiles [18]. This is reflected on the size change of the regression coefficient.

The conditional quantile is denoted by:

$$Qy_{it}(\tau|x'_{it}) = x'_{it}\beta(\tau) + z'_i\alpha(\tau). \tag{3}$$

For this study, we consider that z_i contains only a constant term.

The advantage of using quantile regression to modeling the socioeconomic impacts related to the existence of sugarcane industry in the municipality is the possibility to compare these impacts according to the different levels of development of the municipalities for the State of São Paulo.

3.2 Data and Empirical Strategy

In order to measure the socioeconomic impacts of the sugarcane industry in the municipalities of the state of São Paulo, we estimate the proposed model using panel data analysis methodology and quantile regression approach:

$$INDEX_{it} = [\text{DU, area, GDP per capita}]'_{it}\beta + z'_i\alpha + \varepsilon_{it}, \tag{4}$$

where:

- **INDEX** is the FIRJAN Municipal Development Index (IFDM) used to measure the level of development in each municipality of the state of São Paulo – the index varies from 0 (least developed) to 1 (most developed);
- **DU** is a dummy variable used to identify the existence of sugar and/or ethanol mills/distillery in each municipality – 1 if it has a mills/distillery and 0 if it hasn't;
- **area** represents the sugarcane harvest area in each municipality (the variable is the percentage of the total area of agriculture, cattle and pasture in each municipality), and;
- **GDP per capita** is used because it is well known that other factors could influence the Firjan development index, and the GPD is an important variable to capture this effect – it is a control variable – in 2008 US$.

Furthermore, we use binaries variables for years; the objective is control the time effect as suggested by Greene [14].

The information used to build the database were collected from IBGE (Brazilian Institute of Geography and Statistics), FIRJAN (Rio de Janeiro Federation

Table 1 Description of the IFDM indicators and components [16]

IFDM		
Employment and income[a]	Education[b]	Health[c]
• Formal jobs	• Primary school enrollment	• Number of prenatal consultation
• Jobs for local workers	• Primary school leaver	• Death due to not defined cause
• Formal income generating	• Age-series distortion on primary school	• Child mortality
• Median wages	• Undergraduate teachers in primary school	• Hospitalizations
• Income inequality	• Average hours in class	
	• IDEB index[d]	

Source Performed by authors
[a]Data from Brazilian Ministry of Labor and employment (MTE)
[b]Data from Brazilian Ministry of Education (MEC)
[c]Data from Brazilian Ministry of Health (MS)
[d]The IDEB is the Basic Education Development Index carried out by Brazilian Ministry of Education to evaluate the school quality and the students' performance

of Industries), IPEA (Applied Economic Research Institute) and UNICA (Brazilian Sugarcane Industry Association) [3, 10, 16, 36].

To verify the existence of sugar and/or ethanol mills/distillery for each municipality the information from UNICA [36] are used. The sugarcane area (hectare), crops, pasture and cattle were obtained from IBGE data base (SIDRA/IBGE) [16]. To build the GDP per capita series we use data from IBGE and IPEA [3, 16]. Finally, we use data from FIRJAN for the development index [10]. The FIRJAN Municipal Development Index (IFDM) closely follows the annual social and economic development of municipalities, reporting on employment and income, education and health issues. The IFDM follows the IDH (ONU) methodology. Table 1 shows the IFDM composition.

The study was realized with annual data for the period 2005–2009 using the commercial statistical package STATA® 10.0. The study was performed using data for the São Paulo state; which is the main sugarcane, sugar and ethanol producer in Brazil. The models were estimated using aggregate IFDM index and sub-index IFDM Employment and Income.

4 Results and Discussions

We can observe important changes in land use as a consequence of the sugarcane industry's expansion in Brazil. First, the expansion is concentrated in the center-south region, especially in the states of São Paulo, Mato Grosso do Sul, Mato Grosso

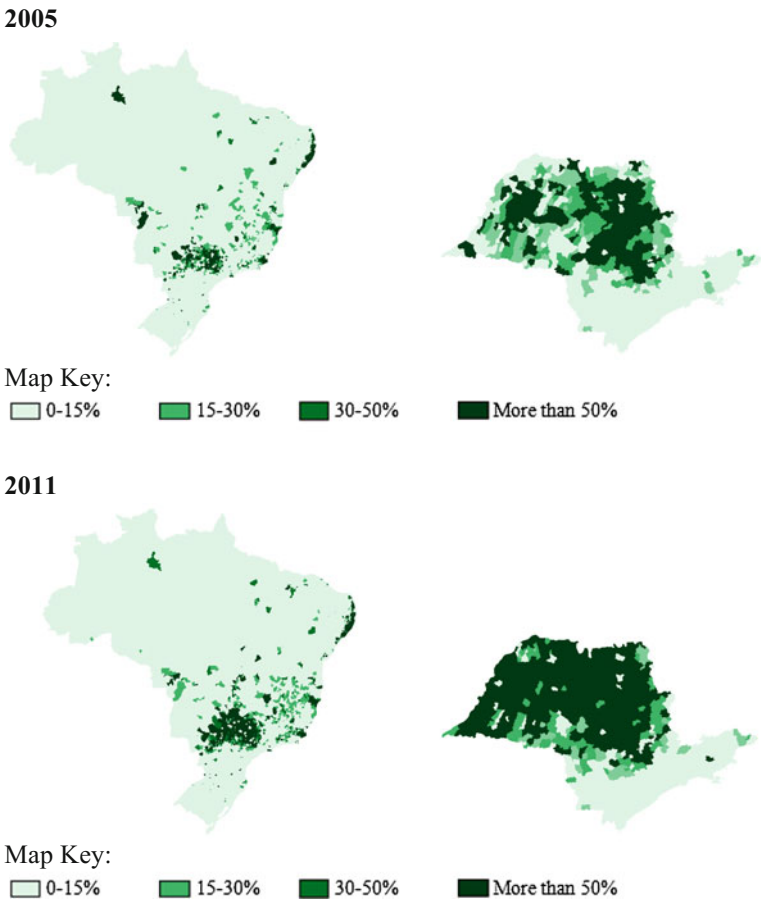

Fig. 1 Sugarcane area in Brazil and in the State of São Paulo for 2005 and 2012 – Percentage of agricultural area allocated to sugarcane crops [16]. *Source* performed by authors

and Minas Gerais. In the case of the state of São Paulo, 1990–91 harvest accounts for 59.26% of the Brazilian sugarcane production; in 2001–02 the percentage was 60.26% and in 2012–13 this participation was 56.06% [36]. Figure 1 shows the evolution of sugarcane cultivation in Brazil and in the State of São Paulo.

Figure 2 presents the Aggregated IFDM and the Employment and Income IFDM evolution for all the São Paulo municipalities, from 2005 to 2009. The overall analysis show that Employment and Income indicador has a more dispersed distribution than Aggregated IFDM. The characteristic of these data corroborate the methodological tools used.

It is also important to underline that both indicators have presented constant trend for the analysed period, excepted for 2008, when the Brazilian economy was impacted for the international crisis. According to Paula and Ferrari-Filho the most intense

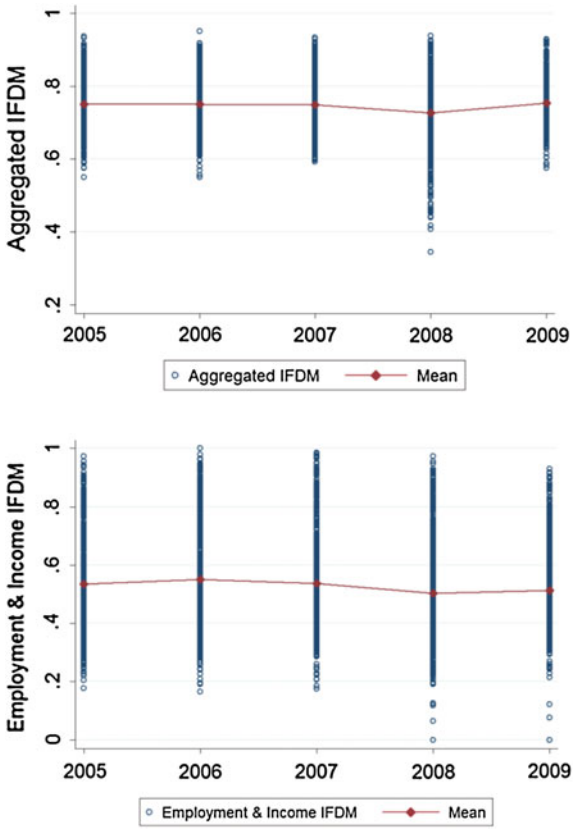

Fig. 2 Evolution of the IFDM index – Aggregated IFDM and Employment and Income IFDM – for all São Paulo municipalities from 2005 to 2009. *Source* Performed by authors using FIRJAN [10]

impacts of the international crisis in the Brazilian economy were observed in the second semester of 2008; the most affected economic variables were job market and GDP, therefore the observed decrease on the mean of the Employment and Income IFDM in 2008 [27].

Table 2 presents the variables' descriptive statistics. We considered 3225 observations for each variable. The observations contain data from all 645 municipalities in the Brazilian state of São Paulo over 5 years, 2005 through 2009. Since this is a panel data analysis, the descriptive statistics presented in Table 2 are divided into the dimensions Within (variance between municipalities) and Between (average variation over a period of time).

Table 3 presents the results of the estimatives of the socioeconomic impacts of sugarcane industry using panel data analysis.

The findings (Table 3) suggest that there is a positive and statistically significant impact between the explanatories variables sugar mills and/or ethanol distilleries (DU) and area of sugarcane in each municipality (area) on the dependent variable development indexes (IFDM and IFDM Employment and Income).

Table 2 Summary statistics for the variables used in the model estimation

Variables	Mean	s.d	Min.	Max.	Obs.
IFDM *overvall*	0.75	0.06	0.54	0.95	N = 3225
between		0.06	0.60	0.92	n = 645
within		0.02	0.61	0.86	T = 5
IFDM_ER *overvall*	0.53	0.16	0	1	N = 3225
between		0.15	0.28	0.95	n = 645
within		0.07	0.01	0.83	T = 5
area *overvall*	0.18	0.14	0	0.79	N = 3225
between		0.14	0	0.72	n = 645
within		0.12	0.01	0.74	T = 5
GDP per capita *overvall*	6392	601	1214	8768	N = 3225
between		5548	1789	67934	n = 645
within		2324	–28096	38867	T = 5

Source Performed by authors

Table 3 Socioeconomic impacts of the sugarcane industry in the State of São Paulo – from 2005 to 2009 – using panel data analysis (Fixed Effects The fixed effects model was chosen based on Chow, Breusch-Pagan and Hausman tests results)

	Aggregated IFDM			Employment and Income IFDM		
Variable[a]	Coefficient (%)	*t* test	$P > \|t\|$	Coefficient (%)	*t* test	$P > \|t\|$
DU	1.34	2.53	0.01	6.07	3.21	0.00
area	0.30	3.07	0.02	1.22	3.69	0.00
GDP per capita	3.19	2.15	0.03	12.04	3.84	0.00

Source Performed by authors

[a]*Note* Binaries variables for years and units were used to estimate the model, but the results were omitted; Robust standard errors were used

When we analyze the variable DU, we can observe two important results: (i) municipalities that have mills or distilleries have an aggregated index of development 1.34% higher than municipalities that doesn't have; (ii) municipalities that have mills or distilleries presents the index of employment and income about 6.07% higher.

The impacts of the variable area on the development indexes are also positive, the coefficients are respectively 0.30% for IFDM and 1.22% for IFDM Employment and Income; although the coefficients are small when compared to the variable DU.

It is interesting to highlight that development indexes have been widely influenced by the existence of processing sugarcane plants (ethanol and/or sugar plants) than sugarcane production. In general, it was possible to identify a closer relation between

Table 4 Socioeconomic impacts of the sugarcane industry in the State of São Paulo on Aggregated IFDM – from 2005 to 2009 – using quantile regression

Quantile	Variable[a]	Coefficient (%)	*t* test[b]	$P > \|t\|$
0.25	*DU*	**1.76**	5.30	0.00
	Area	**0.71**	3.66	0.00
	GDP per capita	7.13	15.14	0.00
0.5	*DU*	**1.40**	7.90	0.00
	Area	**0.64**	2.47	0.00
	GDP per capita	8.72	16.38	0.00
0.75	*DU*	**0.93**	3.66	0.00
	Area	**0.45**	2.19	0.02
	GDP per capita	11.02	17.91	0.00

Source Performed by authors

[a]Binaries variables for years were used to estimate the model, but the results were omitted; Robust standard errors were used

[b]Additional tests were performed to evaluate the regressions; the regressions have a good explanatory power

Table 5 Socioeconomic impacts on Employment and Income IFDM index of the sugarcane industry in the State of São Paulo – from 2005 to 2009 – using quantile regression

Quantile	Variable[a]	Coefficient (%)	*t* test[b]	$P > \|t\|$
0.25	*DU*	**6.84**	7.32	0.00
	Area	**2.11**	3.21	0.00
	GDP per capita	20.00	12.41	0.00
0.5	*DU*	**6.84**	8.31	0.00
	Area	**3.24**	5.54	0.00
	GDP per capita	23.55	18.57	0.00
0.75	*DU*	**3.69**	4.63	0.00
	Area	**2.30**	3.77	0.00
	GDP per capita	32.06	12.82	0.00

Source Performed by authors

[a]Binaries variables for years were used to estimate the model, but the results were omitted; Robust standard errors were used

[b]Additional tests were performed to evaluate the regressions; the regressions have a good explanatory power

sugarcane production/processing and economic development in the State of São Paulo. The results suggest an association of the sugarcane industry in São Paulo with economic development, especially related to the improvement on the job market and income.

In addition, we present the estimative using quantile regression (Tables 4 and 5). In this point, we are interested in better understanding the impacts of the sugarcane industry on different levels of development municipalities.

The results presented on Tables 4 and 5 corroborate the previous analysis using panel data (Fixed Effects Model); the findings also indicate that sugarcane processing (DU) has a higher impact on economic development indexes than sugarcane area (area) – for all estimated quantiles. On the other hand, the above results (Table 5) suggest an important point, the fact of the municipalities with low and medium levels of development can be more impacted by sugarcane industry than the higher developed.

For the less developed municipalities – quantile 0.25 –, the presence of a sugarcane mill or ethanol distillery increases the Aggregated IFDM by 1.76% and the Employment and Income IFDM by 6.84%. For the other extreme of distribution, highest developed municipalities – quantile 0.75 –, the coefficients are smaller, respectively, 0.93 and 3.69%.

These results are corroborated using interquartile regression – interquartile range; as stated in Tables 6 and 7 (Appendix), the negative coefficients for DU variable means that the presence of the sugar or ethanol mills or distilleries decreases the interquartile range and therefore Aggregated and Employment and Income IFDM dispersion, consequently we have expected a downward trend.

Thus, according to the results, the presence of sugarcane facilities can contribute to the convergence of the poorer municipalities' income towards the more developed municipalities. These results are confirmed by Table 8 (Appendix), which shows that it is possible to reject the null hypothesis (that the coefficients of quantiles regression are the same), confirming the differential impact between municipalities according to GDP per capita levels.

We present (Figs. 3 and 4) the pattern of DU variable obtained using alternative methodologies (quantile regression, Ordinary Least Squared and Fixed Effects) for all quantiles to compare the impacts of the presence of sugarcane mills or distilleries in municipalities with different levels of development.

The relation between processing sugarcane (DU) and economic development can be observed in Fig. 3 (Aggregated IFDM) and Fig. 4 (Employment and Income IFDM), according the data distribution – quantiles describing levels of development. The analysis reinforces that presence of the sugarcane mills or distilleries in the municipalities with low or medium level of development may be associated to the highest socioeconomic impacts.

This way, the results show that the presence of sugarcane industry (sugarcane, sugar and ethanol production) improved the development index for the municipalities of the State of São Paulo in the analyzed period. Those findings point out that public fuel policies, in order to expand sugarcane ethanol production, besides having an important environmental benefit can also improve socioeconomic indicators in municipalities that have low and medium level of development.

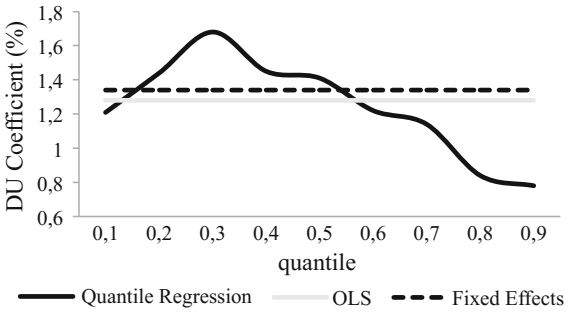

Fig. 3 Comparing the coefficient DU from different models by quantile – for Aggregated IFDM. *Source* Performed by authors

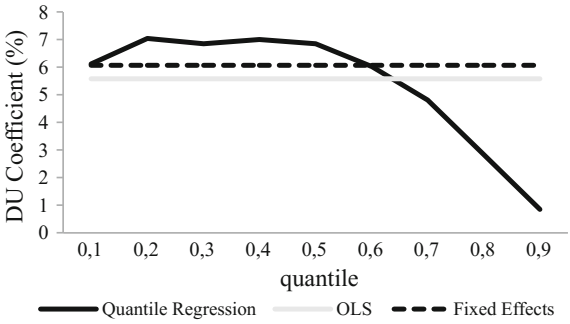

Fig. 4 Comparing the coefficient DU from different models by quantile – for Employment and Income IFDM. *Source* Performed by authors

5 Final Remarks

The replacement of fossil fuels by biofuels in several countries, driven mainly by environmental and energy security concerns, has given rise to discussion about the economic, environmental and social impacts, considering the possibility of sharp growth in biofuels production. On the one hand, academic studies and papers regarding the environmental impacts and on land use flourished, however the social impacts analysis are relatively scarce in the international literature. Moreover, the results on social impacts are quite diverse, which motivated the development of this chapter.

The main innovation of this chapter when comparing with the existing literature is the impacts evaluation considering the different patterns of development of the municipalities. The availability of socioeconomic data series allows the analyses of Brazilian experience under several different approaches, what can be useful for national stakeholders (researchers, police makers, producers), as for the new producer countries that aim to start or expand biofuels production, and aims to assess the socioeconomics impacts.

The approach we use - panel date analysis - has shown that there is a positive and statistically significant effect between the existence of both sugarcane processing plants (sugar mills/ethanol distilleries) and the sugarcane area on the Development Indexes (Aggregated Development Index – IFDM, and Employment and Income Index IFDM).

The results show that municipalities with sugar/ethanol plant and sugarcane area have both IFDM indexes higher than municipalities that don't have. It is interesting to highlight that the impact on the development indexes have been widely higher due to the existence of processing sugarcane plants (ethanol and/or sugar plants) than sugarcane production.

Considering the results using quantile regression, that better allows to address the impacts of the sugarcane industry on different levels of development municipalities, the results also indicate that municipalities that have sugarcane area and sugarcane processing units have better development indexes than those ones that do not have, for all quantiles analyzed. One important finding is that municipalities with low and medium levels of development are more impacted by industry than the higher developed ones. This way, the conclusion is that the sugarcane industry improved the regional development index for the municipalities of the state of São Paulo in the analyzed period.

Those findings point out that besides have an important environmental benefit, as widely discussed in the literature, sugarcane ethanol production can also improve socio-economic indicators, mainly in municipalities that have low and medium level of development.

We hope this research can contribute for national policymakers, as well as for other developing countries that aim to expand biofuels production as well as to improve regional development.

Appendix

See Table 8.

Table 6 Interquartile regression on Aggregated IFDM – from 2005 to 2009

Interquartile range	Variables[a]	Coefficient (%)	t test	$P > \|t\|$
0.25 0.75	*DU*	–0.81	–2.83	0.00
	Area	–0.26	–0.71	0.47
	GDP per capita	3.89	7.04	0.00
0.25 0.50	*DU*	–0.35	–1.66	0.09
	Area	–0.06	–0.33	0.74
	GDP per capita	1.58	3.31	0.00
0.50 0.75	*DU*	–0.46	–2.46	0.01
	Area	–0.19	–1.05	0.29
	GDP per capita	2.30	5.34	0.00

Source Performed by authors

[a]*Note* Binaries variables for years were used to estimate the model. but the results were omitted

Table 7 Interquartile regression on Employment and Income IFDM – from 2005 to 2009

Interquartile range	Variables[a]	Coefficient(%)	t test	$P > \|t\|$
0.25 0.75	*DU*	–2.93	–3.07	0.00
	Area	–0.19	0.22	0.82
	GDP per capita	12.06	6.46	0.00
0.25 0.50	*DU*	0.003	0.00	0.99
	Area	1.13	2.22	0.02
	GDP per capita	3.55	2.04	0.04
0.50 0.75	*DU*	–2.93	–4.22	0.00
	Area	–0.94	–1.83	0.06
	GDP per capita	8.50	4.74	0.00

Source Performed by authors

[a]*Note* Binaries variables for years were used to estimate the model. but the results were omitted

Table 8 Joint F-test for equality of different quantiles for DU variable

Hypothesis	Aggregated IFDM	Income and Employment IFDM
test $H_0[q.25 = q.50 = q.75]$	$F(2.3217) = 3.21$	$F(1.3217) = 8.11$
	$Prob > F = 0.04$	$Prob > F = 0.00$
test $H_0[q.25 = q.50]$	$F(1.3217) = 3.26$	$F(1.3217) = 0.00$
	$Prob > F = 0.07$	$Prob > F = 0.99$
test $H_0[q.50 = q.75]$	$F(1.3217) = 4.73$	$F(1.3217) = 15.82$
	$Prob > F = 0.02$	$Prob > F = 0.00$
test $H_0[q.25 = q.75]$	$F(1.3217) = 6.37$	$F(1.3217) = 7.09$
	$Prob > F = 0.01$	$Prob > F = 0.00$

Source Performed by authors

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