Impact of reducing the pre-harvest burning of sugar-cane area on respiratory health in Brazil*

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Abstract

This paper analyzes the impact of the increase in the raw sugar-cane harvest area on the population respiratory health in Brazil. We collect data for the São Paulo state municipalities for two different periods: 2000, before state law defining gradual elimination of pre-burning sugar-cane area and 2007. We used panel models for inpatient visits due to respiratory diseases, outpatient visits for inhalation procedure and length of stay for inpatient visits due to respiratory diseases, controlling for the endogeneity between health and pollution. Results show that the increase of raw sugar-cane harvest area reduces the number of inpatient visits and do not impact the number of inhalation and length of stay.

JEL classification: I12, I18, Q42, Q53
Keywords: health, sugar-cane, air pollution, ethanol.
ANPEC: **Área 10 - Economia Agrícola e do Meio Ambiente**

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Resumo

Este artigo analisa o impacto do aumento da área de cultivo de cana-de-açucar na saúde respiratória da população. Utilizamos dados para os municípios do Estado de São Paulo em dois períodos: 2000, antes da legislação estadual definindo a redução gradual da queimada e 2007. Utilizamos modelos para dados em painel para visitas nos hospitais devido a problemas respiratórios, visitas para inalação e tempo de internação devido a doenças respiratórias, controlando a endogeneidade entre saúde e poluição. Os resultados indicam que o aumento na área de colheita da cana-de-açucar crua reduz o numero de visitas e não tem impacto sobre inalações e duração da internação.

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1 Introduction

Ethanol is a biofuel that can be derived from several renewable sources as sugar-cane, corn, sugar-beet, sweet sorghum, cassava, cellulose and woody crops (Giampietro et al. 1997). The use of biofuel is gaining importance in the world energy matrix. Projections indicate that the biofuel will account for 5% of the liquid fuels by 2025 (EIA 2006). In 2009 Brazil has the share of 34% of the world ethanol production. The final Brazilian consumption in this year reach $22,823\ 10^3 m^3$ of ethanol and $19,057\ 10^3 m^3$ of gasoline and the sugar-cane products account for 18.1% of the Brazilian energy matrix (EPE 2010).

There are mainly three reasons for the ethanol demand growth. First the Brazilian government made for more than 30 years a great investment [1] in R&D for industrial and agricultural ethanol sector (Martines-Filho et al. 2006, Nass et al. 2007). Those investments had the effect of rise the productivity of sugar-cane in Brazil from $34t.ha^{-1}$ in 1960 to $69t.ha^{-1}$ in 2006 (IBGE 2010*a*) and reduce the cost of hydrate ethanol [2] from US\$ $980m^3$ in 1975 to US\$ 260-$305m^3$ in 2004 (2005 prices) (van den Wall Bake et al. 2009). Also, the literature shows that Brazil's ethanol has one of the best progress ratios (PR) of technology among renewable sources of energy (Goldemberg et al. 2004, van den Wall Bake et al. 2009).

Second, the rise of oil prices and the decline of ethanol prices turned the use o ethanol economically viable. The ethanol price for producers in the state of São Paulo in 2009 was US\$ $301m^3$ and the gasoline price [3] in the refinery was US\$ $502m^3$ (CEPEA 2010, UNICA 2010). It is worth to note that ethanol market was completely deregulated in 1999 and prices could freely vary in the market (Martines-Filho et al. 2006).

Third, new technologies bring new perspectives to the sector. In addition to the obligatory actual blend of 25% of anhydrous ethanol in gasoline, the fleet of flex fuel[4] cars are increasing. The percentage of flex fuel light-cars sold in Brazil in 2005 was 39% rising to 87% in 2009 (ANFAVEA 2010).

[1] For example, the investment in production of automotive ethanol between 1975-1989 was US\$ 12.3 billion (1995 prices), Moreira & Goldemberg (1999)

[2] Brazil produces a anhydrous ethanol (99.6 GL) as a octane enhancer in gasoline with blending rates that ranges from 20 to 26%, and hydrated ethanol (95.5 GL) for neat-ethanol engines and flex fuel engines

[3] Both prices without tax in 2009 and currency of R\$1.99/US\$

[4] The flex fuel technology is a engine that give the consumer the possibility to use ethanol and gasoline in the tank in any proportion desired.

This growth of ethanol demand has been supported by significant increase in sugar-cane production area, which rose from 4.9 million ha in 2000 to 8.2 million ha in 2008, a growth rate of 6.7% a year. The state of São Paulo is the main producer, responding for 60% of total Brazilian production and 55% of total sugar cane area in 2008, with an annual area growth rate of 7.8% for the same period. (IBGE 2010*b*).

The sugar-cane is a semi perennial culture and has two different harvest systems. One uses mechanical harvest of the raw sugar-cane and other uses manual harvest with previous burning of sugar-cane. In the State of São Paulo in 2009 almost 56% of the sugar-cane was harvested mechanically without previous burning. Due to sugar-cane expansion and the coexistence of this two different production system, some question arises about the health, social and environmental impact of ethanol production.

Although the literature still lacking or finding controversial results related to the impact of sugar-cane production on labor (Moreira & Goldemberg 1999, Nass et al. 2007), soil degradation (Giampietro et al. 1997, Oliveira et al. 2005, Moreira & Goldemberg 1999), water pollution (Gunkel et al. 2007, Moreira & Goldemberg 1999) and Green House Gases emission (Börjesson 2009, Crutzen et al. 2008, Oliveira et al. 2005, Moreira 2000, Moreira & Goldemberg 1999), it seems that exist a convergence of results of the impact of sugar-cane plantation on air pollution due to the pre harvest burning and cultivation (Andrade et al. 2010, Lara et al. 2005, Allen et al. 2004).

Those studies show that sugar-cane burning is responsible for the increase of fine particulate matter ($PM_{2.5}$), coarse particulate matter (CPM) and Black Carbon concentration (BC) specially in burning hours. (Lara et al. 2005). The matter increases due sugar-cane burning alter positively the air concentration of substances as nitrite, sulfite, oxide of carbon and others (Allen et al. 2004). The literature also demonstrated that short- and long-term exposition to classical pollutants (matter, sulfite, nitrite, oxide carbon etc) can affect negatively human health capital (Sicard et al. 2010), specially for young and elderly people (Roseiro & Angela 2006, Farhat et al. 2005, Gonçalves et al. 2005, Braga et al. 1999).

Although the pollution from sugar-cane pre-harvest burning may be as harmful as the pollution from traffic and industries (Mazzoli-Rocha et al. 2008), just few studies try to measure the impact of pre-harvest burning of sugar-cane on health (Uriarte et al. 2009, Ribeiro 2008, Arbex et al. 2007, Cançado et al. 2006, Arbex et al. 2000). Most of those studies analyze the impact of pre-harvest burning on health for specific municipalities (Arbex et al. 2007, Cançado et al. 2006, Arbex et al. 2000) and just one consider a larger region (Uriarte et al. 2009). In addition, none of those studies take in account the increase in the area of sugar cane harvested mechanically.

This paper evaluates the impact of the increase in the raw sugar-cane harvesting area on inpatient and outpatient visits due to respiratory diseases in the state of São Paulo. As far as we know, this paper is the first in the literature to incorporate other sources of pollution as car and industries, to differentiate among inpatient and outpatient visits, to incorporate socio-economic variables such as education, salary, health system supply, and to control for the size of private sector.

Our results shows that the increase of raw sugar-cane harvest area diminish the number of inpatient visits per 1000 habitants and do not impact inhalation and length of stay. Other sources of pollution, as total fleet and industrial energy consumption, were also important to explain the increase of inpatients visits. In addition, the increase of health professionals decrease the number of inpatient and out patient visits. Finally, higher average salary are associate with a smaller number of inpatient and outpatient visits.

2 Conceptual Framework

The unit of analysis in this paper is the municipalities of the state of São Paulo. So, only the average of individual data is observed. To understand the effect of air pollution on health, it is convenient to start with the Grossman's (1972) model for health human capital. Although this model was designed for individuals, we believe that the aggregation for municipalities do not invalidate the model and can still provide a heuristic conceptual framework to the empirical analysis.

In Grossman's (1972) model, the individual born with an amount of health stock (H_0) which depreciates at a certain rate (δ_t) along her life, and can increase through investments (I_t). Therefore, the individual variation of health capital (ΔH_{t+1}) from one period to the another is

$$\Delta H_{t+1} = H_{t+1} - H_t = I_t - \delta_t Ht. \tag{1}$$

For a municipality, the average health capital variation will be

$$\Delta \overline{H}_{t+1} = \overline{H}_{t+1} - \overline{H}_t = \overline{I}_t - \overline{\delta}_t \overline{H}t. \tag{2}$$

So, two variables are important to understand the municipalities variation of health capital, the per capita investment ($\overline{I}_t$) and the average rate of depreciation ($\overline{\delta}_t$). If investment and depreciation was the same for all municipalities in the State of São Paulo, no difference would exist in the mean health status of those populations. This is not the case.

The average rate of decay or depreciation of health capital in a municipality ($\overline{\delta}_t$) will depend of the average age of the population and other environmental factors ($\overline{S}_t$) and air pollution ($\overline{\Psi}_t$) (Cropper 1981), so:

$$\overline{\delta}_t = f(\overline{S}_t, \overline{\Psi}_t) \tag{3}$$

So, the older a population is the higher will be the depreciation rate. Another important environmental factor is the weather. The literature shows that climate can impact negatively health status (Nastos & Matzarakis 2006, Braga et al. 2002, Chestnut et al. 1998, Kalkstein 1991) and facilitated the disease dissemination (Lowen et al. 2007, Alonso et al. 2007).

The air pollution can be derived from two main sources. One is urban with industries and traffic (Sicard et al. 2010, Roseiro & Angela 2006, Farhat et al. 2005, Gonçalves et al. 2005, Braga et al. 1999) and other is rural as deforestation, soil cultivation and pre harvest burning of sugar-cane (Uriarte et al. 2009, Ribeiro 2008, Arbex et al. 2007, Rittmaster et al. 2006, Cançado et al. 2006, Arbex et al. 2000). It is important to note that the state of São Paulo has a small area of forest and deforestation has no longer a significant impact on air pollution. So, more pollutant per m^3 of air can imply in a higher average rate of depreciation of health capital. To build up health stock will be necessary more investment.

The municipality per capita investment in health capital is a function of the average time ($\bar{t}_t^h$) the citizens spend with health, the average purchase of health good ($\overline{M}_t$) such as preventive medical care, average education ($\overline{E}_t$), that affect the efficiency of producing health and average individual healthy behavior ($\overline{\Upsilon}$) (Novi 2007), so the investment for a municipality can be describe as:

$$\overline{I}_t = f(\bar{t}_t^h, \overline{M}_t, \overline{E}_t, \overline{\Upsilon}) \tag{4}$$

We assume that the average time spent for health ($\bar{t}_t^h$) among the municipalities is the same and so not impacting the investment among cities. Regional differences in health facilities across the state of São Paulo is considerable. Therefore, the purchase of health goods ($\overline{M}_t$) is likely not the same due to access, quality and the presence of the private health sector. Education ($\overline{E}_t$) also varies and should be incorporated in the model.

The mean individual health behavior ($\overline{\Upsilon}$) can be different among cities. In areas with high long-term history of pollution, the individual may adapt her behavior to alleviate the effect of this externality. This fact can make pollution an endogenous variable (Neidell 2004).

Investment is not costless. The mean marginal cost to invest in health ($\overline{\pi}_t$) is a function of average wage ($\overline{W}_t$) and average price of health goods ($\overline{P}_t^M$) (Cropper 1981):

$$\overline{\pi}_t = f(\overline{W}_t, \overline{P}_t^M) \tag{5}$$

Although the Brazilian Public Health System (*SUS - Sistema Unico de Saúde*) is free, the access is not homogenous with different time of queuing and transportation. As a result, the indirect price will be different. Wages ($\overline{W}_t$) also vary and impact positively the capacity of investment in health.

Therefore, this model shows that polluted areas raises de decay of health depreciation and makes the health capital recovering more costly. Due to the high cost, individuals in polluted area choose a lower level of health capital and therefore are subject to higher incidence of illness (Cropper 1981).

3 Methodology

3.1 Region and Data Base Description

Region

As already mentioned the state of São Paulo is biggest producer of sugar-cane, accounting for 60% of total Brazilian production in 2007/2008 (IBGE 2010*b*). Also the state has a more detailed socio-economic data base for municipalities than other states.

In addition, in 2002 the state of São Paulo promulgated a law to gradually decrease the pre harvest burning of sugar-cane (State Law N. 11.241 of 2002). This law states that in 2002 the areas with less than 12% of slope should eliminate 20% of the burning areas in this year and completely abolish in 2021. The areas with more than 12% of slope should eliminate 10% in this year and completely abolish in 2031.

In 2007 the São Paulo State Secretary of Environment and the Brazilian Sugar-cane Industry Association (*União da Indústria da Cana-de-Açúcar - UNICA*) signed a protocol to anticipate the abolishment of pre-harvest burning of sugar-cane to 2014 and 2017, depending on the area slope. In this year almost 47% of total area of sugar-cane in São Paulo state was harvested without burning.

Because the Law N. 11.241 came into effect in 2002, and there is data available before and after this year, it is possible to identify the its effect on population health. In other words, we can identify the effect of increasing the area harvested mechanically on population respiratory health.

Therefore, we use 643 São Paulo state municipalities as a unit of analysis and collected data for two different years 2000 and 2007. For 2000 is assumed that none of the sugar-cane area was harvested mechanically.

Data Base

We consider three different dependent variables from the database of the Ministry of Health (DATASUS). It is important to note that those variables cover only the public health sector. On average 38% of São Paulo state population in 2007 are beneficiary of a private plan and this figure vary considerably among municipalities.

The first dependent variable is the number of inpatient visits or hospital admissions due to respiratory diseases per 1000 habitants per year and local of residence (according to *International Classification of Diseases* 10^{th} codes j00 to j99). This variable was classified into three categories: all population, 14 years old or less and 60 years old or more. The second dependent variable is the number of outpatient visits due to inhalation procedure per 1000 habitants per year (procedure after oct/99 code 0102208). Third variable is the duration of hospitalization due to respiratory diseases per local of residence (according to *International Classification of Diseases* 10^{th} codes j00 to j99), DATASUS (2010).

Pollution can be seen as a non-rival and non-excludent good, i.e. it is not possible to exclude someone from the consumption and the consumption of one individual do not affect the consumption of others. Hence, the key characteristic of pollution is the concentration of pollutants in the atmosphere. Three indicators of pollution (Ψ_t), in the level, were used to account for the volume of pollutants for m^3 of air: (i) area in thousand of hectare of raw sugar cane that was harvest without pre-burning (IBGE 2010*b*, SMA 2010); (ii) total fleet in 2002 as a proxy for 2000 fleet, in thousand units (SEADE 2010); (iii) the 2001 total consumption of industrial energy, as a proxy for 2000's consumption, in 1000 MWh (SEADE 2010). Implicit is the hypothesis that energy consumption is related with production which is related with the amount of pollution generated.

The environmental factors ($\overline{S}_t$), that can also impact the decay or depreciation of health ($\overline{\delta}_t$), were population density to control for disease spread capacity and the percentage of population above 60 years old to control for age (SEADE 2010).

For the investment in health ($\overline{I}_t$) were used number of health professionals and nurses per 1000 habitants registered in the regional council for the municipalities (SEADE 2010) and the percentage of population covered by private health insurance in June ($\overline{M}_t$) (DATASUS 2010), coded in three categories: all ages, 14 years old or less and with 60 years old or more.

Due to the fact that wage ($\overline{W}_t$) and education ($\overline{E}_t$) have high correlation we use the average of real salary [5] for formal workers to account for both factors that can affect the capacity and efficiency of investing in health (SEADE 2010).

Although the weather is an important variable to understand health respiratory diseases, the yearly average temperature, precipitation and humidity do not vary substantially in a city from 2000 to 2007. Therefore, we assume that the year average climate variables are constant variable over time for each municipality, whose heterogeneity is captured by the panel data model.

Also, pollution can be endogenously determined variable (Neidell 2004). Because individuals in polluted areas may change behavior ($\overline{\Upsilon}$) to alleviate the consequences of pollution. We assume that behavior is also constant in the medium term for a municipality, i.e., it is a time invariant variable. So, the panel model can deal with this endogeneity caused by the individual heterogeneity.

3.2 Econometric Specification and Effect Identification

To treat the endogeneity caused by the individual and municipality heterogeneity we use a panel model and assume that specific effects are additive and time invariant (Cameron & Triverdi 2005). Hence, the impact of increasing the raw sugar-cane harvested area on population respiratory health can be estimated as follow:

$$\overline{h}_{it} = \beta_1 \Psi^c_{it} + \beta_2 \mathbf{\Psi^o_{it}} + \beta_3 \overline{\mathbf{S}}_{\mathbf{it}} + \beta_4 \overline{\mathbf{M}}_{\mathbf{it}} + \beta_5 \overline{W}_{it} + \varepsilon_{it} \varepsilon_{it} = u_{it} + \theta_i u_{it} \sim N(0,1) \quad (6)$$

where i represents the 643 municipalities and t the two periods 2000 and 2007. The variable $\overline{h}^*_{it}$ is the number of inpatient visits per thousand habitants, the number of

[5] This series is in real price of 20009 deflated by INPC for income (IPEADATA (2010))

Table 1: Summary statistics for the variables used in the models

Variable	**Mean**	**Std. Dev.**	**N**
Inpatient visits (1000hab)	11.143	7.472	1288
Inpatient visits with private sector (1000hab)	12.939	9.374	1288
Inpatient visits <15 years (1000hab)	18.347	12.669	1288
Inpatient visits >60 years (1000hab)	30.105	20.064	1288
Inhalation (1000hab)	442.449	382.447	1288
Average length of stay (days)	5.031	1.465	1288
Population density	284.069	1141.331	1288
Population <15 years (per hab)	0.249	0.038	1288
Population >60 years (per hab)	0.112	0.028	1288
Raw sugar-cane (1000ha)	1.411	3.617	1288
Total fleet (1000 unit)	22.118	194.219	1288
Industry energy (1000MWh)	71.850	320.318	1286
Health professionals (1000hab)	4.799	2.782	1288
Nurses (1000hab)	4.18	2.373	1288
Private Beneficiaries (per hab)	0.151	0.153	1288
Private Beneficiaries < 15 years (per hab)	0.146	0.167	1288
Private Beneficiaries > 60 years (per hab)	0.155	0.141	1288
Salary (price 2009)	1052.553	320.991	1288

inhalation procedure per thousand habitants, and the average length of stay. Ψ^c_{it} is the harvest area of raw sugar-cane, $\mathbf{\Psi^o_{it}}$ is the total fleet and total industrial energy consumption, $\overline{\mathbf{S}}_{\mathbf{it}}$ is the population density and percentage of population above 60, $\overline{\mathbf{M}}_{\mathbf{it}}$ is the number of health professionals and nurses per thousand habitants and the percentage of private health plans beneficiaries and $\overline{W}_{it}$ is the average salary. The error term u_{it} is homocedastic and non-autocorrelated and θ_i is the time invariant individual and municipality specific effects, such as weather and individual behavior in the presence of pollution.

4 Results

The mean and standard deviation of the variables used in the models area presented in Table 1. The linear correlations among independent variables are presented in Table 2. We observe that the values are relatively small and do not exceed $|0.59|$. Therefore, the multicollinearity problem should be small.

To analyze the model stability we successively add blocks of independent variables and observe the changes in size, signal and significance of the parameters. Table 3 presents the linear panel fixed effect regressions with robust standard errors clustered in municipality for inpatient visits due to respiratory diseases per 1000hab.

The first equation uses just the environmental factors, the second add the pollution factors, the third add the health goods and the forth is the complete equation with salary. We observe that the magnitudes, signs and significance of parameters are reasonably stable. For instance, the impact of raw sugar-cane harvested area on inpatient visits was -0.172 without control for health good, education and

Table 2: Linear correlation among variables use in the models

Variables	Pop. Density	Pop. >60	Raw sugar-cane	Total Fleet	Ind. energy	Health Profes.	Private Benef.	Salary
Population density	1.000							
Population >60	-0.265	1.000						
Raw sugar-cane	-0.068	0.075	1.000					
Total fleet	0.303	-0.045	-0.000	1.000				
Industry energy	0.310	-0.183	-0.007	0.582	1.000			
Health professionals	0.191	0.149	0.188	0.188	0.200	1.000		
Private beneficiaries	0.314	-0.214	0.160	0.197	0.415	0.332	1.000	
Salary	0.367	-0.355	0.113	0.226	0.517	0.295	0.587	1.000

salary and decrease in module to -0.129 for the complete specified regression. So, not controlling for those factors can overestimate the impact of the increasing raw sugar-cane area harvested.

The city of São Paulo is the capital of the state and has a population around 11 millions habitants. This is almost 10 times bigger then the second biggest city in the state. To check the influence of São Paulo city we run the complete model without this city. The results are presented in the last column of Table 3. In this model all variables keep the signal, significance and magnitude, except for the total fleet that change signal, significance and magnitude. This show the influence of São Paulo city for total fleet in the state. The subsequent models incorporate the São Paulo city.

Inpatient visits

We specified four different models to account for the effect of raw sugar-cane harvested area on inpatient visits due to respiratory diseases. Those models are present in Table 4.

Also, we perform the Hausman test for random and fixed effects model. The results are present for each model in the bottom of the Table 4. At 1% level of significance we reject the hypothesis that the difference in the coefficients of both model are not systematic. So, the invariant specific effects term seems to be correlated with the independent variables and so the suitable model is the fixed effect. In addition, the models are performed using robust standard errors clustered in municipalities.

The first model used the number of inpatient visits per 1000 habitants and control for percentage of beneficiaries of health plan in the municipalities.

The second model we assume that the number of inpatient visits was done just by those individuals that do not have a private health plan. I addition, we assume that the level of utilization of the system per individual is the same for the public and private. Though, the number of inpatient visits was divided by the percentage of the municipality population that was not covered by private health plans. Therefore, the

Table 3: Results from the stability of the panel data model for inpatient visits per 1000 habitants due to respiratory diseases

	Dependent variable - Inpatient visits per 1000 habitants due to respiratory diseases				
Independent Variables	$\overline{S}_t$ FE model	$\overline{S}_t$, $\overline{\Psi}$ FE model	$\overline{S}_t$, $\overline{\Psi}$, $\overline{M}_t$ FE model	$\overline{S}_t$, $\overline{\Psi}$, $\overline{M}_t$, $\overline{E}_t$, $\overline{W}_t$ FE model	$\overline{S}_t$, $\overline{\Psi}$, $\overline{M}_t$, $\overline{E}_t$, $\overline{W}_t$ FE model - SP
Population density	0.00121	0.000615	0.00145	0.00101	0.00118
	(0.00122)	(0.00124)	(0.00120)	(0.00123)	(0.00118)
Population >60	-147.6***	-125.4***	-75.54**	-66.84**	-66.36**
	(21.37)	(23.69)	(31.93)	(31.72)	(31.91)
Raw sugar-cane		-0.172***	-0.140***	-0.129***	-0.127***
		(0.0379)	(0.0355)	(0.0355)	(0.0355)
Total fleet		0.00269***	0.00342***	0.00267***	-0.00246
		(0.000949)	(0.000893)	(0.000955)	(0.0154)
Industry Energy		0.00128***	0.00159***	0.00161***	0.00168***
		(0.000421)	(0.000457)	(0.000423)	(0.000428)
Health professionals			-0.492**	-0.480**	-0.476**
			(0.194)	(0.191)	(0.192)
Private beneficiaries			-3.860**	-3.486*	-3.520*
			(1.928)	(1.904)	(1.918)
Salary				-0.00297**	-0.00301**
				(0.00134)	(0.00136)
Constant	27.27***	25.07***	22.12***	24.29***	24.32***
	(2.300)	(2.514)	(2.864)	(2.933)	(2.933)
Observations	1,288	1,286	1,286	1,286	1,284
R-squared	0.113	0.130	0.145	0.152	0.152
Number of Municipalities	644	643	643	643	642

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

number of inpatients visits per 1000hab was 'corrected' and incorporate the private health sector utilization.

The third model uses the number of inpatient visits done by individuals with less then 15 years (excluding 15) per 1000 habitants with less then 15 years (excluding 15). In this model we use the percentage of population in this stratus that have private health plans. The last model uses inpatient visits per 1000 habitants for the population over 60 years and the percentage of health plans beneficiaries in this age stratus.

For the environmental factors ($\overline{S}_t$), population density for all models was not significant and do not explain the changes of health respiratory diseases per 1000hab. The two models with inpatient and inpatient corrected for private used the variable percentage of population over 60 years. The results show a negative effect significant at 5%. So, increase the population over 60 decrease the number of inpatient visits per 1000 hab. Although, the signal was opposite than expected by the theoretical model, the increase of over 60 year population is related with the diminishing of young population. The young individuals have a high level of utilization of the health system. So, the diminishing of age pyramid base can be related with the decrease of the number of inpatient visits per 1000hab.

The increase of raw sugar-cane harvested area (Ψ^c) has a negative and significant (at 1 and 5%) impact in all models. The increase of 1000 hectare harvested without burning in a municipality decrease the number of inpatient visits by 0.129 per 1000hab. Correcting the inpatient visits by the private sector this impact increase in module for -0.148 inpatient visits per 1000hab. In addition, it is worth to note that those coefficients are lower then those ones presented in Table 3 without controlling for health goods.

Also, the impact of raw sugar-cane harvested area is more important for population under 15 and over 60 years old. The impact of increase 1000 ha of sugar-cane harvested without burning in the municipality decrease the inpatient visit by 0.192 for the population under 15 and 0.378 for population over 60 years old.

Although this is the first work that try to analyze the impact of the increase of raw sugar-cane harvest area in the population health, our results are in accordance with the literature. Uriarte et al. (2009) using data for 2003 for the state of São Paulo found a positive impact of occurrence of fire on inpatient visits due to respiratory diseases for child with less the 10 years and elderly over 60 years. But, this work does not take in account the increase of raw sugar-cane harvest area and the increase of the size of private health sector in the state. Using data for a specific municipality Arbex et al. (2007), Cançado et al. (2006) and Arbex et al. (2000) found a positive impact of pre harvest burning of sugar-cane in the respiratory health admission.

For the other sources of pollution ($\mathbf{\Psi^o}$) we observe that the total fleet (1000 units) is positive and significant for the model with inpatient visits and inpatient visits over 60 years. The industry energy consumption (1000MWh) also has a positive and significant impact in the number of inpatient visits per 1000hab for the four models.

Again, this impact is more expressive for young with less than 15 years old and for individuals over 60 years. Although the previous works that studied the impact of sugar-cane production on health do not consider explicitly other pollution sources, there is considerable number of studies that presents evidence, as in our results, of a positive impact of urban air pollution on health status (Sicard et al. 2010, Roseiro & Angela 2006, Farhat et al. 2005, Gonçalves et al. 2005, Braga et al. 1999).

For health goods ($\overline{\mathbf{M}}$) the number of health professionals per 1000hab has a negative and significant (at 1 and 5%) impact in the number of inpatient visits. So, if there are more doctors and nurses per 1000hab in the municipality the population can have easier access to this health good for treatment and so less acute problems that lead to inpatient visits. Though, more health goods imply in better health conditions. This is especially important for the individuals less than 15 and over

60 years old. Thus, for inpatient visits model the increase of 1 health professionals per 1000 hab decrease the inpatient visits by 0.48 for the whole population, 0.628 for inpatient with private health sector model, 0.871 for the population less than 15 years and 1.737 for the population over 60 years.

The percentage of population in the municipalities that is beneficiary of private health plans has a negative and significant impact (at 10%) in number of inpatient visits for the model considering the whole population and not significant for the population under 15 and over 60 years old.

Finally, the average municipality's salary ($\overline{W}$) has a negative impact in the inpatient visits. Better salaries which are correlated with better education imply in higher and more efficient capacity of invest in health and so less inpatient visits. The impact of salary was higher for population over 60 years and has no effect for the population under 15 years.

Outpatient visits and length of stay

In this section we specified two models. The first model has the number of inhalation procedure per 1000 habitants (outpatient visits) as a dependent variable. The second has inpatient length of stay due to respiratory diseases. Both models are presented in Table 5.

For both models we performed the Hausman test and the results are presented in the bottom of Table 5. For the inhalation we do not reject the hypothesis that the difference in the coefficients of both model are not systematic. Although, the random effect model is more suitable as pointed by the test, we presented both fixed and random effect models. For the length of stay the fixed effect model is presented.

For the random effect model for inhalation procedure, the percentage of the population under 15 years was important to explain the number of inhalation. Higher the population at this ages higher the number of inhalation. We could not identify any impact of the pollution factors on the number inhalation procedure in the random effect model. Although, the sign for raw sugar-cane area was negative, it do not present statistical significance. Therefore, the increase of raw sugar-cane harvested area has no significant impact.

The health goods present a significant effect. In this model we use number of nurses instead of health professionals due to the fact that inhalation procedure in general do not use doctors as a resource. The increase of 1 nurse per 1000 habitants decreases the inhalation in 11.17 per 1000hab. On the other side the number of beneficiaries of private health plans has positive effect. This last result was not expected, i.e., that the higher the percentage of population with private health plans the higher is the number inhalation in the public sector for a municipality.

Finally, the salary presents a negative and significant effect. Thus, the higher is average salary in a municipality, the smaller will be the number of inhalation procedure. For the length of stay just the population over 60 years is significant and negative. None of pollution variables, health goods and salary was important to explain the changes in the average length of stay. So, it seems that pollution do not generate more severe cases in comparison with standard case not caused by pollution.

5 Conclusion

This paper analyze the impact of the increase of raw sugar-cane harvested area on the population respiratory's health. We use municipality data for two periods before and after the state law that gradually diminish the pre burning of harvested sugar-cane area (Law 11.241 of 2002), ie, from 2000 and 2007. Using a panel data model that control the endogeneity caused by the individual heterogeneity we estimate three blocks of equation, for inpatient visits due to respiratory diseases per 1000 habitants, inhalation per 1000 habitants and length of stay due to respiratory diseases.

This paper contributed to the literature to be the first attempt to use the raw sugar-cane harvested area and the increase of private health sector to analyze the health respiratory consequences of sugar-cane production. Also, using a broad area and a wide time spam this is the first paper to explicitly consider other sources of pollution and medical goods.

Four main results can be derived from this paper. First, the increase raw sugar-cane harvested area decrease the number of inpatient visits and the total fleet and industrial energy consumption increases the number of inpatient visits. This variables has stronger effect for those individuals with less than 15 years and for those over 60 years old. Exception for the population under 15 where the total fleet had no effect. However, pollution was not important to explain inhalation and length of stay.

So, we conclude that the state law and the protocol sign in 2007 apparently had a important contribution to the improvement of population respiratory's health in the states of São Paulo. Also, this contribution was considerable large comparing with the contribution of the total fleet and industry pollution.

Second, the environmental factors are important to explain the inpatient visits and inhalation. The population over 60 decreases the number of inpatient visits, probably because the increase of this age stratus is related with the decrease of the young age stratus, which has a significant higher rate of utilization. In addition, the population under 15 years was important to explain the increase of inhalation per 1000 habitants.

Third important result are related with health goods. The numbers of professional decrease the number of inpatient visits and inhalation. So, more accessible health goods can improve considerably the health status.Therefore, when decreasing the pollution is relatively difficult in the short run investment in health goods can partially compensate this effect. Also, the health goods contribution is larger from individuals over 60 and under 15 years old.

In addition, the private beneficiaries decrease the number of inpatient visits significatively and should be taking into account when analizing a distinctive time spam of the Brazilian health data from the DATASUS, which consider just the public visits.

Finally, the salary decrease the number of inpatient visits and inhalation. Thus, better salary are associate with better education and so to a better efficiency and capacity to invest in health. This is specially true for those individuals over 60 years old.

Therefore, as the sugar-cane production has gained and will increase its importance in the energy market in Brazil and in the world it is relevant to understand the effects of production and the sector specific laws on population health status, socio-economic indicators and environment. This work contribute to the literature showing the positive impact on the health status of the population due to the raw sugar-cane harvest and so the benefits of the state law that diminish the pre harvest burning. Thus, investments in new technologies and government incentives that can increase the adoption of raw sugar-cane harvest can considerably improve the population health conditions in Brazil.

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Table 4: Results from the panel data model for distinct measures of inpatient visits per 1000 habitants due to respiratory diseases

	Dependent variable - Inpatient visits due to respiratory diseases			
Variable	Inpatient	Inpatient with private sector	Inpatient < 15	Inpatient visits > 60
	Fixed Effect Model			
Population Density	0.00101	-0.00133	0.00282	-0.00229
	(0.00123)	(0.00215)	(0.00214)	(0.00360)
Population >60	-66.84**	-66.94**		
	(31.72)	(33.88)		
Raw sugar-cane	-0.129***	-0.148**	-0.192**	-0.378***
	(0.0355)	(0.0678)	(0.0772)	(0.103)
Total fleet	0.00267***	0.00203	0.00271	0.00609***
	(0.000955)	(0.00349)	(0.00283)	(0.00233)
Industry energy	0.00161***	0.0168***	0.00203**	0.00336***
	(0.000423)	(0.00203)	(0.000864)	(0.000860)
Health professionals	-0.480**	-0.628***	-0.871***	-1.737***
	(0.191)	(0.221)	(0.241)	(0.429)
Private beneficiaries	-3.486*			
	(1.904)			
Private beneficiaries <15			-2.275	
			(2.560)	
Private beneficiaries >60				-4.507
				(8.136)
Salary	-0.00297**	-0.00295*	-0.00294	-0.00863**
	(0.00134)	(0.00159)	(0.00203)	(0.00419)
Constant	24.29***	25.87***	25.24***	49.06***
	(2.933)	(3.236)	(2.341)	(4.641)
F	19.24***	20.14***	6.27***	13.25***
Observations	1286	1286	1286	1286
Hausman test	60.40***	53.15***	32.20***	34.69***

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Results from the panel data model for outpatient visits per 1000 habitants and length of stay due to respiratory diseases

	Dependent variable - Outpatient visits for inalation per 1000hab and Length of Stay		
Variable	Inalation FE Model	inalation RE Model	Length of stay FE Model
Population density	-0.0315	-0.00584	0.000421
	(0.0523)	(0.00956)	(0.000385)
Population <15	2,043***	1,633***	
	(627.5)	(298.7)	
Population >60			-10.59*
			(5.470)
Raw sugar-cane	0.701	-1.770	0.0106
	(2.707)	(2.327)	(0.00996)
Total fleet	0.0725	-0.0167	0.000690
	(0.0882)	(0.0418)	(0.000657)
industry energy	-0.122**	-0.0434	0.000350
	(0.0483)	(0.0411)	(0.000264)
Nurses	-6.053	-11.17***	
	(9.986)	(4.106)	
Health professionals			0.0458
			(0.0402)
Private beneficiaries	-12.10	220.6**	0.456
	(153.0)	(109.0)	(0.518)
Salary	0.0316	-0.0794*	-0.000397
	(0.0781)	(0.0471)	(0.000274)
Constant	-61.17	136.6	6.166***
	(222.4)	(86.04)	(0.554)
F	7.78***	1535.74***	1.55
Observations	1286	1286	1286
Hausman test	9.52	9.52	12.19**

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1