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A spatial difference-in-differences analysis of the impact of sugarcane production on respiratory diseases

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ABSTRACT

Sugarcane production represents around 10% of the agricultural area and 1% of GDP in Brazil, and has grown substantially in recent years. The traditional harvest method involves burning the field to facilitate access to the canes, resulting in well-documented negative effects on health. The existing studies do not consider the effects on health in the surrounding areas. This article presents a new variety of a spatial diff-in-diff model to control for the effects of sugarcane production in neighboring non-producing regions. This method is an addition to the Spatial Econometrics literature, as it includes spatial effects on treated and untreated regions, so that the effects on both producing and surrounding non-producing regions can be properly estimated. The results indicate that the effects on the producing regions are 78% larger than if the effects on the surrounding areas were ignored. Moreover, the effects on the surrounding areas, typically ignored in other studies, are relevant, and almost as large as the effects on the producing areas.

1. Introduction

Brazil is a traditional producer of sugar and has been an important player in the international market for centuries. In 2013, the country was the largest producer in the world, producing almost 27% more than the second largest producer, India. Although this market has somewhat stagnated in recent years, its growth was substantive in recent decades. Sugar is produced from sugarcane, an input that is also used to produce ethanol as fuel for automobiles. A governmental incentive program to substitute ethanol for fossil fuels was established in the late 1970s and reached full steam in the first decade of this century, as the automobile producers developed techniques to allow cars to run on both gasoline and/or ethanol. High oil prices powered the fuel substitution and the demand for ethanol increased dramatically, and production followed. As a result of these two influences, the production of sugarcane has increased sharply in the last 20 years, with the ethanol industry representing approximately 3.5% of Brazilian industrial GDP. The sector as a whole employs more than 6 million people and the planted area doubled in the last 20 years, occupying 10% of the agricultural area of the country.

The ethanol program has been considered a success in terms of emissions reduction by replacing pollutant fossil fuels (Goldemberg et al., 2008), but there are many issues related to the possible negative by-products of sugarcane production. There are doubts about the quality of the employment in the sugarcane fields, because the activity is hazardous and physically demanding. There are also questions on environmental aspects, such as soil contamination, atmospheric pollution generated by the burning of the fields, water consumption, and dislocation of other crops towards native forests (Noronha et al., 2006). Some studies have shown that the balance of costs and benefits is positive from the standpoint of the entire country (BNDES and CGEE, 2008), but not so evidently in the growing regions that disproportionately bear the negative impacts.

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The most studied aspect is related to the labor market, and the negative impacts of manual harvesting are highlighted (Alves, 2006, 2007; Baccarin et al., 2008). Toneto-Jr and Liboni (2008) indicated that sugarcane generates more jobs than soybean, and only slightly less than corn. As it generates more value per hectare and more jobs as well, cane growing generates more income per area planted than other staple crops. Because transportation costs on the raw material are high, processing plants (sugar mills and/or ethanol distilleries) must be located close to the fields, increasing the sector's indirect effects on the producing region. Chagas et al. (2011) evaluated the impact of sugarcane on the local Human Development Index using spatial propensity score matching, controlling for the fact that sugarcane production in one specific region is not random. The results suggest that sugarcane growing is not relevant to determine local social conditions.

This paper deals with the impacts of sugarcane production on health conditions in the planting areas and their neighborhood. Because harvesting involves burning the fields, it releases fine and coarse particulate matter that affects the population in the vicinity. We explore a new ground in presenting a spatial difference-in-differences model (SDID) to control for the effect of sugarcane production on both producing (treated) and nonproducing (untreated) neighboring regions. This procedure for measuring the effects is more complete than the ones used in previous studies, such as Heckert and Mennis (2012) and Dubé et al. (2014). It brings a new way to look at both the true effects of sugarcane production on health and the measurement of spatial effects in general.

The article is organized in six sections, including this introduction. The next section deals with a review of the literature of the effects of sugarcane production on human health. Section 3 presents a review of the methodological questions present in the literature, the methodology proposed to identify the possible impacts of sugar-cane production on the respiratory health conditions in the producing regions, and the data used. Section 4 presents the results followed by robustness checks of the estimates, as presented in Section 5. The last section contains the final remarks of the analysis.

2. Sugarcane production, air pollution, and human health

Sugarcane is harvested by unskilled workers mostly manually. This traditional harvest method involves burning the planting area to facilitate access to the canes. There are concerns about the possible negative direct and indirect effects on health in the planting regions. The burning of the fields is intended to increase workers? productivity, as it eases access to the plants, saves on time otherwise spent in the separation of leaves, and reduces work hazards (dry leaves are harmful and there might be poisonous insects and snakes). It takes place at the beginning of harvest, which coincides with the dry season in the production areas. Many studies highlight the increase in both fine and coarse particulate matter, black carbon concentration, especially during burning hours (Lara et al., 2005), and the increase of the air concentration of substances as nitrite, sulfite, oxide of carbon, and others in the air (Allen et al., 2004). Considering smoke dispersion, the literature relates that short and long-term exposition to classical pollutants (matter, sulfite, nitrite, oxide carbon, etc.) can negatively affect the economy of a country by damaging the health status of the workers, specifically among the young and the elderly (Braga et al., 1999; Fischer et al., 2003; Gangadharan and Valenzuela, 2001; Goncalves et al., 2005; Roseiro, 2002; Sicard et al., 2010; Sun and Gu, 2008; Wen and Gu, 2012).

Sugarcane burning generates a massive quantity of particles and toxic gases that spread all over the region, reaching cities and becoming a potential threat to human health. According to Mazzoli-Rocha et al. (2008), pollution from sugarcane burning may be as harmful as pollution from traffic and manufacturing activities. There are many studies in this topic on the Brazilian case, mostly coming from the public health literature (Arbex et al., 2000, 2004, 2007, 2014; Cançado et al., 2006; Carneseca et al., 2012; Goto et al., 2011; Ribeiro, 2008; Santejo Silveira et al., 2013; Uriarte et al., 2009). The study of Nicolella and Belluzzo (2015) is an exception. They use a classical difference-in-differences approach to evaluate the impact of the reduction in the pre-harvest burning sugarcane on respiratory health. The results indicate that reducing the area where sugarcane is harvested after burning reduces the number of hospitalization cases. These are mostly case studies focusing on the effects of burning on respiratory health problems at the local level. They concentrate on the short-distance effects, failing to capture the consequences of burning events on other places (spillover effect), which is the focus of this work.

The literature on spillover effects of environmental events is increasing rapidly, but it is still limited. There are many papers testing the well-known Environmental Kuznets Curves (EKC), associating low levels of environmental problems both at low or high per capita income levels, and at high levels of environmental problems at intermediate income levels (Dinda, 2004; Grossman and Krueger, 1991, 1995). Spatial econometrics techniques were used to measure if per capita emissions in a country (county) were spatially dependent on the environmental characteristics of the neighboring countries (counties), as in Ciriaci and Palma (2010), Hao and Liu (2016), Maddison (2006, 2007), Rupasingha et al. (2004), Stern (2000), Su et al. (2009).

3. Methodology and data

Spatial econometrics techniques are becoming more popular in the study of environmental interactions, such as Hosseini and Kaneko (2013), at the institutional level, Renard and Xiong (2012) and Li et al. (2014), on industrial structure similarity, Pandit and Laband (2007), on imperiled species, Won Kim et al. (2003) and Chen and Ye (2015), on housing and gasoline prices, Li et al. (2014), on local economic development, and air quality and urbanization, Fang et al. (2015) on automobile and population density, and Chen and Ye (2015) on the levels of precipitation and the direction and speed of the wind. However, to the best of our knowledge, there are still only few studies measuring the effects of pollution of any source on health indicators considering the spatial correlation (Lagravinese et al., 2014; Wang et al., 2014, 2015, are exceptions).

3.1. The difference-in-differences model

The literature on impact evaluation sets to measure the impact, or the marginal effect, of a single binary regressor that equals one if the treatment occurs and zero otherwise (Ashenfelter and Card, 1985). The simplest case is one where outcomes are observed for two groups in two time periods. One of the groups receives a treatment in the second period, and the other group is not exposed to the treatment during either period. In the case where the same units within a group are observed in each time period, the average gain in the second (control) group is subtracted from the average gain in the first (treatment) group. This should remove any biases in second-period comparisons between the treatment and control groups that could be the result of permanent differences between those groups, as well as biases from comparisons over time in the treatment group that could be the result of common trends.

In the equations that follow, y_{it} is the variable of interest (hospitalizations due to respiratory diseases) and $\mathbf{x}_{it}$ is a vector of observable characteristics specific to region i in period t. We consider two situations for each region: before (b) and after (a) treatment. Additionally, we introduce a fixed effect φ_i and a drift term θ_t.