# The Impact of Rising Ethanol Production on the Brazilian Market for Basic Food Commodities: an Econometric Assessment

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## Abstract

The recent debate on the impacts of rising biofuel production on food markets is of great policy relevance in Brazil, as the country is a major global player in ethanol and agricultural markets and households (especially the poor) usually spend the major part of their income on food consumption. This paper contributes to the literature with an explorative econometric assessment by applying interaction regression models with entity and time fixed effects using OLS. Our panel dataset comprises annual production/harvested area data for the sugar-alcohol sector and for five other staple commodities (rice, beans, corn, soybeans and manioc) ranging from 1981 to 2009 for 24 Brazilian states. Our results indicate the following: (1) rising ethanol production has a significant positive impact on sugar production and on sugarcane acreages; (2) we could not find significant impacts for corn and manioc; (3) increasing ethanol production exerts a statistically significant (but rather moderate) negative impact on the harvested areas for rice, beans and soybeans. The effects on the harvested areas for the commodities have implications for prices. Thus, ceteris paribus, the prices for rice, beans and soybeans are expected to increase and sugar prices to decrease as a result of rising ethanol production.



Key words: biofuels, staple commodities, econometric assessment

## 1. INTRODUCTION

Prices for basic agricultural commodities have been rising sharply in recent years. This raises concerns, because food commodities constitute a substantial proportion of family budgets for the majority of the world population. Thus, several studies amongst others, Headey and Fan (2008), von Braun (2008), Mitchell (2008), Abott et al. (2009) and Schaffnit-Chatterjee (2009) have assessed the main factors contributing to the increase in food commodity prices. They have all pointed out that the combination of the following new and ongoing forces are driving the food situation in the world. On the demand side, income and population growth (especially in developing and emerging economies such as Brazil, China and India), globalization and urbanization, changes in consumption patterns due to shifts in consumer preferences and speculation pushes the prices for food up. On the supply side, land and water constraints, weather disruptions, climate change, underinvestment in rural infrastructure and agricultural technology as well as high input costs are challenging agricultural markets (Abott et al., 2009; Schaffnit-Chatterjee, 2009; von Braun, 2008). Additionaly, some macroeconomic and institutional factors such as the depreciation of the US dollar, low interest rates and, most notably, export restrictions have been discussed as possible explanations for the recent developments in crop prices (Mitchell, 2008; Headey and Fan, 2008 and The Economist, 2012a).

Moreover, several authors claim that the complex and strong linkages among the world's food and energy markets have become more prominent over the last years, with the rapid increase in energy prices (especially crude-oil prices) as well as with the intensification of biofuel production.[1] According to the literature (e.g., Mitchell, 2008 and OECD-FAO, 2009), the links between energy and agricultural markets are on the one hand related to the production costs for crops and livestock products, as well as to the transportation costs. On the other hand, the links are associated with the increasing biofuel demand that is due to its production as a substitute for liquid fossil fuels used in transportation.[2] Along with high oil prices, the main drivers behind this sharp increase in biofuel production are government policies (e.g. mandates, targets and subsidies) which aim to achieve higher energy security and to deal with climate-change issues (Janda et al., 2012). It is worth mentioning that the positive environmental impacts of biofuels, first glorified as a blessing, have also become widely debated in the last years.

On these grounds, scientists and economists are raising concerns about a food, energy and environment trilemma (Tilman et al., 2009). A new competition for land is arising from the growing and changing demand for food. This is combined with the rising demand for transport biofuels as fossil fuels are becoming scarce and greenhouse-gas emissions must urgently be reduced (Harvey and Pilgrim, 2011).

The economic research on biofuels is an expanding research area which is far from being exhausted. While there is a wide range of theory-based economic studies which make use of partial and general-equilibrium structural models for the assessment of the impacts of biofuels on agricultural markets, there is a lack of econometric assessments[3]. Partial equilibrium models usually provide results that are more meaningful in the short run and explore the impacts of expanding biofuel production, paying particular attention to the role of biofuel mandates.[4] In the case of heavy increase in biofuel production and under the assumption of constant crop productivity, most partial-equilibrium models predict drastic increases in food prices and a reduction of food supply (Rosegrant, 2008).

Computable-general-equilibrium (CGE) models investigate long-term economic impacts of large-scale biofuel expansion by virtue of biofuel mandates and targets (see, for instance, Al-Riffai et al., 2010 and Timilsina et al., 2012).[5] The research topics of such CGE studies include impacts

[1] Kristoufek et al. (2012) argues that the connections between biofuels and food commodities have become much stronger after the food crisis of 2007-2008.

[2] Biodiesel and ethanol are the most important biofuels used in the transport sector. Nevertheless, in this paper we will only evaluate the impacts of ethanol production.

[3] See Rajagopal et al.(2007) and Janda et al. (2012) for comprehensive reviews of the main economic biofuel models.

[4] See Witzke et al. (2008), Rosegrant (2008), and Al-Riffai et al. (2010) for an overview of the main models and results.

[5] Again Rajagopal et al. (2007) and Janda et al. (2012) provide a comprehensive classification of these models, as well as an overview of the main results.

on food supply and prices, on land-use change, and on national and global incomes. Results are heterogeneous across countries and commodities: for instance, Timilsina et al. (2012) point out that developing countries will probably experience a stronger decrease in food supply and the authors expect some feedstock commodities such as sugar, corn, and oil seeds to experience much more significant price increases than other commodities. However, most studies agree that recent increases in biofuels production have markedly strengthened the correlations between the prices of energy and agricultural commodities (Janda et al., 2012). Because the agriculture-energy links are manifold and complex, addressing all aspects related to it would go beyond the scope of this paper. Moreover, this paper does not aim to assess the wide range of factors influencing food production and prices, but it will focus on the impact of rising biofuel production on the market for basic food commodities.

The recent econometric literature on the economic impacts of biofuels usually investigates the relationship among agricultural commodities, biofuels and fossil-fuel prices by relying on time-series approaches (Janda et al., 2012).[6] For instance, Monteiro et al. (2012) investigate the impacts on food prices of ethanol production from Brazilian sugarcane and U.S. corn. They find a positive and significant effect of the increasing Brazilian market share (in global ethanol markets) on food prices. For their analysis, they conducted Ordinary Least Squares (OLS) regressions in first differences considering food and consumer national price indices. However, their analysis' accuracy is diminished due to the data's high aggregation level.[7] Kristoufek et al. (2012) develop a methodology of taxonomy (using minimal spanning trees and hierarchical trees) usually used in networks and complex systems analysis. They find that the correlation between biofuels and related commodities becomes more structured in the medium-term and ethanol connections with the food branch strengthen after the food crisis of 2007/2008. Their approach is straightforward and allows for the inclusion of several different biofuels and related commodities. Nevertheless, this methodology is not able to capture causality and it does not account for possible cointegration or non-stationarity of the time series.

Hausman et al. (2012) apply a structural-vector-autoregression (SVAR) approach to investigate crop price responses to negative shocks in acreage supply due to reallocation from food to fuel production in the US corn-ethanol market. According to their calculations for the boom production year 2006, rising ethanol production would explain 27% of the increase in corn prices in the US. Their approach is interesting as SVAR models seem to be suitable to despict dynamics in agricultural supply processes. However, their results are based on hypothetical scenarios, because they assume that rising ethanol production automatically leads to acreage shortages for food production. Finally, Hausman (2012) estimates the responsiveness of the Brazilian sugarcane and soybeans acreage to changes in crop prices. The paper uses a dynamic panel data model of input demand for agricultural land conditioning on price changes of other commodities. The author finds that the Brazilian soybean acreage grows much faster in response to price changes than does sugarcane acreage (both in national and regional levels) especially in the short run. However, they conduct their analysis under the presumption that rising biofuel production increases crop prices and do not investigate how biofuel production directly influence acreages and prices.

At this point a few common caveats in the econometric literature should be mentioned. Most previous econometric estimations relying on time series focus on price variables that are frequently available only on a highly aggregated level. Those estimates are therefore seldomly able to quantify the direct impacts of biofuel production on the supply of related agricultural commodities. As price variables are highly volatile, it is quite difficult to filter out biofuels impacts from a lot of other factors which influence prices. Furthermore, almost all studies focus only on agricultural commodities that are used for fuel production (e.g. sugarcane, corn, soybeans) and thereby do not account for indirect effects on other basic food commodities.

Hence, the main purpose of this paper is to add to the literature by assessing the impacts of rising ethanol production (based on sugarcane) on the Brazilian sugar market and, in addition, on the market for other basic food commodities which are essential in the Brazilian diet.

[6] Janda et al. (2012) provides a brief review of representative econometric studies on biofuel impacts.
[7] The very small number of observations (28) also calls into doubt the robustness and reliability of their analysis.

This paper uses panel data for the sugar-alcohol sector and five other commodities, namely rice, beans, corn, soybeans, and manioc for 24 Brazilian federative units (states) covering the period from 1981 to 2009. We estimate entity and time fixed effects regression models in order to assess the average impacts of rising ethanol production on the production of sugar and on the acreages of the other commodities considered.

The analysis proceeds via two steps: we first assess effects on the production/acreages of agricultural commodities and then make some inferences with respect to prices. This approach allows us to conduct a more robust analysis, since production and acreage data represent real values and are available on a regional level.[8] The rationale underlying our investigations is as follows: biofuel mandates and/or increasing oil prices encourage biofuel production. Higher biofuel production, in turn, puts more pressure on the fuel and agricultural sectors and might lead to a reduction of the food supply and to higher food prices. This effect might occur due to a reallocation of food crops to fuel production or due to the diversion of agricultural land from food to energy crops.

It makes sense to start with an explorative econometric analysis of the impact that the production of sugarcane-based ethanol has on the sugar market since there might exist direct competitive links as the production of both goods is based on the same agricultural commodity. Likewise, the choice of the country is reasonable since we expect effects in Brazil to be pronounced as Brazilian ethanol and sugar production are cost-efficient and highly competitive and the country is a major world player in both markets.

Starting from the presumption that increasing ethanol production puts more pressure on the sugar market, one should expect sugar production to decrease as ethanol production rises.[9] Nevertheless, we find a positive and significant effect of ethanol production on sugar production for food purposes. We also include the import prices for Brazilian crude oil as a control variable in our regression. We similarly find a positive and significant coefficient meaning that, ceteris paribus, higher oil prices do not necessarily go along with lower food production (at least in the Brazilian sugar market). Our findings suggest that the sugarcane area and the sugar production have historically increased together with ethanol production. In fact, we find that ethanol and sugar production have (separately and together) a positive and significant impact on the area devoted to sugarcane. This raises the question if the expansion of the area devoted to sugarcane production is suppressing the availability of land areas which would otherwise be dedicated to the production of other important food commodities. Indeed, we find a negative and significant impact on the harvested areas for allmost all crops under investigation except for corn and manioc for which we do not find any significant effect.

The remainder of this paper is structured as follows. Section 2 first provides some basic figures about the Brazilian ethanol and agricultural markets, including relevant information regarding the commodities under investigation. Section 3 then presents the data, the empirical methodology, and the results for our first estimations regarding the impacts on the Brazilian sugar market. Subsequently, Section 4 describes our enhanced dataset and the empirical methodology applied in the analysis of the impacts of rising ethanol production on the harvested areas of rice, beans, soybeans, manioc, and corn. The section also presents individual estimation results and an overall evaluation. Concluding remarks and some prospects for future research are provided in the final section.

## 2. BRAZILIAN ETHANOL AND THE MARKET FOR BASIC FOOD COMMODITIES

Before we start with our empirical assessment of the impacts of ethanol production on the Brazilian market for basic food commodities, it is instructive to provide a brief summary of some basic information on the Brazilian ethanol and agricultural markets.

[8] This is in contrast to price data, which are much more volatile and only available on a national level.

[9] If sugar production were suppressed due to higher ethanol production, sugar prices would rise (ceteris paribus) signalizing scarcity.

## 2.1 Brazilian ethanol

Since the year 2000, the Brazilian first-generation ethanol production has steadily been increasing and Brazil has become a key player in the world biofuel markets.[10] The Brazilian total production of ethanol in the year 2009 was above 25 billion liters and the country ranks as the second biggest ethanol producer in the world (after U.S.). Furthermore, Brazil is the biggest world ethanol exporter with annual exports totaling about five billion liters (Walter & Dolzan, 2009). Figure A1 (see appendix) is based on data provided by the Brazilian Sugarcane Association (UNICA) and shows the rapid increase in sugarcane based ethanol production in Brazil (especially since 2000):

The Brazilian ethanol production, based on sugarcane crops, is very competitive due to many reasons. On the one hand, the country possesses big "natural" absolute advantages, such as vast agricultural frontiers, fertile soil and a relatively favorable climate. In addition to that, sugarcane crops have a higher energy content than other crops used for ethanol production, such as corn. Further, processes for converting sugarcane into ethanol are the most efficient because the residue of ethanol production (bagasse) can be used to power sugar and ethanol mills and the remaining energy can be sold to distribution networks of electricity. On the other hand, there are some "constructed" cost advantages, which are the result of government support for both demand and supply of ethanol, and large investments in the development of agricultural technology and in the ethanol industry. The Brazilian efforts to diminish oil dependence, with a strong government focus on developing biofuels, have contributed to the development of new technologies and to more efficient processes.[11]

Besides, the flex-fuel vehicles designed to run on both ethanol and gasoline were successfully introduced in the Brazilian market in 2003. In fact, according to the REN21 report (2010), sugarcane ethanol replaced 50% of gasoline for transport in 2009. This advanced stage of the market for flex-fuel vehicles means much more flexibility on the demand side, since consumers can opt for the cheapest available fuel on short notice (De Almeida, 2009). After 2009, however, the Brazilian ethanol industry has been experiencing some difficulties due to several factors, such as poor sugarcane harvests (bad weather), cash-strapped growers (financial crisis), and not least because of high sugar prices in the world market that made it more attractive to produce sugar instead ethanol (The Economist,2012).[12]

Nonetheless, this bad phase might be transitory and the ethanol industry is expected to recover soon. The current government has made many efforts towards establishing trade agreements in order to develop the export markets and by the end of the last year, the United States (a major ethanol producer) has lifted protectionist measures such as tax credits for national production and import tariffs on Brazilian ethanol (The Economist 2012). This might open new perspectives for enlarging the Brazilian share in the international trade scenario in the coming years.

Finally, recent foreign investments coming particularly from the United States and Europe will also contribute for the improvement of ethanol distillation plants as well as of sugarcane production techniques in Brazil (Janda et al., 2012).

## 2.2 The Brazilian market for basic food commodities

The agro-food sector is also very important for the Brazilian economy. It accounts for about 6% of the Brazilian gross domestic product (GDP) and for about 38% of all Brazilian exports (OECD, 2011).[13] Agriculture in Brazil has been harnessed to poverty reduction efforts by creating employment and improving food security. It has contributed to macroeconomic stability by guaranteeing valuable inflows of foreign currency inflows and played a key role in the Brazilian

[10] Brazilian ethanol belongs to the first-generation biofuels which are produced from crops rich in sugar or starch, such as sugarcane in the Brazilian case or corn in the US. Nowadays, there are already biofuels of the second-, third-, and fourth-generation but they are still not commercially viable (Janda, et al., 2012). That is why we will only refer to first-generation ethanol production throughout the whole paper.

[11] According to Hettinga et al., (2009), processing costs of Brazilian sugarcane ethanol have decreased by 70% since 1975.

[12] These supply shortages have affected prices so that in some periods ethanol was no longer attractive for owners of flex-fuel vehicles.

[13] The OECD-Report is partially available online at: http://dx.doi.org/10.1787/agr_pol-2011-22-en

strategy for energy security. Therefore, the agricultural sector plays three main roles within the Brazilian economy simultaneously: the food security function, the energy function and the export function (De Almeida, 2009). Thus, there is a big debate on potential conflicts among the food, energy and export roles of the Brazilian agricultural markets. Several simulation models predict shifts in crops' cultivation in favor of biofuel production, which may potentially result in higher food prices. This displacement problem may be particularly prominent in countries with low incomes and high inequity, such as Brazil, because households in those countries usually spend the major part of their incomes on food consumption (OECD-FAO, 2009). One could argue that higher food prices could be favorable for poor households in rural zones, who depend on agriculture as means of subsistence. However, rising demand for land increases the cost of production for small-scale producers (as the costs for leasing the land increase). Furthermore, large-scale agriculture (which relies on monocultures) still dominates in the country for most commodities and landowners are unlikely to share increasing returns with their workers in a fairly way. Therefore, increases in the prices of staple food in most cases affect the purchasing power of the poor (in rural as well as in urban zones) negatively.[14]

The Brazilian agriculture is a wide sector, which includes a large number of commodities.[15] Nevertheless, an extensive study of all commodities would go beyond the scope of this paper. We therefore focus our econometrical analysis on the impacts of ethanol on the sugar market and on the market for five other essential commodities: rice, beans, soybeans, corn and manioc.[16]

*Sugar*

As in the case of ethanol, Brazilian sugar production is low cost and highly efficient. Brazil is the largest global producer and exporter of sugar, and since it dominates sugar supply in South America and in the world markets, the country is one of the price setters in the world sugar economy. Because sugar production is based on the same crop as the production of ethanol (sugarcane), trade-offs in the allocation of sugarcane crops (either to ethanol or to sugar) might be pronounced and several studies have predicted that most sugarcane will be allocated to ethanol production displacing it from the sugar production for food purposes (OECD-FAO, 2009).

However, UNICA data on sugar production which is depicted in Figure A2 (see appendix) shows that contrary to expectations sugar production has actually increased over the years even in the period starting from 2000 for which an intensification of ethanol production is also evident. Moreover, as discussed in the previous subsection, sugar production has markedly increased in 2011 due to high prices in the world market, which made sugar production more profitable.

Expectations on crop returns and on input prices have a strong influence on farmers' land use decision. Therefore, the developments in the sugar and ethanol markets (high demand for sugarcane) lead to the conjecture that sugarcane is likely to take over land from other staple foods. That is why we investigate impacts on the land areas for other basic food commodities.

*Rice*

Rice is one of the most important staple foods in Brazilian households and plays a major role in food security.[17] Brazil is the world's 10th largest rice producer, but the country is also a major rice importer. All states in Brazil produce rice but the major regions producing this commodity are the States of 'Rio Grande do Sul', 'Santa Catarina' and the 'cerrado' region.[18] 'Rio Grande do Sul' and 'Santa Catarina' dominate the rice production by using advanced technologies. According to a report published by the FAO (2006), this technology could be transferred to the

[14] The Economist (2012a) provides a similar discussion.

[15] Agricultural production in Brazil differs notably from region to region with respect to climate, soil quality, degree of mechanization and input costs. All factors influence crops choices in each region. However, it would be out of the scope of this paper to examine regional differences in detail.

[16] According to the Brazilian Institute of Geography and Statistics (IBGE) these commodities are counted among the most important crops. Wheat, cocoa and coffee are also important agricultural commodities in Brazil, but there exist only incomplete data on these commodities, which is why we do not include them in our analysis. Furthermore, wheat and cocoa are mainly produced in regions that do not produce ethanol and sugar and coffee is a permanent crop, which occupies the land for long periods and need not to be replanted.

[17] There are many rice dishes in Brazil but the most popular is "arroz com feijão"(rice with beans) as most Brazilians eat it every day in combination with salads and some protein food.

[18] "Cerrado" is a vast ecological region in Brazil (tropical savanna) and accounts for 21% of the country's land area.

other states in order to make national production more competitive. In general, two types of rice production prevail in the country, by irrigation and by rain-feeding. While the productivity of irrigated rice has improved in Brazil, the upland rice (rain fed) production has markedly decreased, mainly due to land area reduction (FAO, 2006). In fact, Brazilian overall harvested areas for rice have steadily decreased as shown by Figure A3 (see appendix)[19]:

*Beans*

Similarly to rice, dry beans are essential for the Brazilian diet. Brazil is currently the largest beans producer in the world but as the country is also the largest consumer of beans, it imports the commodity to meet demands in the national market.[20] The prices of dry beans are highly volatile mainly due to the high susceptibility to climatic conditions and difficulties with the storage due to its perishable nature. Almost all states produce the commodity but eight states (spread in the different regions Center, South and Southeast, North and Northeast) dominate most part of the production, which is distributed in three distinct harvests during the year. Although small-scale farmers dominate the production of beans, the participation of medium and large-scale producer has grown in the last years, with the introduction of new techniques for irrigation, especially in the 'cerrado' region (Morin, 2010).

Figure A4 (see appendix) which is based on data provided by IPEA demonstrates that the areas dedicated to the production of beans have been reduced in the last years, but not to the same extent as in the case of rice. Moreover, beans productivity has also improved in the last years due to new technologies that make production less dependent on climate.

*Soybeans*

The production of soybeans in Brazil has grown rapidly in the last three decades as well as exports of this commodity. The Brazilian production of soybeans is relatively low cost if compared to other countries, so that Brazil has become the largest soybeans producer in South America and the second largest producer in the world (Flaskerud, 2003 and Hausman, 2012). According to the Brazilian Agricultural Research Corporation (EMBRAPA), soybean is a very versatile commodity, which is largely used in the food industry (chocolates, spices or pastry products), in the chemical industry (e.g. fertilizers) and in the feedstuff industry.[21] Additionally, the commodity has increasingly been used in the production of transport biodiesel, whose production will increase in the next years due to more stringent blending mandates (i.e. a higher content of biodiesel) up to 2013. Soybeans are mainly cultivated in the South and Southeast but its production has largely expanded to the north and center-west ('cerrado') and into the Amazon (Hausman, 2012). Land competition among soybeans and sugarcane is pronounced, particularly in the Southeast (Nassar, et al., 2010). Thus, although expansions in soybean areas have been observed (see Figure A5 in the appendix), it is conceivable that ethanol production suppresses the cultivation of soybeans in the traditional areas, which may lead to the expansion of soybeans areas in regions like the 'cerrado' where soil is less appropriate for sugarcane cultivation and ethanol refineries are rare.

*Corn*

Brazil is the third largest world producer of corn, is self-sufficient, and is a large exporter. The commodity is very important for food purposes but the largest share of the production is applied to feed animals. The country produces two seasonal corn crops (summer and winter) and the producing region is widely dispersed geographically (central-west, southeast and south). The Brazilian corn production has grown in the last years more than the harvested areas, which have grown slightly since 2005 (see figure A6 in the appendix). Thus, crops productivity has enhanced and greater investments have been undertaken in order to meet increasing foreign demand.[22]

*Manioc*

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[19] The Institute for Applied Economic Research (IPEA) provides an extensive dataset on harvested areas for several commodities. Available at: http://www.ipeadata.gov.br/

[20] Brazil produces and consumes three main types of beans (carioca, black and macaçar).

[21] Information is available at http://www.cnpso.embrapa.br/.

[22] Last year (2012) exports have been particularly large, as the US (largest corn producer in the world) was not able to meet internal demand (feedstock, food and ethanol production) due to severe draughts. Information on corn markets are available at the official website of the Ministry of Agriculture, Livestock and Food Supply (MAPA): http://www.agricultura.gov.br/vegetal/culturas/milho.

Brazil is a major producer of manioc (cassava), which is produced with low technology (often small-scale producers) and is produced in all regions in Brazil due to the ease of adaptation of the plant. Harvested areas for manioc have slightly decreased over the years (see figure A7 in the appendix based on data by IPEA) and productivity has increased.

After beans, manioc is the second most consumed commodity by the low-income households in Brazil and therefore, price spikes directly damage the poor. According to EMBRAPA, prices have increased in the last years but are still favorable. However, the costs of production are expected to rise, in particular due to rising demand for land which leads to higher land costs (leasing).[23]

The foregoing remarks show that all commodities chosen for our analysis are very important in the Brazilian economy. Moreover, competitive links might exist, as the cultivation of sugarcane and other commodities is technically possible in the same regions. Therefore, it will be quite relevant to assess whether rising ethanol production is affecting the markets for these commodities.[24] Given the relevance and controversy in the debate on the impact of ethanol production on food markets in Brazil, the econometric assessment presented in the following pages will make some relevant contributions to the literature.

## 3. IMPACTS OF ETHANOL PRODUCTION ON SUGAR MARKETS

As sugar and ethanol production are based on the same agricultural commodity (sugarcane), it is reasonable to expect some direct competitive links between both commodities. Therefore, we start with an explorative econometric analysis investigating the impacts of rising ethanol production on sugar production.

### 3.1. Data and empirical methodology

The dataset[25] used in our econometric assessment consists of a panel with annual production data ranging from 1981 to 2009 for 24 Brazilian federative states.[26] The data analysis has been carried out by using the standard statistical software "STATA".

Our estimations regarding the sugar market have been carried out based on data for sugar and ethanol production provided by the database of the Brazilian Sugarcane Industry Association (UNICA)[27]. Data on sugar production for food purposes constitute the basis for our dependent variable and are given in thousand tons for all regions and years. Data on total ethanol production constitute the key independent variable that allows us to test our hypothesis regarding the relationship between ethanol and sugar production and are given in thousand $m^3$ for all regions and time observations. Data on production of anhydrous and hydrous ethanol are also separately available and add up to total ethanol production.[28] The Brazilian UNICA in cooperation with the Brazilian Institute of Geography and Statistics (IBGE) supplies data on sugarcane planted area given in hectares.[29] This variable is not included in our first regressions but plays an important role later on. Average annual hydrous ethanol prices given in US$/$m^3$ are provided for the national level

[23] The Brazilian Agricultural Research Corporation (EMBRAPA) available at http://www.cnpmf.embrapa.br/index.php?p=pesquisa-culturas_pesquisadas-mandioca.php and the Center for Advanced Studies on Applied Economics (CEPEA) available at http://www.agricultura.gov.br/arq_editor/file/camaras_setoriais/Mandioca/26RO/App_desempenho_ind%C3%BAstria_f%C3%A9cula.pdf provide information on the markets for manioc.

[24] Even in the cases for which harvested areas have increased over the years, it is conceivable that ethanol production could be countervailing other effects (e.g. rising foreign demand).

[25] Most data were available online and whenever data were not available or there were uncertainties, contact to the institutions (e.g. UNICA Brazil) provided the missing information.

[26] Our original dataset has production data for 24 Brazilian federative units but for the estimations regarding sugar production as a dependent variable we have dropped three regions that have not produced any sugar over almost the whole period of observation to avoid distortions in our estimations.

[27] Data can be provided upon request; http://www.unicadata.com.br/index.php.

[28] Anhydrous ethanol is blended with gasoline to fulfill national biofuel mandates. We also have run estimations with the separated values but it has not improved our results, which can be obtained upon request.

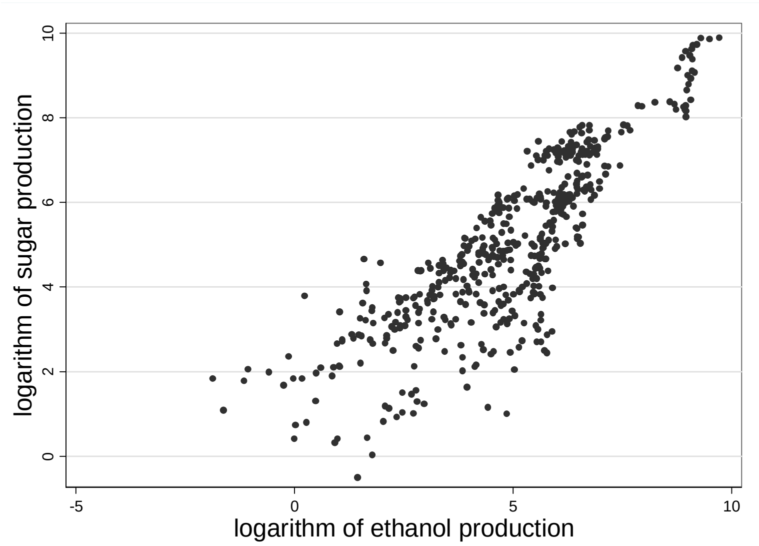
[29] http://seriesestatisticas.ibge.gov.br/lista_tema.aspx?op=0&no=1

from the Brazilian Ministry of Mines and Energy (MME).[30] Finally, the price of Brazilian free on board (FOB) oil imports is given in US$/barrel of oil equivalent (US$/beq) and is provided by the MME in cooperation with the Brazilian National Agency of Petroleum and Natural Gas (ANP)[31]. As price data are not available in the regional level, we replicated the annual values for each state. Some measurement and/or report errors cannot be foreclosed since we observe in some cases "zero" production values for sugar and ethanol production and this has no applicable explanatory power especially regarding the dependent variable.

We have chosen a log-log specification as it provided by far the best results in comparison with other specifications, such as lin-lin specification or a regression in terms of growth rates. The choice of logarithmic specification has some side benefits as it allows us to interpret the coefficients as elasticities and the transformation of our data into natural logarithms allows us to clean up the mentioned gaps in the data. Since the natural logarithm of "zero" is mathematically not defined, STATA correctly generates missing values wherever sugar or ethanol production is equal to "zero". As we have lost a number of observations, the length of the available time series varies across states due to this data constraint. We have therefore an unbalanced panel, which is often the case in panel analysis.

In a further step, we plot our dependent variable and our main independent variable (see figure 1 below). Contrary to our initial intuition, we observe positive relationship among the variables instead a negative one. This is in line with our observation that sugar production has actually increased over the years although ethanol production has intensified. The scatter plot for our sample (21 states and period 1981-2009) is presented below[32]:

**Figure 1: Scatter plot with logarithm of sugar and ethanol production**




In order to evaluate the average impact per year ($t$) of ethanol production on sugar production in region ($i$) we estimate the following entity and time fixed effects regression model using OLS:

$$\ln Y_{it} = \beta_1 \ln X_{it} + \beta_2 \ln Z_{it} + \alpha_i + \lambda_t + u_{it} \quad (1)$$

where the character $Y$ stands for the sugar production (our dependent variable), $X$ stands for the ethanol production (independent variable) and $Z$ is a control variable. The terms $\alpha_i$, $\lambda_t$ , $u_{it}$ represent the entity fixed effect, the time fixed effect and the error term, respectively. The

[30] It is acceptable to use prices for hydrous ethanol as an approximation for ethanol prices since small differences between prices for hydrous and anhydrous ethanol are due to additional processing required to convert hydrated into anhydrous ethanol making the latter slightly more expensive.

[31] Oil prices are provided in 2008-constant US$ (consumer price index - CPI-U). For the MME data see: http://www.mme.gov.br/mme/menu/todas_publicacoes.html and for ANP data see http://www.anp.gov.br/?pg=14685 .

[32] We have removed two outliers (log of sugar production = - 4.961845 and 11.88383) due to the large deviation from the other data points, but it does not affect estimation results.

coefficients $\beta_1$ and $\beta_2$ are the unknown parameters which can be interpreted as average elasticities of the sugar production with respect to the ethanol production and to the control variable. This means that ceteris paribus, on average, a one percent change in ethanol production is associated with a $\beta_1$ percent change in sugar production.

The main advantage of this method (panel estimation with fixed effects) is that we control for omitted variables that vary across states but are constant over time (e.g. favorable basic climatic conditions) as well as for some other variables that vary over time but are constant across entities (e.g. poor harvests).[33]

We account for heteroskedasticity in our estimations by specifying robust standard errors (Eicker-Huber-White heteroskedastic-consistent standard errors). In addition, we compute post-estimation F-tests (Wald-Test) for each independent variable and time-dummies; all F-statistics values are significant at the one percent level. Finally, as we are dealing with time series data ranging from 1981 to 2009, we test for stationarity conducting the Fisher-type augmented Dickey-Fuller unit-root test for panels. The advantage of the augmented Dickey-Fuller test is that it allows for testing for stationarity in unbalanced panels. We could reject the hypothesis that all panels contain unit roots at the one percent significance level.[34]

## 3.2 Estimation results

Table 1 presents the results of estimating four specifications of equation (1) using OLS.

**Table 1 :** Regressions on log of sugar production

**Dependent Variable: log of sugar production**

| **Independent variable** | **Regression 1** | **Regression 2** | **Regression 3** | **Regression 4** |
|---|---|---|---|---|
| Log of ethanol production | 0.5069783***<br>(0.1587645) | 0.5069783***<br>(0.1587645) | - | - |
| Log of ethanol mean price | - | - | 0.7798041***<br>(0.2921338) | 0.6759516**<br>(0.2921581) |
| Log of oil price | - | 0.2554343***<br>(0.0758099) | - | 0.2014269***<br>(0.0739063) |
| $R^2$ | 0.6903 | 0.6903 | 0.0366 | 0.0366 |
| Entity fixed effects | Yes | Yes | Yes | Yes |
| Time fixed effects | Yes | Yes | Yes | Yes |
| Observations | 507 | 507 | 507 | 507 |

Note: *** and ** indicate significance at the one and five percent levels, respectively. Robust standard error values are indicated in parentheses under the coefficients. Fixed and time-specific effects are groupwise significant at the one percent level.

While in Regression 1 the logarithm of ethanol production is solely included as independent variable (reduced form of equation 1), regression 2 introduces the logarithm of oil import prices as a control variable and features our best specification. Regressions 3 and 4 serve as a robustness check as we substitute the production variable “log of ethanol production” by the price variable “log

[33] See for instance Stock and Watson (2012), pp. 294-337.

[34] Tests for unit roots indicate no evidence of unit roots in any of our variables. Test results are not reported here but can be obtained upon request.

of ethanol price".[35] Again, we first estimate a reduced form of equation 1 including ethanol price as independent variable (column 3) and then add the control variable "log of oil price" (regression 4).

As expected, results in regression 3 and 4 are similar with those of regressions 1 and 2 with positive and significant coefficients for both regressors, but the $R^2$-values in regression 3 and 4 are very low (0.0366). This result is plausible as $R^2$-values measure the fraction of the variance of the dependent variable explained by the regressors. Indeed, a price variable will have lower explanatory power with respect to the dependent variable, which is a quantity variable, than another quantity variable (ethanol production). Maybe some criticisms to the robustness of our analysis might appear as we just include few control variables due to data constraints. Nevertheless, fixed effects regression models controls for omitted variables improving the robustness of the analysis.

Now we come back to our best specification (regression 2), which exhibits an acceptable $R^2$-value (0.6903) indicating that our estimates fit the data quite well. It will be relevant to interpret results with somewhat more details and afterwards discuss some possible reasons for the outcomes.

For regression 2 both coefficients $\beta_1$ and $\beta_2$ are positive and significant with elasticities of 0.5069783 and 0.2554343, respectively. This indicates that, all other things equal, on average, a one percent increase in ethanol production is associated with a 0.5069783 percent increase in sugar production. Similarly, a one percent increase in oil prices, ceteris paribus and on average, is associated with a 0.2554343 percent increase in sugar production, i.e. sugar production increases albeit to a lesser extent. It is worth to mention that one should be careful when interpreting magnitude of the effects to avoid over-interpretation as the coefficients reported in table 2 are only averages over a number of states and years. These coefficients may therefore hide differences across states.[36] However, the direction of our results is quite robust as for all specifications increasing ethanol production has, on average, a positive and significant impact on sugar production.[37]

This outcome contradicts our initial intuition that rising oil prices and increasing ethanol production would lead to lower sugar production and consequently higher sugar prices. Instead, according to basic economic principles, if rising ethanol production pushes sugar production up, then prices will not increase on that account.[38] The same holds for oil prices. Rising oil prices encourage ethanol production as an alternative fuel.[39] Rising ethanol production, in turn, leads to higher sugar supply, consequently exerting downward pressure on sugar prices.

A possible explanation for our contra-intuitive results might be related to the expansion of the planted sugarcane area over the last years. Figure A8 (see appendix) shows a large expansion of the sugarcane area at the same period as ethanol and sugar production had been intensified (see again Figures A1 and A2 in the appendix).

The ratio between ethanol production ($m^3$) and sugarcane area (hectares) provides additional evidence on the fact that ethanol production is not suppressing available sugarcane area. If sugarcane area were running short due to ethanol production, we would expect the ratio between ethanol production and sugarcane area to increase steadily. However, figure 2 shows that this is not the case. After a first adjustment period (ca. 1980-1987) the ratio between ethanol production and sugarcane area has shown slight fluctuations but remained at relatively constant levels.

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[35] Of course, we could not include both variables simultaneously because both variables capture the same effect and results would be distorted due to multicollinearity. The descriptive statistics for this sample is provided in the Appendix.

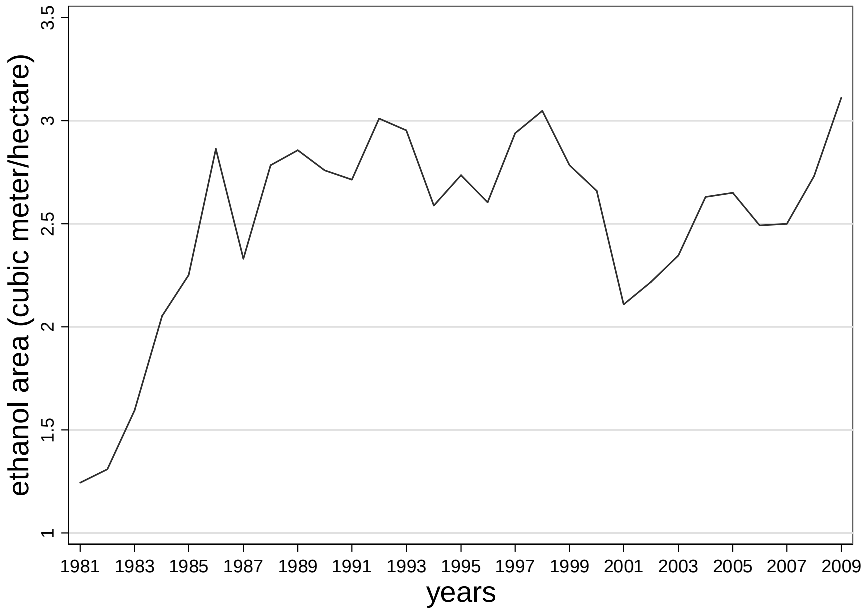
[36] If we look at the plots of ethanol and sugar production by region, we see that the courses of the variables are similar but levels of production vary significantly across states.

[37] As already mentioned we have also carried out estimations with a lin-lin specification and estimations in terms of growth rates. Also in these cases the coefficient regarding the ethanol production was positive and significant but the $R^2$-values were very low. Again we will not report results, which are available upon request.

[38] Actually, ceteris paribus prices would then fall but there are several other factors that might influence price fluctuations.

[39] Of course, the magnitude of this effect will depend on fuel demand elasticities and on ethanol prices. In Brazil, elasticity of demand (substitution) for transport fuel tends to be high due to the large number of "flex-fuel" vehicles in the market that can run on both gasoline and ethanol.

**Figure 2: Ethanol production / sugarcane area ratio**




Similarly, a look at the correlation coefficients between ethanol production and sugarcane area (r= 0.9331), and sugar production and sugarcane area (r=0.9107) reveals that these variables are highly correlated. Therefore, what might be happening is that the sugarcane area, and consequently sugar production, historically increased together with the ethanol production attenuating competition for land. In the next section, we will scrutinize this hypothesis and analyze whether the cultivation of other basic food commodities is being suppressed due to the expanding sugarcane acreages for ethanol and sugar purposes. Thus, in the following section, we will extend our dataset and analysis to include other basic food commodities.

## 4. THE IMPACT OF ETHANOL PRODUCTION ON AGRICULTURAL AREAS FOR BASIC FOOD COMMODITIES

Contrary to our initial intuition, our explorative analysis in the previous section has shown that ethanol production has a positive impact on sugar production. This result raises the question whether the expansion of sugarcane acreages for ethanol purposes is displacing the cultivation of other staple foods in Brazil. This question will be investigated in this section.[40]

We will proceed as follows: first, we will quantify effects on sugarcane acreages of additional ethanol production depending on the values of sugar production. After that, we investigate the effects on the agricultural areas assigned for other food commodities. The next subsection describes our dataset and general methodological approach more comprehensively. The subsections thereafter present the results regarding the individual commodities under investigation. An overall evaluation of the results concludes this chapter.

### 4.1 Dataset and methodological approach

For the next steps of our assessment, we augment the original dataset described in section 3 with data on annual harvested areas and on annual production for agricultural commodities ranging from 1981 to 2009 for 24 Brazilian federative states. These major crops of the Brazilian agriculture are rice, beans, soybeans, corn and manioc. The data were taken from the database of the Institute for Applied Economic Research (*IPEA*) and merged with our original dataset in “STATA”.[41] Due to data constraints, the length of the available time series varies across states for some commodities. The panel is therefore unbalanced.

[40] For this purpose ethanol and sugar production serve as explanatory variables. It would be interesting to use sugarcane areas as explanatory variables in our analysis but unfortunately, our data on sugarcane area do not enable us to distinguish how much sugarcane has been dedicated for ethanol and how much for sugar production.

[41] The database is available online at http://www.ipeadata.gov.br/.

Data on planted areas for sugarcane and on harvested areas for rice, beans, soybeans, corn and manioc are given in hectares. Production data for the mentioned commodities are available in tons.

The harvested areas for the mentioned major crops constitute the basis for our dependent variables in the different regressions we conduct. Our choice (area instead production data) can be justified by the fact that there are many additional factors influencing production, such as stages of production, storage, transport, which can lead to losses. Harvest data might therefore be more suitable to reflect farmers' decision with respect to crops cultivation.[42] Furthermore, we have tested for different specifications of regressions on production data but regressions on harvested areas provided results that are more robust.[43]

Thus, in the next subsections we aim to evaluate the average impacts of ethanol production on the harvested areas for each of the agricultural commodities included in the analysis. The rationale underlying our investigations is that if ethanol production suppresses areas previously dedicated for food crops, this leads, ceteris paribus, to lower food production, which in turn leads to higher food prices.

We begin our analysis by estimating a base specification of a regression model with entity and time fixed effects by using OLS in order to assess the average impact per year $(t)$ of a change in ethanol production on the harvested area for a specific commodity in region $(i)$:

$$Y_{it} = \beta_1 X_{1,it} + \alpha_i + \lambda_t + u_{it} \qquad (2)$$

where $Y_{it}$ is our dependent variable given by the specific commodity's harvested area, $X_{1,it}$ is the ethanol production in region $(i)$ and year $(t)$ constituting our explanatory variable, and $\alpha_i, \lambda_t, u_{it}$ represent the entity fixed effect, the time fixed effect and the error term, in that order. Because we know that ethanol and sugar production are based on the same feedstock and increase together, we suppose some interaction between both variables and therefore expect that the effects ethanol production has on the areas of agricultural commodities also depend on the value of sugar production. For this reason, we augment our regression model with an interaction term that is the product of both independent variables.[44] This interaction term allows the effect of a unit change in ethanol production to depend on sugar production.

Hence, in order to evaluate the average impact per year $(t)$ of a change in ethanol production (depending on the value of sugar production) on the harvested area for a specific commodity in region $(i)$ we estimate an entity and time fixed effects interaction regression model using OLS. The following equation represents the full specification of this interacted regression model:

$$Y_{it} = \beta_1 X_{1,it} + \beta_2 X_{2,it} + \beta_3 \left(X_{1,it} \times X_{2,it}\right) + \alpha_i + \lambda_t + u_{it} \qquad (3)$$

where $Y$ stands for the dependent variable (area or logarithm of area of the commodity under scrutiny), $X_{1,it}$ and $X_{2,it}$ stand respectively for ethanol production and sugar production in region $(i)$ and year $(t)$ and $X_{1,it} \times X_{2,it}$ is the interaction term (independent variables). The coefficients on ethanol production, on sugar production and on the interaction term are $\beta_{1,}\ \beta_2\ and\ \beta_3$, in that order. Again, the terms $\alpha_i, \lambda_t, u_{it}$ represent the entity fixed effect, the time fixed effect and the error term, respectively.

We apply the general method to compute expected changes in $Y_{it}$, $\Delta Y_{it}$, in nonlinear regression functions[45], as we aim to evaluate the average impacts of ethanol production (depending on values of sugar production) on the areas for the commodities.

Thus, the average effect on $Y_{it}$ of a change in $X_{1,it}$, $\Delta X_{1,it}$, holding $X_{2,it}$ constant can be represented as follows:

$$\Delta Y_{it} = \left(\beta_1 + \beta_3 X_{2,it}\right) \Delta X_{1,it} \qquad (4)$$

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[42] Actually, data on planted areas would be even better but they were not available for most crops. Sugarcane is the only crop for which data only on planted areas were available.

[43] We do not report regressions on production data but estimation results can be obtained upon request.

[44] $Sugar\ production \times ethanol\ production$

[45] $\Delta Y = f(X_1 + \Delta X_1, X_2, \ldots, X_k) - f(X_1, X_2, \ldots, X_k)$

The average marginal impacts of a unit change in ethanol production (holding sugar production constant) can also be obtained by computing, the partial derivation of equation 3 with respect to ethanol production ($X_{1,it}$) and obtain the following result:

$$\frac{\partial Y_{it}}{\partial X_{1,it}} = \beta_1 + \beta_3 X_{2,it} \qquad (5)$$

We will provide stricter interpretation in the individual cases in the next subsections, because the precise interpretation depends on the specification of the model which varies among commodities.[46] Finally, the interaction model enables us to put both effects together if $X_{1,it}$ and $X_{2,it}$ change by $\Delta X_{1,it}$ and $\Delta X_{2,it}$, respectively. In this case, the expected change in $Y_{it}$ is as follows:

$$\Delta Y_{it} = (\beta_1 + \beta_3 X_{2,it})\Delta X_{1,it} + (\beta_2 + \beta_3 X_{1,it})\Delta X_{2,it} + \beta_3(\Delta X_{1,it} \times \Delta X_{2,it}) \quad (6)$$

On the right-hand side, the first term represents the effect of changing $X_1$ holding $X_2$ constant; the second term is the effect of changing $X_2$ holding $X_1$ constant and the last term $\beta_3(\Delta X_{1,it} \times \Delta X_{2,it})$ represents the extra effect of changing both $X_1$ and $X_2$.

As data availability for Brazilian agriculture is restricted, we do not have additional control variables but again we count on the advantage of the method of panel estimations with entity and time fixed effects.[47] In particular, our estimations are not subject to omitted variable bias from variables that are constant across states but vary over time (for example poor harvests due to draughts or excessive rain falls), as well as from variables that are constant over time but vary across states (favorable basic climatic conditions, available fertile areas, type of soil, etc.).[48] Nevertheless, this specification could still be subjected to omitted-variable bias from variables that do not fall into this category. However, the tool of fixed effects regressions enables us to undertake a more robust analysis.

We account again for heteroskedasticity in all estimations by specifying 'Eicker-Huber-White' heteroskedastic-consistent standard errors. In addition to that, we compute post-estimation F-tests (Wald-Test) for each independent variable and time-dummies; F-statistics values are in all cases significant at the one percent level. Finally, as we are still dealing with time series data, we test for stationarity by conducting the Fisher-type augmented Dickey-Fuller unit-root test for panels, which is advantageous as it allows for testing for stationarity in unbalanced panels. We could reject the hypothesis that all panels contain unit roots at the five percent significance level. This means that once more there is no evidence of unit roots in any of our variables.[49]

In the following sections, we apply the general methodology developed above to the specific basic food commodities considered in this analysis. At this point, we will move on from the general aspects of our approach to the individual cases. The next step of our analysis consists of the evaluation of the average impact of rising ethanol production on sugarcane areas. For illustrative purposes we will describe our individual approach in the case of sugarcane comprehensively but results for the other commodities will be presented more concisely.

## 4.2 Impacts on sugarcane area

A look at Figure A8 in the appendix reveals that sugarcane areas have largely expanded over the last years. In this step, we extend our analysis in order to verify by how much expansions of sugarcane areas have occurred on the account of rising ethanol production.

[46] See for example Stock and Watson (2012), pp. 294-337, for a detailed exposition of nonlinear regression models and the interpretation of coefficients in such models.

[47] The control variable used in the previous section is no longer suitable for the analysis, since oil prices will hardly exercise direct impacts on harvested areas for commodities like rice, beans, etc. Besides, the impacts on input costs due to rising oil prices are normally moderate.

[48] The control for such omitted variables varying across states is particularly important in our analysis, as Brazil is a very big country with five different climatic regions and with unequally distributed fertile soil. Consequently, some regions are more favorable for cultivation than others are.

[49] We do not provide a detailed report of all test's results (F-statistics or unit root) but they can be obtained upon request. We have applied these econometrical tests to all regressions presented in the next pages.

Sugarcane area (in hectares) constitutes our dependent variable, total ethanol production (in thousand $m^3$), and sugar production (in thousand tons) are explanatory variables. Further, we augment our regression model with the interaction term previously described, as this interaction term allows the effect of a unit change in ethanol production on sugarcane area to depend on sugar production.[50]

We have chosen a lin-lin specification of our regression model (both dependent and independent variables are not in logarithms) as it fits better the data and provided by far the best results in comparison with other specifications (e.g. log-lin or log-log).[51] We first estimate a base specification (see equation 2) of the regression model but as we observe that both continuous variables (sugar and ethanol production) increase together, we expect that effects of ethanol production on sugarcane area depend on sugar production. Hence, in order to evaluate the average impact per year $(t)$ of ethanol production (depending on the value of sugar production) on sugarcane area in region $(i)$ we estimate the following interaction regression model using OLS[52]:

$$Scarea_{it} = \beta_1 eth_{it} + \beta_2 sug_{it} + \beta_3 (eth_{it} \times sug_{it}) + \alpha_i + \lambda_t + u_{it} \quad (7)$$

Hence, equation (7) is a modification of equation (3). Estimation results and interpretation are reported in table 2 which presents the results of estimating two specifications of our regression model.[53]

**Table 2:** Regressions on sugarcane area

Dependent Variable: sugarcane area (hectares)

| **Independent variable** | **Regression 1** | **Regression 2** |
|---|---|---|
| Ethanol production (1000 $m^3$) | 286.2574*** (1.571214) | 107.9103*** (28.61548) |
| Sugar production (1000 tons) | - | 66.40895*** (14.16562) |
| Interaction term $(sugar \times ethanol)$ | - | 0.0035526** (0.0017794) |
| $R^2$ | 0.7880 | 0.9582 |
| Entity fixed effects | Yes | Yes |
| Time fixed effects | Yes | Yes |
| Observations | 675 | 675 |

Note: ***, ** and * indicate significance at the one, five and ten percent levels, respectively. Robust standard error values are indicated in parentheses under the coefficients. Fixed and time-specific effects are groupwise significant at the 1 per cent level.

[50] We provide descriptive statistics for the sample in the Appendix.
[51] We have tested for different specifications because our analysis is explorative and not based in theoretical models. Thus, our results indicate that a linear relationship among the dependent and independent variables prevail.
[52] Scarea = sugarcane area, eth= ethanol production and sug = sugar production
[53] Estimated coefficients are reported with all decimal digits and without rounding but whenever we provide illustrative calculations, we report results up to two decimal digits.

All coefficients are highly significant, which endorses our first intuition that effects of ethanol production on sugarcane area depend on the values of sugar production. Furthermore, the direction of our results is quite robust as coefficients on ethanol production are positive in both regressions.

Our best specification (regression 2) exhibits a very high $R^2$-value (0.9582) indicating that our estimates fit the data very well. This means that this specification of our regression model including entity and time fixed effects explains 95.82% of the variance of the dependent variable. It is also worth to point out that sugarcane is primarily used in the production of ethanol and sugar, so that the associated variables have a strong explanatory power regarding farmer's decisions on sugarcane plantation.[54]

For regression 2, all coefficients are positive and significant: $\beta_1 = 107.9103$, $\beta_2 = 66.40895$ $and$ $\beta_3 = 0.0035526$. As we aim to evaluate the average marginal impact of ethanol production on sugarcane area, holding sugar production constant, we compute the partial derivation of equation (7) in terms of ethanol production:

$$\frac{\partial\ Scarea_{it}}{\partial\ eth_{it}} = \beta_1 + \beta_3 sug_{it}$$

This means that, all other things equal, on average, a marginal change in ethanol production (1000m$^3$) is associated with a $\beta_1 + \beta_3 sug_{it}$ hectares change in sugarcane area. Therefore, a change by one unit (1000m$^3$) in ethanol production is associated with $(107.9103 + 0.0035526 sug_{it})$ hectares change in sugarcane area. As we first aim to measure average impacts holding sugar production constant, we insert the mean value of sugar production for our sample provided in the descriptive statistics: $107.9103 + 0.0035526 * \mathbf{649.7387} = 110.22$. This means ceteris paribus that, on average, a marginal increase in ethanol production (1000m$^3$) at mean values of sugar production (for this sample 649.7387 thousand tons) is associated with an increase in sugarcane areas of 110.22 hectares or 1.10 km$^2$.

However, ethanol production increases on average by more than one unit (1000m$^3$) per region and year. Therefore, it will be interesting to select a representative state from our sample in the production years 2005/2006 to provide some illustrative calculations. We select the state of 'Minas Gerais'(MG) for those purposes.[55]

A look back at equation (4) shows that the average effect of a change in ethanol production on sugarcane areas (holding sugar production constant) can be computed as follows:

$$\Delta scarea_{MG\ 05/06} = (\beta_1 + \beta_3 sug_{MG\ 05})\Delta eth_{MG\ 05/06}$$

For calculating, we insert the values of the estimated coefficients, the actual value of sugar production for the year 2005 and the actual change in ethanol production from 2005 to 2006 in the equation above:

$$\Delta scarea_{MG\ 05/06} = (107.9103 + 0.0035526 \times 1664.69)155.327 = 17{,}679.98$$

Our calculation is based on the estimated regression model and indicates that, ceteris paribus, a change in ethanol production by about 155.33 thousand cubic meters at a sugar production value of 1,664.69 thousand tons is associated, on average, with an increase in sugarcane area by about 17,679.98 hectares or 176.8 km$^2$. This is equivalent to about one ninth of the area of the Brazilian city of 'São Paulo'.

This illustrative calculation is useful to put numbers into context. However, caution is needed when interpreting the magnitude of the effects in order to avoid over-interpretation, since

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[54] Sugarcane can also be used for the production of spirits (e.g. the sugarcane rum "cachaça") or other alcohol types (other than fuels) but this utilization represents a small fraction of overall sugarcane production.

[55] Minas Gerais is a state in the Brazilian Southeast, which has rich farmlands and produces all commodities scrutinized in this paper. Besides, up to the selected period, most regions have experienced significant increases in ethanol and sugar production. The overall harvested areas for all agricultural commodities in Minas Gerais in the year 2005 amounted 4,812,335 hectares. Total sugarcane area amounted 349,112 hectares, i.e. about 7.25% of total area in this year.

the estimated coefficients are only averages over a number of states and years. Nevertheless, these results confirm the relevance of the investigation whether the cultivation of other food commodities is being displaced due to the expansion of sugarcane areas to produce more ethanol. As described above, in this paper we aim to assess the impacts of rising ethanol production on the major staple foods, in particular on rice, beans, soybeans, corn and manioc.

For the commodities corn and manioc, we have conducted several regressions and tested for various specifications, but we could not find any significant impact of rising ethanol production (base specification or with the inclusion of the interaction term) on the harvested area or on production. We continue now our investigations with the analysis of the impacts on the area used for cultivating rice, beans and soybeans.

## 4.3 Impacts on rice, beans and soybeans area

As discussed in section 2.2, rice is one of the most important staple food commodities for the Brazilian households. Therefore, it will be very relevant to investigate if the harvested area for rice is being suppressed. Indeed, a look back at Figure A3 reveals that despite of some fluctuations, the agricultural area for rice supply has been drastically reduced over the last years. Similarly to rice, beans are essential in the Brazilian daily diet. As we can see from Figure A4, the harvested area for beans has been reduced over the last years. Of course, there are many factors influencing these developments but we now aim to investigate if to some extent these reductions are due to increases in ethanol production. The analysis of the impacts of ethanol production on harvested areas for soybeans constitutes the last individual assessment in this paper. As we have pointed out in section 2.2, harvested areas for soybeans have rather increased than decreased over the years. Nevertheless, it will be interesting to assess the impact of ethanol on the areas for growing soybeans as both commodities compete on land (especially in the Southeast region) and it is conceivable that ethanol production exercises negative impacts on the cultivation of soybeans, countervailing part of the positive impacts from the demand side.

We applied the methodology extensively discussed in the previous subsections for all commodities. The descriptive statistics for the samples are provided in the appendix and table 3 summarizes the equations that we estimated in order to evaluate the average impact per year ($t$) of ethanol production (depending on the value of sugar production) on the area for the individual commodities:

**Table 3:** Regressions for the commodities rice, beans and soybeans

| **Commodity** | **Specification** | **Equation for the full specification** |
|---|---|---|
| Rice | log-lin | $\ln(rc\_area_{it}) = \beta_1 eth_{it} + \beta_2 sug_{it} + \beta_3(eth_{it} sug_{it}) + \alpha_i + \lambda_t + u_{it}$ |
| Beans | lin-lin | $beans\_area_{it} = \beta_1 eth_{it} + \beta_2 sug_{it} + \beta_3(eth_{it} sug_{it}) + \alpha_i + \lambda_t + u_{it}$ |
| Soybeans | log-lin | $\ln(soy\_area_{it}) = \beta_1 eth_{it} + \beta_2 sug_{it} + \beta_3(eth_{it} sug_{it}) + \alpha_i + \lambda_t + u_{it}$ |

Estimation results for the individual commodities are presented in table 4. As interpretation depends on the individual specifications of the regression models we will discuss the results for the individual commodities and after that provide an overall evaluation.

**Table 4:** Regressions for rice, beans and soybeans[56]

| Dependent variable | Log of rice area | Log of rice area | Beans area (hectares) | Beans area (hectares) | [57]Log of soybeans area | Log of soybeans area |
|---|---|---|---|---|---|---|
| Independent Variables | Regression 1 | Regression 2 | Regression 1 | Regression 2 | Regression 1 | Regression 2 |
| Ethanol production ($1000m^3$) | - 0.0002178*** (0.0000439) | - 0.0002039* (0.0001117) | - 35.91048*** (4.137536) | - 50.77998*** (7.793777) | - 0.000338** (0.0001353) | - 0.0005808* (0.0003046) |
| Sugar production (1000 tons) | - | - 0.0002216** (0.0000754) | - | - 29.92735*** (6.150354) | - | - 0.0005157** (0.0002564) |
| Interaction term (sugar×ethanol) | - | 0.0000000131* (0.00000000784) | - | 0.002482*** (0.0005831) | - | 0.0000000411* (0.0000000234) |
| $R^2$ | 0.4141 | 0.4418 | 0.3020 | 0.3371 | 0.3910 | 0.4249 |
| Entity Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Time Fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 675 | 675 | 675 | 675 | 429 | 429 |

[56] Note: ***, ** and * indicate significance at the one, five and ten percent levels, respectively. Robust standard error values are indicated in parentheses under the coefficients. Fixed and time-specific effects are groupwise significant at the 1 per cent level.
[57] Unfortunately, the data quality for soybeans is inferior in comparison with the other commodities. Several observations are missing and in many cases, observations reported as ‘zero’ leave room for the assumption that there are measurement/report errors. However, since the dependent variable is in logarithms, ‘STATA’ generates missing values whenever harvested areas for soybeans are equal to zero. Due to these data constraints, a number of observations get lost.

*Rice*

Regression 2 features our best specification as the $R^2$-value improves slightly in comparison to the first regression. Moreover, all coefficients are significant at least at the ten percent levels. Our best specification (regression 2) exhibits a relatively low $R^2$-value (0.4418) indicating that this specification of our regression model including entity and time fixed effects explains solely 44.18% of the variance of the dependent variable. Thus, 55.82% of the variance of the dependent variable remains unexplained, as we are not able to add more control variables due to data constraints.[58] For both regressions, the coefficients on ethanol production are negative, which shows that rising ethanol production has a negative impact on rice areas and the direction of our results is quite robust. For the purpose of a more detailed interpretation, we focus on our best specification, for which coefficients on ethanol and on sugar are $\beta_1 = -0.0002039\ and\ \beta_2 = -0.000216$ and the coefficient on the interaction term is positive $\beta_3 = 0.0000000131$.[59]

A log-linear specification of the model requires the following interpretation[60]: on average, a marginal change in ethanol production (1000$m^3$) is, ceteris paribus, associated with an approximate change in rice area of $100 \times (\beta_1 + \beta_3 sug_{it})\%$. We are now able to calculate the average impacts on rice areas of marginal changes in ethanol production (1000$m^3$), holding sugar production constant at mean values provided in the descriptive statistics: $100(-0.0002039 + 0.0000000131 \times \mathbf{649.7387})\% \cong -0.02\%$. This means that, ceteris paribus, an increase in ethanol production by one unit (1000$m^3$ or 1000000 liters) at mean values of sugar production (649.7387 thousand tons) is associated with an approximated average decrease in rice areas of 0.02%. To put this number into context we use the mean value of rice areas for our sample (178,952.7 hectares) and find out that this small fraction (0.02%) would mean average decreases in rice areas of 35.79 hectares or 0.36 $km^2$.[61]

Once again, it will be interesting to provide some illustrative calculations of the effects on rice areas for the representative region 'Minas Gerais' in the production years 2005/2006:

$$\Delta rc\_area_{MG\ 05/06} \cong 100[(-0.0002039 + 0.0000000131 \times 1664.69)155.327]\% \cong -2.83\%$$

Hence, according to our regression model, ceteris paribus, a change in ethanol production by about 155.33 thousand tons, holding sugar production unchanged at the 2005 levels (1664.69 thousand tons), is associated with an average decrease in rice areas of approximately 2.83%. Considering the actual rice area in the year 2005 (109,363 hectares) this would mean an average decrease in rice areas of about 3,094.97 hectares or 30.95 $km^2$ (ca. 0.02% of São Paulo)[62].

*Beans*

Our best specification (regression 2) exhibits a low $R^2$-value (0.3371) indicating that this specification of our regression model including entity and time fixed effects explains solely 33.71% of the variance of the dependent variable. Thus, 66.29% of the variance of the dependent variable remains unexplained, which is acceptable, as this paper does not aim to explain all factors affecting beans cultivation but to assess the impacts of ethanol production.

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[58] It is worth to recall that we do not aim to provide comprehensive supply models but to investigate effects of rising ethanol production on areas/production of agricultural commodities. Thus, for this purpose, our approach with fixed effects provides reliable results.

[59] The inclusion of the interaction term attenuates the negative effects from changes in ethanol and sugar production alone as its coefficient is positive. The effect of ethanol production on rice areas is the lower the higher the values of sugar production are. This result is plausible, as expansions of sugarcane area for the production of sugar will somehow limit the possibility of expanding areas for ethanol production.

[60] For a more detailed explanation of interpretations on coefficients in logarithmic regression models, see again for example (Stock & Watson, 2012, pp. 309-314).

[61] It is important to point out that these calculations are only approximations to get an impression about the magnitude of the effects.

[62] Total harvested area for rice amounted 109,363 hectares (1,093.63$km^2$), i.e. about 2.27% of total harvested area in MG in 2005.

The coefficients on ethanol production are negative in both regressions, which indicate that the direction of our results is quite robust and rising ethanol production has negative impacts on harvested areas for beans. We focus now on the full specification (regression 2), for which the coefficients on ethanol and on sugar are negative $\beta_1 = -50.77998$, $\beta_2 = -29.92735$ and the coefficient on the interaction term is positive $\beta_3 = 0.002482$.[63] Inserting the values of the estimated coefficients and the mean value of sugar production for this sample provided in the descriptive statistics (649.7387 thousand tons), we obtain $-50.77998 + 0.002482 \times 649.7387 = -49.17$. As we have a lin-lin specification this result can be interpreted as follows: ceteris paribus, on average, a marginal increase in ethanol production ($1000m^3$) at mean values of sugar production is associated with the decrease in the harvested area for beans of 49.17 hectares or 0.49 $km^2$.

Besides, we provide again illustrative calculations for the selected region 'Minas Gerais':

$$\Delta beans\_area_{MG\ 05/06} = (-50.77998 + 0.002482 \times 1664.69)155.327 = -7{,}245.73$$

Thus, according with our calculations, a change in ethanol production by ca. 155.33 thousand tons is in our regression model, ceteris paribus and on average, associated with the decrease in the harvested area for beans of 7,245.73 hectares or 72.46 $km^2$.[64] This is equivalent to ca. 5% of the area of the Brazilian city 'São Paulo'.

*Soybeans*

Our best specification (regression 2) exhibits a relatively low $R^2$-value (0.4249) indicating that this specification of our regression model including entity and time fixed effects explains solely 42.49% of the variance of the dependent variable. Thus, the model is not able to explain a large fraction of the variance in the dependent variable. The coefficients on ethanol are negative for both regressions, which shows that rising ethanol production has a negative impact on soybeans areas and the direction of our results is quite robust. For the purpose of a more detailed interpretation, we focus on the best specification, for which coefficients on ethanol and on sugar are $\beta_1 = -0.0005808$, $\beta_2 = -0.0005157$ and the coefficient on the interaction term is positive $\beta_3 = 0.0000000411$.[65] Because we have a log-linear specification, we can interpret results as follows: on average, a marginal change in ethanol production ($1000m^3$) is ceteris paribus associated with an approximated change in soybeans area of $100 \times (\beta_1 + \beta_3 sug_{it})\%$. Thus, we are now able to calculate the average impacts on soybeans areas of marginal changes in ethanol production ($1000m^3$), holding sugar production constant at mean values provided in the descriptive statistics: $100(-0.0005808 + 0.0000000411 \times \mathbf{828.8448})\% \cong -0.05\%$. This means that, ceteris paribus, an increase in ethanol production by one unit ($1000m^3$ or 1000000 liters) at mean values of sugar production (for this sample 828.8448 thousand tons) is associated with an approximated average decrease in soybeans areas of 0.05%. To put this number into context we use the mean value of soybeans areas for our sample (905,829.7 hectares) and find out that this small fraction (0.05%) would mean an approximated average decrease in soybeans areas of 452.91 hectares or 4.53 $km^2$.[66] Once again, it will be interesting to provide some illustrative calculations and the average effect of a change in ethanol production on soybeans areas (holding sugar production constant) can be approximated as follows:

[63] Again the effect of ethanol production on beans areas is the lower the higher the values of sugar production are. This result is plausible, as expansions of sugarcane area for the production of sugar will somehow limit the possibility of expanding areas for ethanol production.

[64] Total harvested area for beans amounted 433,127 hectares ( 4,331.27 $km^2$), i.e. about 9% of total harvested area in MG in 2005.

[65] Once again the inclusion of the interaction term attenuates the negative impacts from ethanol and sugar production alone.

[66] Again, these calculations are only approximations to get an impression about the magnitude of the effects. Total harvested area for soybeans amounted 1,118,867 hectares (11,188.67 $km^2$), i.e. about 23.25% of total harvested area in MG in 2005

$$\Delta soy\_area_{MG\ 05/06} \cong 100[(-0.0005808 + 0.0000000411 \times 1664.69)155.327]\% \cong -7.96$$

Hence, according to our regression model, ceteris paribus, a change in ethanol production by ca. 155 thousand tons holding sugar production unchanged at the 2005 levels (1664.69 thousand tons) is associated with an average decrease in soybeans areas of approximately 7.96%. Considering the actual soybeans area in the year 2005 (1,118,867 hectares) this would mean an average decrease in the area for soybeans of about 89,061.81 hectares or 890.62 $km^2$. This is equivalent to 60% of the area of São Paulo. At this point, it is worth to mention that environmental concerns have been raised with respect to ethanol and soybean production, since a large expansion of soybeans acreages have been observed in the 'cerrado' region - with clearing of new lands and conversion of pastureland. If ethanol production suppresses soybeans cultivation in the traditional regions (South and Southeast), this leads ceteris paribus to increases in soybeans prices. Because the price-elasticity of soybeans acreages is relatively high in the 'cerrado' region (Hausman, 2012) larger and fast expansions of soybeans acreages could be expected in those regions. Additionally, this would affect soybeans prices since the cost of production in these new land areas is much higher due to inferior soil quality. However, these are still speculative ideas, which cannot be investigated in this paper.

*Overall evaluation*

So far, we have assessed the impacts of ethanol production on the areas dedicated to individual basic food commodities: sugarcane, rice, beans, soybeans, corn, and manioc. In the following, we will put the magnitude of these individual findings together in order to draw some general conclusions about the impacts that rising ethanol production has on the Brazilian markets for basic food commodities. Quantitatively, the impacts of rising ethanol production turn out to be quite different depending on the commodity under investigation. Table 5 summarizes some key results and in order to put the magnitude of the effects into context, it sets the changes in the harvested areas in relation to the overall harvested areas in the state 'Minas Gerais' (2005).

**Table 5:** Summary of the impacts of ethanol production

| | $\partial\ ethanol = 1000m^3$ $(sugar\ mean\ values)$ | $\Delta\ ethanol_{MG}$ 2005/2006 $\cong 155.33\ (1000\ m^3)$ ( sugar values for 2005) |
|---|---|---|
| Δ Sugarcane area | $\cong$ 0.03% of sugarcane area $+1.11$ km$^2$ | $\cong +\ 176.8$ km$^2$ $\cong +\ 5\%$ of sugarcane area $\cong$ 0.37% of total agricultural area in MG (2005) |
| Δ Rice area | $-\ 0.02\%$ of rice area $\cong -0.36$ km$^2$ | $\cong -30.95$ km$^2$ $\cong -\ 2.83\%$ of rice area $\cong$ 0.06% of total agricultural area in MG (2005) |
| Δ Beans area | $-\ 0.01\%$ of beans area $-\ 0.49$ km$^2$ | $\cong -\ 72.46$ km$^2$ $\cong -\ 1.67\%$ of beans area $\cong$ 0.15% of total agricultural area in MG (2005) |
| Δ Soybeans area | $-\ 0.05\%$ of soy area $-4.53$ km$^2$ | $\cong -890.62$ km$^2$ $\cong -\ 7.96\%$ of soy area $\cong$ 1.85% of total agricultural area in MG (2005) |

The first column reports the results of a marginal change in ethanol production holding sugar production constant at mean values; the second column presents results of the changes in ethanol production in the representative state 'Minas Gerais' from 2005 to 2006, holding sugar production constant at 2005 values.

The illustrative calculations for the selected region are helpful to put the numbers into perspective. As expected, increasing ethanol production leads to a relatively large expansion of sugarcane areas (ca. 5%) in Minas Gerais from 2005 to 2006. Further, increases in ethanol production are associated with a percentage decrease in rice areas of -2.83% and in beans acreages of ca. -1.67%. The average impact on the harvested areas for soybeans is more pronounced with a negative impact of - 7.96%.[67] It might be helpful to compare these values to the overall harvested areas in the state 'Minas Gerais' in 2005 (ca. 48,123.35 $km^2$).[68] For rice the estimated changes are equivalent to ca. 0.06%, for beans ca. 0.15% and for soybeans ca. 1.85% of total harvested area in 'Minas Gerais' in 2005. These numbers make clear that the estimated average impacts are not very strong.

It is worth to stress that these quantitative results are obtained for the specifications of our regression models and therefore over-interpretation with respect to the magnitude of these impacts should be avoided. Any statistical estimate is subject to sampling uncertainty as confidence intervals have 90%, 95%, or 99% probability of containing the true values of the coefficients.[69] Furthermore, the estimated coefficients are only an average over several states and years and therefore, these coefficients may hide differences across states.[70] If data were available, it would be also interesting to refine our model including indices for the technical substitutability among the crops competing for land areas. The inclusion of prices for these commodities as explanatory variables would also be relevant. Furthermore, the roles of crop rotation, of environmental regulation, and of international trade should not be understated. However, the data availability regarding these aspects is very restricted.

Nonetheless, this thesis provides an explorative analysis that enables us to make some general qualitative statements on the impacts of ethanol production on the Brazilian market for staple food commodities:

1. Similar to our results regarding sugar production in section 3, rising ethanol production has a positive and significant impact on sugarcane acreages.
2. Not all commodities are affected by the developments in the ethanol markets. For example, we could not find any significant impact of rising ethanol production on the harvested areas for corn and manioc.
3. Increasing ethanol production exerts a statistically significant negative impact on the harvested areas for the staple commodities rice, beans and soybeans.

The effects on the areas for sugarcane, rice, beans and soybeans have implications for the associated prices. Again, the expansion of areas dedicated for the cultivation of a crop leads, ceteris paribus, to higher production of this crop, which in turn leads to lower prices. Conversely, if ethanol production suppresses the area dedicated for food crops, this leads, all other things equal (e.g., productivity, demand, etc.), to lower food production, which in turn leads to higher food prices. Of course, there are several factors influencing prices of agricultural commodities, such as whether disruption, trade and regulatory distortions, exchange rate fluctuations, etc. but this thesis solely aims to evaluate how ethanol production affects the prices of commodities.

Thus, our assessment makes several contributions to the discussion on whether rising ethanol production is driving up food prices. The effects are mixed. On the one hand, it does not hold for the Brazilian sugar market, as we have detected, ceteris paribus, a rather negative impact on sugar prices due to the expansion of areas for sugarcane and sugar production. On the other hand, according to basic economic principles and under the assumption that all other things remain

[67] The impacts on the harvested areas for soybeans are overproportional to changes in sugarcane area. This might be related to the high degree of substitutability among both crops (this regarding soil conditions) and the large fraction of overall harvested areas in MG that soybeans represent.

[68] The information on overall harvested areas for Minas Gerais is provided by IPEA.

[69] Moreover, we are not able to control for the reliability of the data provided by the Brazilian institutions.

[70] A new aggregation of regions or computing region specific intercepts would enable us to assess these regional differences more properly. However, this would affect the robustness of our analysis since we do not have enough observations.

equal (for instance demand situation, productivity, institutional aspects etc.) the prices for rice, beans and soybeans are expected to increase. This is because rising ethanol production exerts negative impacts on the harvested areas for these commodities. However, it is not simple to predict the magnitude of actual changes in crop prices due to rising ethanol production because there are several factors counteracting (and also reinforcing) this impact. Nonetheless, ceteris paribus, albeit effects are moderate, rising ethanol production does put upward pressure on prices for these commodities. Additionally, the perspectives of expanding the Brazilian ethanol markets in the coming years make the relevance of further assessments of the impacts of ethanol production on agricultural markets evident. Moreover, increasing demand for land for biofuel crops and rising crop prices lead, ceteris paribus, to an appreciation of land prices, which is good for landowners but bad for small producer depending on lease of land for their production. This would boost the tendency in the country to monoculture and expansion of farming in regions of ecological importance. Obviously, this raises environmental questions regarding, for example, loss of soil quality, deforestation or damages to high-biodiversity areas but this is not a topic for our research. The implementation of second and further generation biofuels, which use cellulosic sources for ethanol production, could alleviate these problems related to first-generation ethanol. However, the development of such technologies is still in early stages.

## 5. Concluding Remarks

Over the last years, there has been a great deal of debate on the impacts of rising biofuel production on food prices. As Brazil is a major global player in the ethanol and agricultural markets, several studies have pointed out that increasing ethanol production based on sugarcane would lead to a displacement of crops from food production to fuel production (ethanol) and consequently to higher food prices. This question is of great policy relevance in Brazil, as the country has a history of strong government incentives to develop ethanol industry and because households (especially the poor) usually spend the major part of their income on food consumption.

Thus, as there is a lack of econometric studies devoted to this issue, this paper contributes to the literature with an explorative econometric assessment using a panel dataset. Our panel comprises annual production data for the sugar-alcohol sector, as well as annual production and harvested areas data for five basic food commodities (rice, beans, corn, soybeans and manioc) ranging from 1981 to 2009 for 24 Brazilian federative states. We have estimated entity and time fixed effects regression models in order to assess the average impacts of rising ethanol production on the production of sugar and on harvested areas for the other commodities under scrutiny.

In the first step of our analysis, we have applied a regression model with entity and time fixed effects using OLS to evaluate the average impact of ethanol production on sugar production. The outcome of our estimations contradicts our initial intuition that rising oil prices and increasing ethanol production would lead to lower sugar production. Both ethanol production and oil prices have a positive and significant effect on sugar production. This means in turn that, ceteris paribus, sugar prices would rather fall than increase with increasing ethanol production and oil prices. Assuming that the data provided by the Brazilian institutions is reliable, our results remain robust with respect to different specifications.

A possible explanation for this contra-intuitive outcome is that sugarcane area, and consequently sugar production, historically increased together with the ethanol production attenuating direct competition for land. Thus, the estimation of an entity and time fixed effects interaction regression model using OLS has confirmed our intuition that effects of ethanol production on sugarcane acreages depend on the values of sugar production and that, on average, increases in ethanol production are ceteris paribus associated with expansions in sugarcane areas.

This result raises the question whether the expansion of sugarcane areas for ethanol production is suppressing the availability of areas for other food commodities. Again, to answer this question we have estimated interaction regression models including entity and time fixed effects with respect to the harvested areas for the commodities rice, beans, soybeans, corn, and manioc. The results of our assessment are mixed and can be summarized as follows: (1) Rising ethanol production has no significant impact on the harvested areas for corn and manioc. (2) Increases in ethanol production are, ceteris paribus, associated with decreases in the harvested areas for rice, beans, and soybeans. Our results regarding the specific basic food commodities considered in this analysis have implications for the associated prices. In contrast to the results for the sugar market, all other things equal, rising ethanol production put upward pressure on prices for rice, beans and soybeans. That is, ceteris paribus, prices for these commodities will increase due to rising ethanol production since it has a negative impact on the areas for these commodities. However, impacts are expected to be rather moderate than strong.

Our analysis on the complex impacts of rising ethanol production on the Brazilian market for basic food commodities contributes to the literature but is far from being exhaustive. First, despite of the virtue of our approach (panel estimations with entity and time fixed effects) we cannot control for omitted variables that vary both across entities and time. Second, we are not able to make precise statements regarding the magnitude of the effects of rising ethanol production, since the estimated coefficients are only an average over a number of states and years. Hence, results might hide differences across states.[71] Furthermore, our regression models do not capture dynamics in the agricultural markets and therefore cannot account for example for productivity enhancements. Third, due to data constraints we could not include important aspects in our analysis, such as the role of binding environmental standards and trade. It would be also important to include prices for commodities and for land in the analysis, as well as indices for possible substitutability among the crops under scrutiny. Moreover, it would be relevant to extend the present analysis to other major crops, as we observe that effects turn out differently across crops and the Brazilian agriculture comprises a wide range of commodities. Finally, the impacts of increasing biofuels production on pastureland and on regions of ecological importance are very relevant but cannot be investigated in this paper. Notwithstanding the mentioned caveats, our explorative analysis makes interesting contributions to the literature. Our findings and the perspectives of expansion of the Brazilian ethanol markets in the coming years indicate that further assessments of the impacts of ethanol production on agricultural markets remains very relevant. However, investigating all these issues would go beyond the scope of this paper but remains high on our future research agenda.

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## APPENDIX

### DESCRIPTIVE STATISTICS

**Table A 1:** Sample for the regressions on sugar production

| Variable | Obs.: | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Log of sugar production | 507 | 4.948248 | 1.984167 | -0.5025268 | 9.886465 |
| Log of ethanol production | 507 | 4.849484 | 2.022679 | -1.877317 | 9.724509 |
| Log of oil price | 507 | 3.653153 | 0.4987289 | 2.687607 | 4.696148 |
| Log of ethanol mean price | 507 | 6.117994 | 0.3390359 | 5.549208 | 6.824365 |

**Table A 2:** Sample for regressions on sugarcane areas[72]:

| Variable | Obs.: | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Sugar (1000 tons) | 675 | 649.7387 | 2,159.163 | 0 | 19,662.4 |
| Ethanol production (1000 $m^3$) | 675 | 541.71 | 1,711.036 | 0 | 16,722.5 |
| Interaction Variable | 675 | 3,732,230 | 23,100,000 | 0 | 329,000,000 |
| Sugarcane area (hectares) | 675 | 211,590 | 522770.2 | 177 | 5,000,000 |

[72] The “zero” minimum values of sugar and ethanol production are either due to the fact that some states have started production in later years or due to measurement and/or report errors. The maximum values are much higher than averages and are observed in the region of São Paulo, which dominates a high share of ethanol and sugar production.

**Table A 3:** Sample for regressions on rice areas

| Variable | Obs.: | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Sugar (1000 tons) | 675 | 649.7387 | 2,159.163 | 0 | 19,662.4 |
| Ethanol production (1000 $m^3$) | 675 | 541.71 | 1,711.036 | 0 | 16,722.5 |
| Interaction Variable | 675 | 3,732,230 | 23,100,000 | 0 | 329,000,000 |
| Rice area (hectares) | 675 | 178,952.7 | 245,729.1 | 63 | 1,167,204 |
| Log of rice area | 675 | 11.69008 | 1.743261 | 4.804021 | 15.86521 |

**Table A 4:** Sample for regressions on beans area

| Variable | Obs.: | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Sugar (1000 tons) | 675 | 649.7387 | 2159.163 | 0 | 19662.4 |
| Ethanol production (1000 $m^3$) | 675 | 541.71 | 1711.036 | 0 | 16722.5 |
| Interaction Variable | 675 | 3732230 | 23100000 | 0 | 329000000 |
| Beans area (hectares) | 675 | 194596.2 | 245729.1 | 63 | 1167204 |

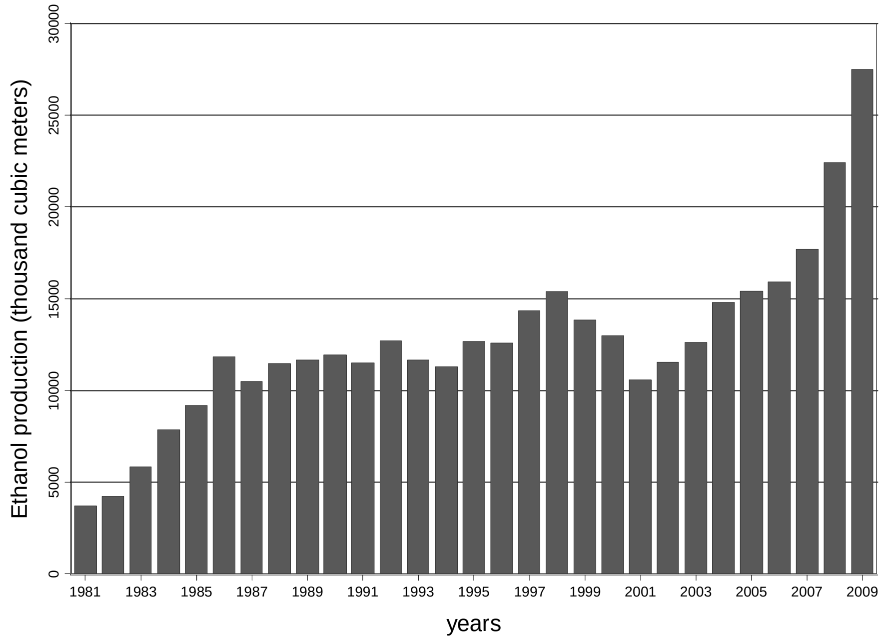
**Table A 5:** Sample for regressions on soybeans area

| Variable | Obs.: | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Sugar (1000 tons) | 429 | 828.8448 | 2,665.566 | 0 | 19,662.4 |
| Ethanol production (1000 $m^3$) | 429 | 753.3297 | 2,113.125 | 0 | 16,722.5 |
| Interaction Variable | 429 | 5,791,036 | 28,800,000 | 0 | 329,000,000 |

| | | | | | |
|---|---|---|---|---|---|
| Soybeans area (hectares) | 429 | 905,829.7 | 123,178.3 | 1 | 6,106,654 |
| Log of soybeans area | 429 | 11.64964 | 3.309665 | 0 | 15.62489 |

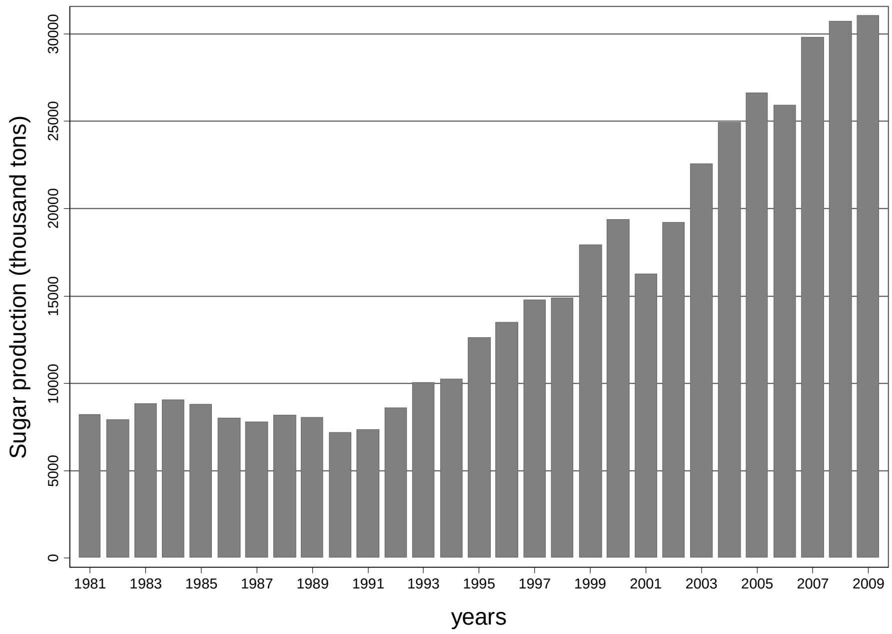
Figures A1 – A8 show developments in ethanol and sugar production as well as in the areas for sugarcane, rice, beans, soybeans, corn and manioc from 1981 to 2009.

**Figure A1: Brazilian ethanol production (1981-2009)**



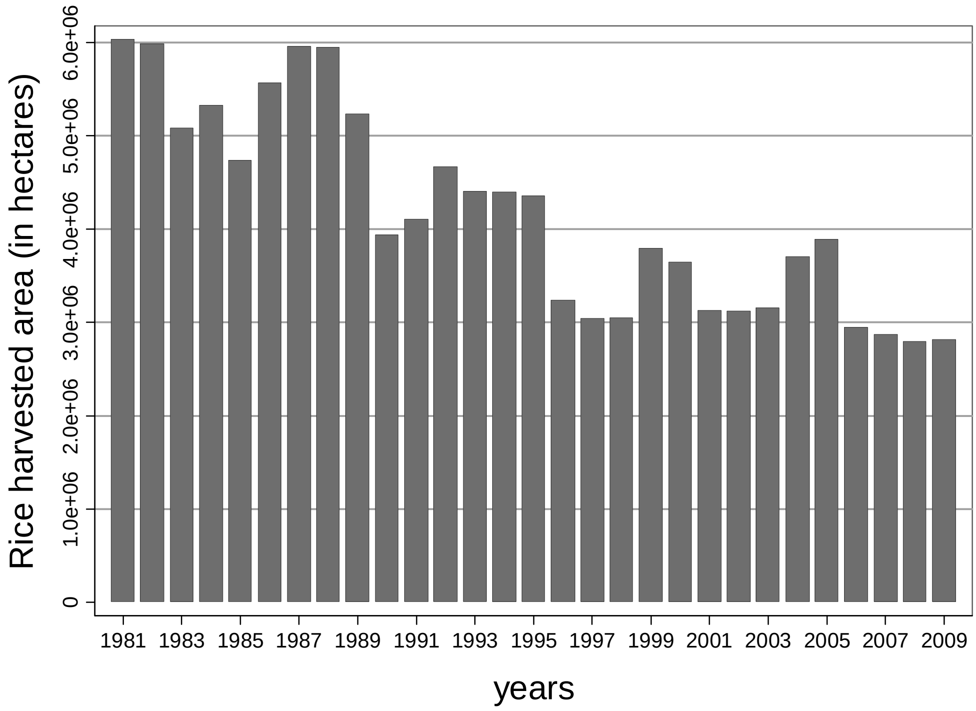

*Data source: UNICA Online Database, own calculations*

**Figure A2: Brazilian sugar production (1981-2009)**



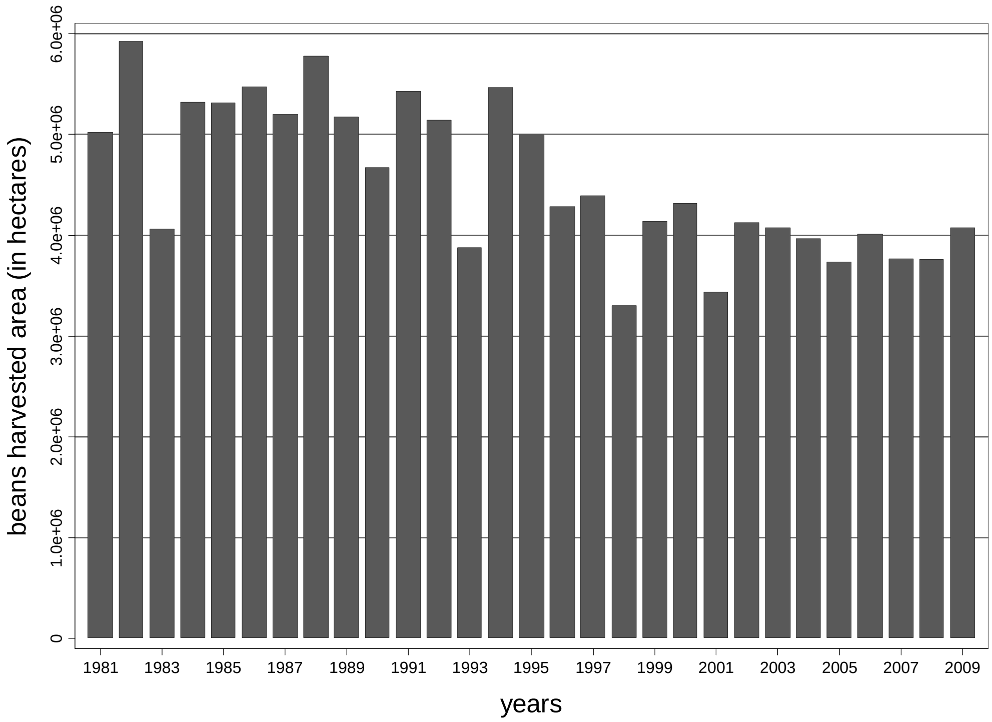

*Data source: UNICA Online Database, own calculations*

**Figure A3: Brazilian harvested areas for rice (1981-2009)**



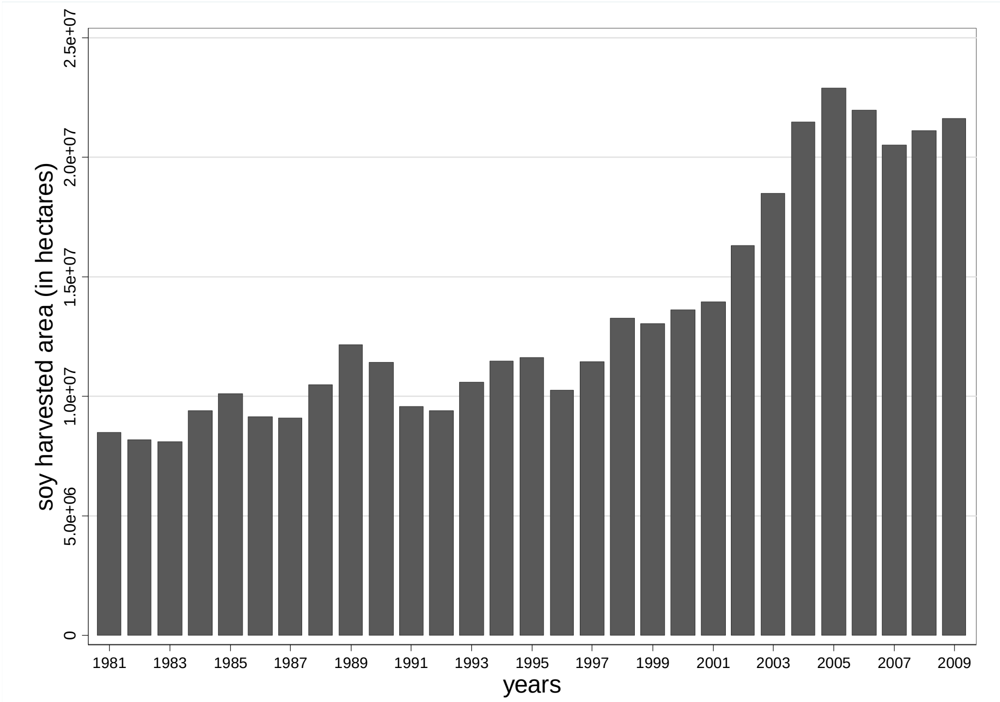

*Data source: IPEA Online Database, own calculations*

**Figure A4: Brazilian harvested areas for beans (1981-2009)**



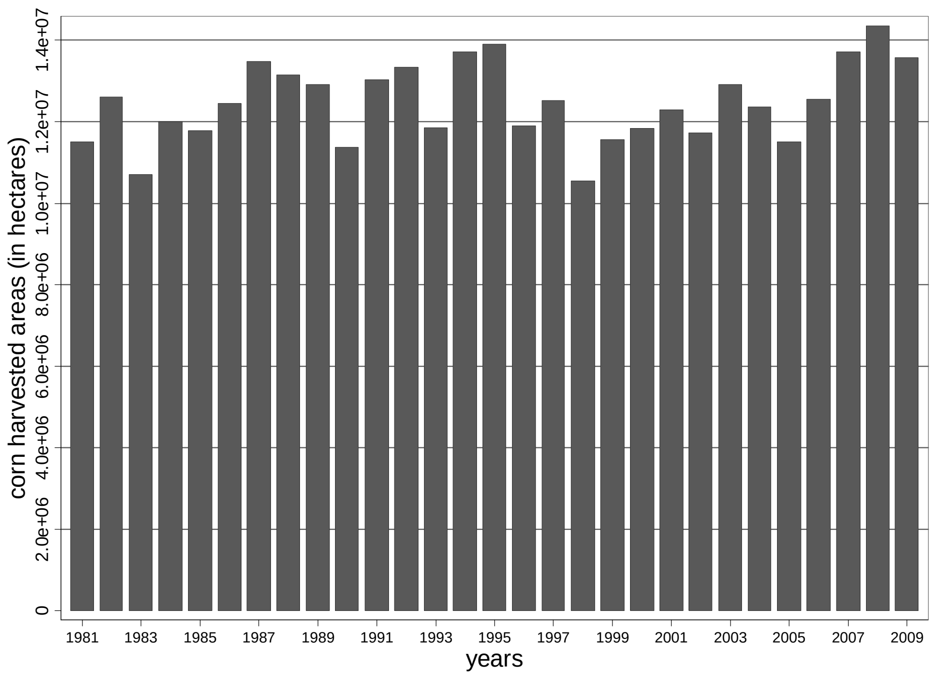

*Source: IPEA Online Database, own calculations*

**Figure A5: Brazilian harvested areas for soybeans (1981-2009)**



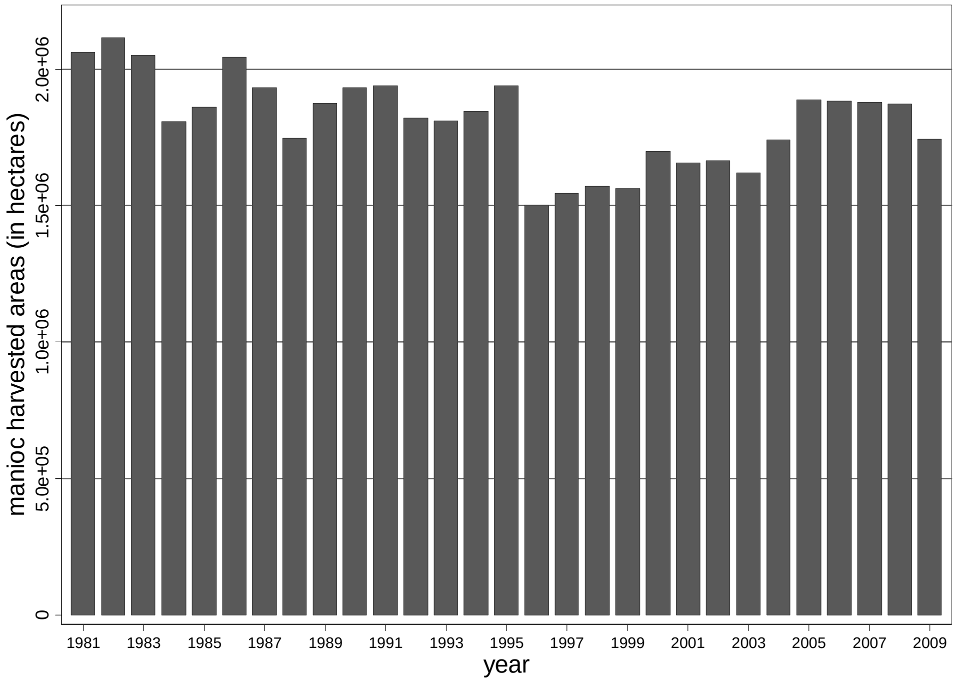

*Source: IPEA Online Database, own calculations*

**Figure A6: Brazilian harvested areas for corn (1981-2009)**



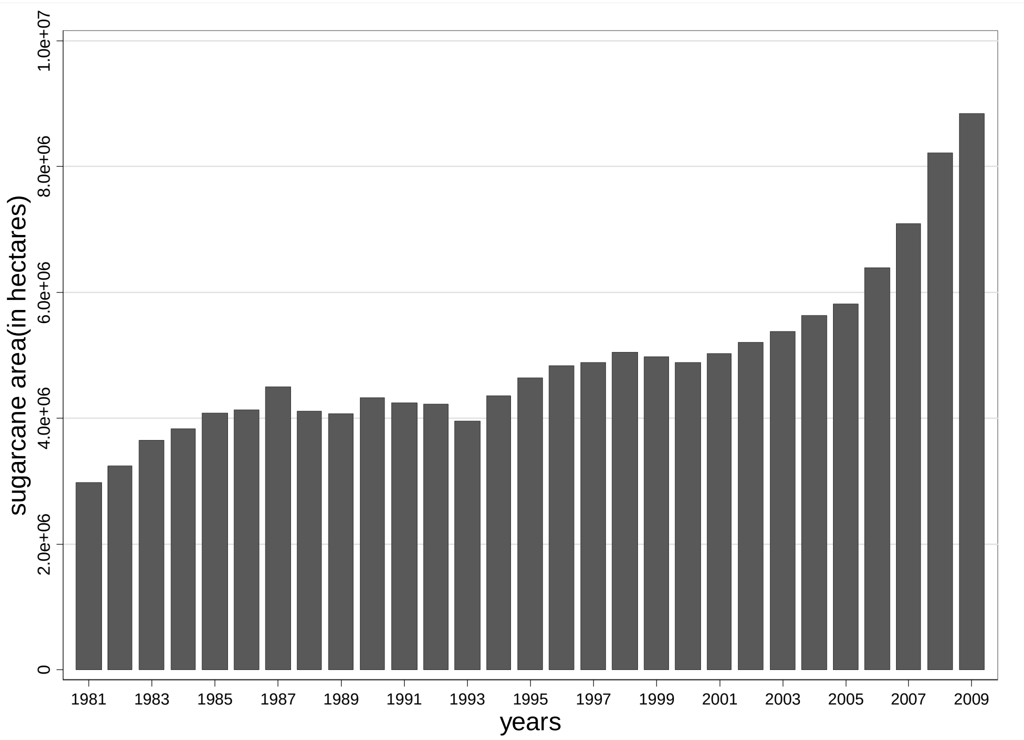

*Data Source: IPEA Online Database, own calculations*

**Figure A7: Brazilian harvested areas for manioc (1981-2009)**




*Data Source: IPEA Online Database, own calculations*

**Figure A8: Sugarcane area (1981-2009)**




*Data source: UNICA Online Database, own calculations*