Banco de México

Documentos de Investigación

Banco de México

Working Papers

N° 2013-16

Study on the Competitiveness of the Mexican Sugar Industry

Francisco Campos-Ortiz
Banco de México

Mariana Oviedo-Pacheco
Banco de México

November 2013

Documento de Investigación
2013-16

Working Paper
2013-16

Study on the Competitiveness of the Mexican Sugar Industry*

Francisco Campos-Ortiz†
Banco de México

Mariana Oviedo-Pacheco‡
Banco de México

Abstract: In this paper, we study various key structural features of sugarcane production and sugar mills in Mexico. Regarding the production of sugarcane: (a) we document a U-shaped relationship between the size of sugarcane cultivation plots and their yield, and show suggestive evidence that this relationship is driven by the more intensive use of inputs in smaller and larger plots relative to those of medium size; (b) we argue that there are factors that complicate the functioning of the land market; and (c) we present evidence refuting the conjecture that the mechanism used to determine payments for sugarcane affects negatively the quality of this crop. With respect to sugar mills, we find that those mills that are able to generate electricity more efficiently tend to observe higher returns in sugar production.
Keywords: Sugar; Sugar Industry; Competitiveness; Sugarcane; Plot Yield; Sugar Mill Efficiency.
JEL Classification: D23, D24, L66, Q1.

Resumen: En este documento estudiamos diversos rasgos estructurales clave del campo cañero y los ingenios azucareros en México. En lo concerniente al campo: (a) documentamos una relación en forma de U entre la extensión de los predios cañeros y su productividad, y mostramos evidencia sugestiva de que esta relación está determinada por el uso más intensivo de insumos en las parcelas de menor y mayor superficie relativo a las de tamaño medio; (b) planteamos que existen factores que dificultan el funcionamiento del mercado de tierras; y (c) presentamos evidencia que refuta la conjetura de que el mecanismo utilizado para determinar el pago de la caña afecta negativamente la calidad de este cultivo. En lo que respecta a los ingenios, encontramos que aquellos ingenios capaces de generar electricidad más eficientemente tienden a observar mejores rendimientos en la producción de azúcar.
Palabras Clave: Azúcar; Industria Azucarera; Competitividad; Caña de Azúcar; Rendimiento en Campo; Eficiencia de Fábrica.

*We thank the comments, guidance and opinions expressed during the interviews we held with members and representatives of the sugarcane and industrial sectors, traders and government authorities. This project benefited from the valuable suggestions of Marcelo Delajara, Santiago Guerrero, Raúl Ibarra, Miriam Juárez, José Antonio Murillo, Salvador Rodríguez, Rainer Schwabe, Eduardo Torres-Torija, Daniel Vaughan, two anonymous referees, and seminar participants at Banco de México, Universidad de Guadalajara, Universidad Autónoma de Guadalajara, Universidad Autónoma de Nuevo León, Universidad Panamericana (Guadalajara campus), the EconLunch at Colegio de México, and the annual meeting of the Agricultural and Applied Economics Association. The authors are responsible of any errors in this paper.

†Dirección General de Investigación Económica. Email: fcampos@banxico.org.mx.
‡Dirección General de Investigación Económica. Email: mariana_oviedo@banxico.org.mx.

I Introduction

One important ingredient for an adequate management of monetary policy stems from the understanding of the institutional factors affecting the price formation process of products and services that are relevant for the dynamics of inflation. The food and beverages group is particularly relevant given its high weight in the consumer price index (22.5%) as well as the clear social welfare implications that fluctuations in the prices of goods comprising this group entail. In particular, sugar has gained notoriety because of the behavior of its price in recent years and its role as one of the most important agro-industrial products in Mexico. This research examines a series of structural features of two key links in the sugar industry: sugarcane production and sugar mills. To our knowledge, there is not any other study on the sugar industry in Mexico with the scope or the methodological rigor of this research.

First, we analyze three institutional factors affecting the production of sugarcane. We start by examining the relationship between the size of sugarcane land plots and their productivity. We find a U-shaped relationship between the size of sugarcane plots and their yields. We present evidence suggesting that this relationship is driven by a more intensive use of production factors (e.g., fertilizer, irrigation systems) in bigger and smaller plots compared to medium-sized plots—those of about eight hectares.

Next, we discuss the operation of the market for land. We show that there are factors generating transaction costs and opportunity costs that hamper the participation of potential sellers and buyers, thereby hindering the functioning of this market.

We wrap up our analysis of sugarcane production by examining the system used to determine payments for sugarcane. We test the conjecture that the formula used to set the price of sugarcane affects negatively the crop quality. According to this argument, the formula discourages improvements in the quality of the crop by considering the average quality of all sugarcane delivered to the mill instead of the specific quality of each supplier's load. We find no evidence in support of this conjecture.

The second link we examine are the sugar mills. We study the extent to which the ownership (public or private) of sugar mills, as well as the capability of mills to diversify their production portfolio beyond sugar, are associated with their productivity. The evidence indicates that neither the ownership of sugar mills, nor their capability to produce alcohol relate significantly to their productivity. In contrast, those sugar mills able to generate electricity more efficiently tend to register higher productivity after controlling for their operational requirements of electric power.

The remainder of the paper is organized as follows. In the next Section, we provide a brief overview of the production of sugar in Mexico. In Section III, we describe the data used in this research. Sections IV and V present our analysis of the production of sugarcane and sugar mills, respectively. Section VI concludes.

II Production of sugar in Mexico[1]

The importance of the sugar industry in Mexico first becomes clear through its share of the food industry's Gross Domestic Product (GDP). The average value of sugar production in cycles 2006/07 through 2010/11 (the sugar cycle in Mexico runs from October 1 to September 30 of the following year) was 2.1 % of GDP of the food industry, reaching in 2011 a maximum of MXN 53,745 million, or 2.4% of GDP of the alluded industry.[2, 3]

The contribution to the agricultural GDP of sugarcane—the crop from which sugar is produced in Mexico—has been at average levels of 7.8% over the 2006-2011 period, rising to 8.6% in 2011, or MXN 30,369 million. This places sugarcane as the second most valuable agricultural commodity in the country, preceded only by grain corn. Likewise, sugarcane constitutes one of the 10 major crops (out of approximately three hundred), judging by the surface of land that it covers, with a harvested area slightly over 710 thousand hectares—circa 3.9% of total harvested area in the agricultural cycle of 2011.[4]

Sugarcane is a crop that grows in tropical or subtropical climates. Its shipment to sugar mills needs to be fast so as to avoid quality losses, which affects negatively the amount of sugar extracted. Based on these factors, sugarcane harvest and sugar production is concentrated in 15 states of Mexico with tropical and subtropical climates, among which Veracruz, San Luis Potosí and Jalisco stand out, with a combined contribution of almost 60% of the national production of sugarcane and sugar (see Table 1).

The industrialization of sugarcane, aimed at turning it into sugar, is carried out in 54 sugar mills, most of which belong to some conglomerate of mills. Table 2 presents a list of sugar mills grouped according to the conglomerate they belonged to in the cycle 2010/11, as well as the contribution of each sugar mill and group to

[1] A more detailed description of sugar production in Mexico can be found in FIRA (2009, 2011).
[2] The GDP of the food industry represents approximately 4% of national GDP. The estimates are based on data from Banco de México and the National Chamber of the Sugar and Alcohol Industries (CNIAA). For the computation of the value of sugar production, we used the reference sugar price employed for the settling of sugarcane payments, published in the Official Gazette of the Federation (DOF) on October 24, 2011.
[3] The high fructose corn syrup (HFCS) is a substitute for sugar, whose share has been growing in the national sweeteners market in recent years. Appendix A1 discusses briefly this situation.
[4] At the end of 2011, the ten major crops in terms of the harvested area were (in order): grain corn, pastures, sorghum, beans, sugar cane, coffee beans, grain wheat, fodder oats, green alfalfa and orange. Source: Agricultural and Fishery Information Service (SIAP).

national sugar production. As one can observe, the sugar sector is not characterized by a clearly dominant producer. No sugar mill contributed more than 4.5% to the national production. The conglomerate that contributed most to total production with 20.8% is the Fund of Expropriated Companies from the Sugar Sector (FEESA). This group was composed of nine sugar mills that for the cycle 2010/11 were owned by the government as a result of the expropriation of sugar mill in 2001. The Herfindahl–Hirschman index, extensively used as a measure of market concentration, is equal to 247.04 points at the sugar mill level and to 1,091.25 points at the conglomerate level. In neither case these values are considered indicative of a concentrated market.

The sugar sector plays a pivotal role in the economic life of some Mexican regions. It is considered to be a high-impact activity in 227 municipalities comprising around 12 million residents. As a whole, the sugar industry generates over 450 thousand jobs (equivalent to 0.9% and 6.7% of the total and primary sector's economically active population, respectively) and direct benefits to more than 2.2 million people.[5]

As a component of the inflation index, sugar has a weight (in a scale from 0 to 100 percentage points) of 0.18 in the Consumer Price Index (CPI, base 2010 and weights updated in April 2013). For its weight, sugar ranks in the 31st place out of 108 generic items constituting the subindex "Food, beverages and tobacco". In Appendix A2 we document the contribution of sugar to inflation over the last decade.

As part of the Producer Price Index (PPI, base 2012), sugarcane has a weight (in a scale from 0 to 100 percentage points) of 0.16, which places this commodity in the 8th slot among 69 items comprising the subindex "Agriculture, breeding and stock of animals, forestry, fishing and hunting". In turn, sugar's weight is 0.34, locating it in 27th place among 361 items comprising the subindex "Manufacturing industry".

In the international arena, Mexico occupied in 2011 the 7th place among the largest sugar producing countries (see Figure 1) and the 9th place as consumer of this sweetener (see Figure 2).[6]

[5] Source: Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA, 2007a), and the National Institute of Statistics and Geography (INEGI).

[6] Koo and Taylor (2011) estimate that in 2010 per capita sugar consumption in Mexico was 40.5 kilograms, compared to 74 kg in the U.S., 60.4 kg in Brazil, 59.8 kg in Australia, 47 kg in the European Union, 39.4 kg in Canada, 23.3 kg in South Korea, 20.4 kg in Indonesia, 20 kg in India, 17.7 kg in Japan, and 11.2 kg in China.

III Data and descriptive statistics

The data used in this research were obtained primarily from three sources. First, the Sugarcane Agroindustry Statistics volumes 2001-2010 and 2002-2011. These data are assembled and published by the National Sugarcane Union, which is part of the National Confederation of Rural Growers (UNC-CNPR) and contains historical information for each one of the 59 sugar mills that have operated during this period. This source provides general indicators of the production of sugar, the quantity and quality of sugarcane, and mills' efficiency; however, it does not have detailed information of the different factors that may affect the productivity of the sugar sector (e.g., if the crops are watered through irrigation or seasonal rain, or the use of fertilizers). This type of data was obtained from a second source, The Mexican Sugar Manual volumes 2002 through 2012, published by the Sugar Manual Editing Company (CEMA). This document contains an exhaustive stock of information about sugarcane fields, the conditions under which sugar is produced at every sugar mill, and the prevailing geographic conditions around mills. Despite the richness of the information contained in the manuals, it lacks complete data for all sugar mills. Besides, the data are only available in printed format and it is primarily written in prose, making it necessary to capture all the information manually.

Finally, we used data from the National Water Commission (CONAGUA) in order to know the rainfall levels that occurred at the stations closest to the mills. We used the software ArcGIS to identify these stations and then computed the total rainfall that was recorded during the 18 months prior to the beginning of the harvest; this is the maximum period that is considered appropriate for the growth of cane before being harvested (FAO, 2012; Pérez Zamorano, 2007; SAGARPA, 2010).

Table 3 presents the variables used in this study (ordered alphabetically) along with their description and source. Table 4 shows the descriptive statistics of these variables for the entire study period (cycles 2000/01-2010/11) as well as for the 2010/11 harvest in order to show the ongoing situation by the last cycle for which we have data. Sugar mills are the unit of observation, out of which we only included the 54 sugar mills that have maintained operations throughout the period of analysis.[7, 8]

Regarding the most relevant variables for sugarcane production, Table 4 reports an average yield of 10 tons of sucrose per hectare (look for variable

[7] We decided to exclude the sugar mills Independencia, La Concepción, San Gabriel, San Sebastian and Santo Domingo to avoid the likely econometric bias generated by the closure of these mills at some point during the period under study; technically, to avoid the attrition bias.

[8] The number of observations differs across variables because some sugar mills fail to report their statistics consistently.

"Sucrose" on Tables 3 and 4) generated by a production of 75 tons of sugarcane per hectare (variable "Cane") which contained 13.5% sucrose (variable "Sucrose Content"). For the 2010/11 cycle, average sucrose yield was 9.5 tons, due mainly to the decline in land yields of 68 tons of sugarcane per hectare, even though sucrose content actually rose to 13.9%.

As a measure of the size of sugarcane farms, we consider the number of hectares cultivated per sugarcane producer (variable "Plot size"); that is, this indicator captures the average size of sugarcane parcels that supply each sugar mill. The average plot was 4.5 hectares, which remained stable throughout the study period, with the average sugarcane farm measuring 4.7 hectares in 2010/11.

Regarding to the use of capital, on average 82% of sugarcane was lifted and placed mechanically on trucks that transported it from the field to the mills (variable "Mechanical lifting"). A measure that captures an even more intensive use of capital is the proportion of cane harvested mechanically, which involves both cutting and lifting the cane in a mechanical way; this metric averaged 22% over the study period (variable "Mechanical harvest"). The use of irrigation provides another indication about the penetration of capital inputs in the production of sugarcane. On average, irrigation covered 48% of sugarcane fields (variable "Irrigation"). Two additional points should be noted. First, there is a high heterogeneity in the use of capital among sugarcane producers. In all of these indicators, the range went from the no utilization of capital to 100%. Second, these measures displayed relatively steady patterns throughout the eleven cycles considered, such that the use of capital recorded for the 2010/11 harvest was similar to the average for the whole period.

Now we turn our attention to the sugar mills. Table 4 shows that the process of re-privatization of mills that followed after the expropriation of 27 mills in September 2001 has not concluded. By 2010/11, nine (20%) of the 54 sugarcane mills in operation still remained in government hands and are administered by FEESA (variable "Mill administration").[9]

[9] On July 23, 2012 an agreement authorizing the sale of the nine sugar mills was published in the Official Gazette of the Federation (DOF). On November 29 of the same year the then Secretary of Agriculture, Francisco Mayorga, said in a press conference that the procedure by which the mills would be sold is through a "mercantile contest". This is a judicial process that consists of two stages, conciliation and bankruptcy. According to Article 3 of the Mercantile Contests Law, conciliation is conducted to preserve the company through the subscription of an agreement between the merchant and recognized creditors. The purpose of bankruptcy is to sell the company, its production units and other assets in order to pay off recognized creditors. In the case of the sugar mills, the government earmarked one billion pesos corresponding to an expropriation bonus that will be used to pay off creditors. Article 198 of the same law states that the sale of property must be made through a public auction, which starts at a minimum price and the winner is defined by the highest bid. However, Article 207 states that the bankruptcy stage should conclude over the course of six months, after which any interested person may submit to the court an offer to buy any remaining goods or assets.

Our key measure of mills' productivity is called factory efficiency, which captures the transformation rate of sucrose into sugar; in other words, it is the ratio of sugar production to the volume of industrialized sucrose. During the 2000/01-2010/11 period, the average mill had an efficiency rate of 82.3% (variable "Factory efficiency"); i.e., it produced just over eight tons of sugar for every ten tons of sucrose. For the 2010/11 harvest, this gauge had a small increase, rising to 82.5%. Another metric commonly used to analyze the productivity of sugar mills is the factory's yield, which consists of the ratio of sugar production to the volume of crushed cane. As shown in Table 4, the average mill recorded a rate of 11.1% throughout the study period (variable "Factory yield"), slightly below the average of 11.5% of the 2010/11 cycle.[10]

Besides being the main source of sugar in Mexico, cane exploitation allows for the generation of electricity and the production of alcohol. During our period of study, the average mill generated 17.3 kWh per ton of cane (variable "Electricity generation"). However, this number masks the growing trend that has been observed since the 2003/04 cycle, when average energy generation was 16.6 kWh/ton; for the 2010/11 harvest, the electricity production reached a maximum of 18.1 kWh/ton.[11] This contrasts with the downward trend that the use of sugarcane for alcohol production has displayed during the 2000/01-2010/11 period. Sugar mills began the decade producing 1.2 liters/ton on average, reaching a nadir in 2009/10, when they generated only 0.2 liters/ton, and finished producing 0.4 liters/ton (variable "Alcohol production"). The average for the entire period was 0.7 liters/ton.[12]

Regarding energy use, mills consumed on average 17 kilowatt-hour (variable "Electricity consumption"), 8 liters of oil (variable "Oil consumption") and 0.6 tons of steam (variable "Steam consumption") per ton of crushed cane. It is worth mentioning that the use of oil has been declining consistently over time, reaching a minimum of 2.3 liters/ton in 2010/11, with eighteen mills completely eliminating the use of this input. In the case of electricity and steam, the use of these inputs has remained stable over our period of study.

[10] Factory yield considers only the amount of crushed cane, ignoring its quality (i.e., sucrose content). Consequently, it is a measure that punishes (rewards) sugar mills receiving low (high) quality, making them look less (more) productive than they really are. The fact that factory efficiency captures both the quantity and quality of cane makes this a more accurate measure of mills' productivity, and for this reason we focus on this indicator.

[11] As explained in greater detail in FIRA (2010) and SAGARPA (2010), electricity is produced from the combustion of fibrous residue (called bagasse) resulting from the milling of the cane. The legislation allows mills to generate themselves the electricity they consume in their production process. For the 2010/11 cycle, sugar mills satisfied 94% of their operating electricity requirements with own production.

[12] Alcohol produced by mills is used for the manufacture of beverages and industrial use. Mexican mills have not ventured into the production of biofuels as only two mills (La Gloria and San Nicolas) have the equipment for the production of dehydrated alcohol, which is blended with gasoline to produce fuel. Over the past decade there has been a gradual reduction in the number of mills that produce alcohol because of its low profitability, and competition from large distilleries using sugarcane exclusively for the production of alcohol. Ethanol production involves an opportunity cost in terms of sugar production (IMCO, 2007), which has been exacerbated by increases in global and domestic prices of sugar that have been observed since 2006.

Another area in which mills have also observed significant decreases is the share of lost work time due to miscellaneous reasons, with an average of 20% throughout the period, reaching a minimum in 2010/11 with 15% (variable "Total lost time"). The improvements in this metric were greater when the loss of time was due to festivities or field issues. In both cases, the average mill recorded minimum levels of 0.4% (variable "Lost time festivities") and 2.4% (variable "Lost time field") during the last harvest considered.

It should also be noted that as part of this investigation we conducted a series of interviews with various stakeholders in the sugar industry, specifically representatives of sugarcane growers and sugar mills, sugar traders, and government officials.

IV Production of sugarcane

The sucrose contained in the sugar cane is the main input for the production of sugar in Mexico.[13] It is thus necessary to examine the ability of Mexican sugarcane farms to provide this input in order to achieve a better understanding of the sugar industry.

Internationally, Mexico was in 2011 among the top ten producers of sugarcane, having ground 44.13 million tons (see Figure 3). This commodity was obtained from the cultivation of 673 thousand hectares, one of the largest in the last decade. However, the production of sugarcane during the 2010/11 harvest was far from the peak reached during the 2004/05-2007/08 cycles, which averaged 48.88 million tons despite the fact that the area of farmland devoted to this crop remained relatively stable in recent years (see Figure 4). These patterns suggest decreasing yields in sugarcane production.

Indeed, during 2011 the productivity of sugarcane land plots—measured by the volume of cane obtained per hectare—places Mexico far below the levels achieved by countries like Peru, Colombia and Egypt. While these countries experienced yields close to or above 100 tons of cane per hectare, in Mexico this metric was 65.6 tons/ha (see Figure 5), a level that preserved the downward trend over the last six cycles.[14] The gradual decline in yields has been the main driver behind the recent drop in the production of sucrose—both in absolute terms and in yield per hectare—as the sucrose content of cane has even shown an upward pattern in recent years, peaking at 14.1% in the 2010/11 cycle (see Figures 6 and

[13] Sugarbeet is another source of sucrose. Unlike cane, which can only grow in tropical and subtropical areas, beets grow in temperate climates and exhibit a high resistance to cold. The production of this crop is concentrated in European countries and the U.S.
[14] Some numbers presented in this section do not match the descriptive statistics because the latter are not weighted by the contribution of each observation unit (mills) to the national statistics.

7). In other words, the decay in the potential of farms to provide sucrose that can be transformed into sugar did not result from changes in the quality of cane, but from the decline in the ability of land to produce larger volumes of the crop per hectare.[15]

In this section we study three institutional factors that affect the productivity of farmlands. First, we analyze the relationship between the size of sugarcane land plots and their productivity. Then, we discuss the functioning of the land market. The third element we examine is the system used to determine the payment for sugarcane.

IV.A Size of sugarcane land plots and productivity

In this section we evaluate empirically the relationship between the size of sugarcane parcels and their yields in the production of sucrose. The motivation of this analysis stems from the opinion shared among various participants in the sugar industry that the agrarian structure in Mexico in general, and sugarcane fields in particular, characterized by its high fragmentation/atomization (i.e., the high prevalence of production units of small size), is a major hurdle hampering productivity in the sugarcane sector.[16]

This analysis contributes to the long debate that has developed over several years about the relationship between farm size and productivity. A seminal reference is Sen (1962), who proposed the existence of an inverse relationship between the size of Indian farms and productivity. Sen attributes this association to the more intensive use of labor in small farms, which results from the larger availability of family labor. Since this publication, several authors have studied this phenomenon in Africa, Asia and Latin America. One branch of this research has found evidence supporting the hypothesis that small farmers are more productive, which is justified by factors such as a more efficient and intensive use of land, labor, and capital by small farmers (Ahmad Khan and Qureshi, 1999; Bardhan, 1973; Carter, 1984; Cornia, 1985 Fan and Chan-Kang, 2005) and imperfections in the markets for land, labor, insurance, and credit (Heltberg, 1998).

Bhalla and Roy (1988) refute this literature arguing that the inverse relationship is generated by the omission of variables in the model, such as land quality. The evidence presented by Chen et al. (2011) echoes this argument. In a similar vein, other studies conclude that the inverse relationship is weakened and even reversed in the presence of increased use of technology, increased use of fertilizers, and other capital-intensive inputs. Thapa (2007) shows that the inverse

[15] The quantity (tonnes of cane per hectare) and quality (sucrose concentration) of cane are not independent measures, but maintain a positive relationship. Appendix A3 discusses this relationship.

[16] The high fragmentation of farms has been identified as one of the most relevant structural feature of the agricultural sector in Mexico (Fernández amd Fernández, 1946; Artís Espriu, 1997; Warman, 2003; SAGARPA, 2007b).

relationship tends to become insignificant if farmers have better access to resources such as credit, advanced technologies, irrigation and market information.

There are three studies that stand out due to their closer relationship to our analysis. First, the exhaustive study that Pérez Zamorano (2007) undertakes on the production of sugarcane in the Matamoros valley, located in the state of Puebla. One of the main thesis of this project is that a high atomization of sugarcane farms undermines their productivity by restraining: (i) their access to credit aimed at acquiring production inputs, machinery and equipment, and crop renewal, among others; (ii) the management of water resources; and (iii) the efficient utilization of labor. The fundamental distinction between our paper and this study lies in the quantitative nature of the former, whereas Pérez Zamorano's work is based on (qualitative) method of a case study.

Due to its focus on the Mexican agricultural sector, the second study that is closely related to ours is the one by Kagin et al. (2012), who exploit panel data of parcels from the National Rural Households of Mexico Survey. Both Kagin et al.'s and our work contribute to a practically inexistent literature on the relationship of farm size and productivity in Mexico (which, in turn, results from the lack of data needed for research on this topic). Kagin et al. find that small farms are more productive and operate more efficiently than large farms. Our results are consistent with theirs in the case of sufficiently small farms. This is complemented with our finding that starting at a critical size, larger sugarcane plots tend to record higher yields.

The third study closely related to ours is the one by Helfand and Levine (2004) on the determinants of productive efficiency in Brazilian sugarcane farms. They show evidence of a U-shaped relationship between productive efficiency and farm size, which they attribute to the fact that big producers have preferential access to institutions, services (e.g., rural electrification, technical assistance, trading mechanisms), and technologies that help to improve productivity. Similar to Helfand and Levine, we document a U-shaped relationship between the size of sugarcane plots and productivity. Unlike these authors, we find that the aforementioned relationship dissipates once we control for the use of some capital factors.

Figure 8 provides a first illustration of the U-shaped relationship between the size of sugarcane plots and the production of sucrose per hectare achieved during the 2000/01 through 2010/11 harvests. In order to give a more robust support to this visual impression, in Figure 9 we present the nonparametric regression of sucrose yield per hectare on the size of sugarcane parcels. The result of this exercise buttresses the inkling of a U-shaped association between these variables, which we now examine econometrically.

A parsimonious strategy that captures this non-monotonic association relies on the estimation of equation

$$sucrose_{ist} = c + \beta_1(plot\ size_{ist}) + \beta_2(plot\ size_{ist})^2 + X'_{ist}\delta + \varphi_t + \varphi_s + u_{ist}, \qquad (1)$$

where $sucrose_{ist}$ represents the sucrose production per hectare achieved by providers of sugar mill i located in state s during the cycle $t = 2000/01$,..., 2010/11; c is a constant; $plot\ size_{ist}$ is the average size of plots supplying mill i; X_{ist} is a vector of controls; φ_t and φ_s denote cycle and state fixed effects, respectively; and u_{ist} is the residual term. Both control variables and fixed effects are introduced gradually in the different specifications we consider. The coefficients of interest are β_1 and β_2.[17, 18]

Table 5 presents the results of our estimations of (1). The first column shows the estimates of our simplest specification, which only includes (besides the intercept) the linear and quadratic terms of our measure of the size of sugarcane farms. The results confirm the U-shaped relationship between the average size of plots and sucrose yields shown in Figure 9, and indicate that the critical plot size where a positive relationship between these variables kicks in is 8.3 hectares.

A first extension of this base specification is to examine whether the relationship holds across cycles. This is achieved by including dummy variables for each harvest. Indeed, column (2) shows that the non-monotonic association is maintained even with the inclusion of the cycle fixed effect, marginally decreasing the critical size of plots to 8.2 hectares. One can also argue that there are conditions sugarcane growers of the same state share (e.g., institutional framework, geography, etc.) that could affect productivity. To capture this effect we include state dummies, which render the estimates shown in column (3). We note that the U-shaped relationship is also robust to the inclusion of state fixed effects; although the point estimates change in magnitude, the critical size of plots remains close to the original specification, standing at 8.1 hectares.

In subsequent specifications we proceed to introduce gradually the control variables. First, we control for rainfall and mills' ownership (private vs.

[17] Equation (1) excludes a sugar mill fixed effect because its inclusion would generate identification problems, as the variable of interest, the average size of sugarcane parcels, lacks enough variation over time. (The extreme case of this problem is when the variable is constant over time, in which case the variable drops out of the regression.) Thus, our results are mainly derived from the cross-mill heterogeneity.

[18] The lack of data for some mills in different cycles (which is reflected in the disparity of N across specifications) forces us to impose the assumption that the lack of observations does not respond to any pattern having conditioned by the explanatory variables of our model. The apparent randomness with which observations drop out of the sample, along with the wide range of controls that we include, gives us confidence that this is the case.

government). Column (4) shows that the parabola-shaped association is preserved under this specification, suggesting a critical size of plots of 8.6 hectares.

We now proceed to control for the use of inputs. Column (5) presents evidence that the U-shaped relationship remains after controlling for the use of fertilizers, indicating a critical size of 8.7 hectares.[19] The next specification includes controls for the mechanic lifting of sugarcane, the number of vehicles carrying the crop from the field to mills, and the number of cane cutters. Under this specification, we find a first indication that the introduction of production inputs can make the effect of plot size on sucrose yields redundant. As shown in column (6), the convex relationship between size and performance is maintained, although the quadratic term loses its statistical significance.[20] The size of land plots becomes completely redundant when we control for the use of irrigation systems (column (7)) or mechanical harvesting of sugarcane (column (8)), both of which correlate positively to sucrose yields. Our estimates suggest that an increase of ten percentage points in the use of irrigation systems, or of the share of cane harvested mechanically, may increase the production of sucrose per hectare by about 4%. Columns (9) and (10) confirm the redundancy of the size of sugarcane parcels under our most complete specifications that include the full battery of control variables.

As we mentioned above, the state fixed effect could be capturing geographical conditions relevant to farms' productivity. One way to assess the robustness of our results is to replace the state fixed effect for the altitude above sea level of sugar mills, which is a more accurate measure of the geographical conditions facing sugarcane parcels. Columns (11) to (13) corroborate our results, namely, the U-shaped relationship is preserved when we do not include controls for the use of irrigation systems or mechanical harvesting. Otherwise, the size of land plots becomes redundant. Further, these results indicate that a higher altitude has beneficial effects on sucrose yields. Plots located at a higher altitude by 100 meters are expected to register larger sucrose yields by 2-3%.

The results in Table 5 also indicate that the type of ownership of mills does not have a significant impact on the productivity of the field.[21] A similar situation occurs with mechanical lifting, vehicles, and cutters variables. We also report mixed evidence regarding the relationship between rainfall and sucrose yields.[22] The

[19] The inclusion of the quadratic term of the fertilizer variable is the result of a visual inspection between this variable and sucrose yield.

[20] This result is obtained only when we use together the controls for mechanical lifting, vehicles and cutters. The inclusion of these variables separately holds the direction and statistical significance at conventional levels of coefficients of interest. (We omit showing these results to save space.)

[21] Although columns (12) and (13) indicate that providers from private mills record lower sucrose yields, the lack of similar results under other specifications keeps us from drawing any conclusion.

[22] Note that the negative relationship between rainfall and productivity (even in cases without statistical significance) emerges when irrigation is omitted, and becomes positive when irrigation is included. This suggests that areas receiving less rainfall are the ones where irrigation systems become more necessary. In these

direction of the coefficients for the use of fertilizers point to a convex relationship with land productivity; however, the lack of robustness of this result raises suspicions about the relationship.[23]

In Appendix A4 we check the robustness of the functional form of equation (1) as well as the main results presented in Table 5. We demonstrate that the inclusion of the quadratic term is a statistically significant improvement over the model that only includes the linear component in those specifications that do not control for the use of inputs. Under those specifications that contain controls of the use of inputs, both the linear and the quadratic terms lose their relevance. Moreover, our results are robust to the exclusion of observations that might be considered outliers—i.e., sugar mills La Primavera (PRI) and El Higo (HIG)—and to the estimation of (1) weighted by the volume of industrialized sugarcane or the volume of sugar produced.

How can these results be rationalized? The size of sugarcane parcels is not a determinant of land productivity per se, but it exerts indirectly its influence through the creation of a more conducive environment for the use of inputs that increase sucrose yields. The fact that the effect of farm size on sucrose yields becomes redundant once we include the irrigation and/or mechanical harvesting variables indicates that the mechanism of this effect operates through the impact of these factors. The support is particularly robust for the case of irrigation.

Under this argument, the next natural step is to examine the relationship between the size of sugarcane plots and the use of the various production inputs we have considered. With this exercise, we aim to further our understanding of the U-shaped relationship between farm size and productivity. For this purpose, we estimate similar regressions to equation (1), with the difference that the dependent variables are the use of fertilizer; the share of sugarcane lifted mechanically; the availability of vehicles, cane cutters, and irrigation; and the fraction of cane harvested mechanically. The regressors of interest are the linear and quadratic terms of the size of plots; in each case we first estimate the regression using the linear term only and then both terms. As control variables, we include rainfall, sugar mills' ownership type, and cycle and state fixed effects.

Table 6 shows the results of the exercise. The first two columns give evidence of a U-shaped relationship between the size of sugarcane plots and the use of fertilizers, with a critical scale of 6.7 hectares. The positive segment of the

areas, an increased precipitation is more likely to foster greater productivity. In contrast, in areas that naturally receive high rainfall amounts, increased precipitation may even have adverse consequences, for example by causing floods.

[23] There may be numerous reasons why we do not find stronger evidence of the relationship between the employment of fertilizers and sucrose yields. For example, our variable reflects the amount of fertilizer applied during the first dose, ignoring the type of fertilizer that each type of soil demands, or subsequent applications; our measure does not capture either if fertilizer is applied correctly.

relationship can be explained by an argument of economies of scale, i.e., a minimum size is required to make investments in fertilizer profitable. The negative segment could be justified as follows. As the investment in fertilizers yields little—or no—profit, managers of small plots would use an insufficient amount of this input. In this context, larger plots (but still smaller than the critical size) would be getting less fertilizer per hectare since the difference in size would exceed the change in the availability of this input.[24]

Columns (3) and (4) suggest a non-significant association between the size of sugarcane plots and the fraction of cane lifted mechanically. One possible reason behind this (apparently) nil relationship is that the mechanical lifting of cane is a service that can be rented for an amount proportional to the plot's area, which keeps larger parcels from taking advantage of the economies of scale that their size generates.

In turn, the size of sugarcane plots appears negatively related to the number of vehicles available per hectare (columns (5) and (6)). In his qualitative study of the Matamoros valley, located in the state of Puebla, and where the sugar mill Atencingo resides, Pérez Zamorano (2007) suggests one plausible explanation, namely, the shipment of each sugarcane producer must be weighed separately at the mill in order to determine unambiguously the payment for each provider. This situation naturally implies that the greater the fragmentation of the land, the larger the number of providers and, consequently, the higher the number of vehicles used to transport the cane to the mill.

Column (8) shows a convex relationship between the size of sugarcane plots and the employment of cane cutters per hectare, with a critical size of 12 hectares. The fact that this critical scale is above the majority of our observations implies that the negative segment of the curve dominates the relationship, which is reflected in the coefficient of the linear term shown in column (7). This result could be seen as consistent with the view that small farmers tend to use labor more intensively (vide supra). Another likely source of this result stems from the greater difficulty that highly fragmented parcels pose on the efficient allocation of cane cutters—a situation that also entails major variations in the optimal timing of harvesting across parcels—so producers simply choose to rely on a larger number of cutters.

Columns (9) and (10) suggest that a higher intensity of rain falling on the adjacent area to mills discourages the use of irrigation systems since they become less necessary. Our estimates indicate that an increase of 10% in average rainfall

[24] Under a monotonicity assumption (which our evidence refutes), Pérez Zamorano (2007) notes that the small size of plots discourages the purchase of fertilizer since the need for this input is below the amount considered wholesale, which has a more accessible price per ton.

leads to lower utilization of irrigation by 5 percentage points. It is worth noting that even when the size of sugarcane parcels appears relegated to a secondary role in the two specifications considered, an inspection of the evidence reveals that this is largely due to the state fixed effect.[25] By excluding this fixed effect, we find a statistically significant U-shaped relationship between the area of plots and the penetration of irrigation, with a critical size of the plots of 6.9 hectares (tables available upon request).[26]

The last two columns use the fraction of sugarcane harvested mechanically as the dependent variable. Column (11) presents evidence of a positive relationship between the average size of sugarcane plots and the degree of mechanization of the harvest. Our point estimate implies that an increase in the size of plots by one hectare is associated with a larger faction of the crop being harvested mechanically by 1.5 percentage points, equivalent to 7% of the average.[27] This result does not hold when we introduce the quadratic term, as shown in column (12). However, a couple of statistical tests indicate that the linear specification captures reasonably well the relationship between these variables, making it unnecessary to include the quadratic term. Both a likelihood ratio test ($\chi_1^2 = 0.1,\ p = 0.75$) and a heteroskedasticity-adjusted Wald test ($F_{1,40} = 0.03,\ p = 0.86$) prevent us from rejecting the null hypothesis that the inclusion of the squared term is not a statistically significant improvement over the model that excludes that term. The zero gain in explanatory power of the regression provides additional support to the argument that the linear specification is sufficient.

These results complement the argument drawn from Table 5—the non-monotonic relationship between the size of sugarcane parcels and their productivity operates through the use of inputs. Despite the lack of decisively conclusive results, as a whole the evidence presented in Table 6 suggests that smaller and larger plots use production inputs more intensively compared to medium-sized parcels (those with a surface close to eight hectares), which leads to higher yields in small and large plots relative to those of medium-sized parcels. In particular, small parcels are more prone to use more intensively fertilizer, labor, and irrigation systems; large plots tend to use more intensively fertilizer, irrigation, and harvesting equipment.

[25] This could be the result if, for example, state governments undertake policies (e.g., subsidies, soft loans) to facilitate sugarcane producers the acquisition of irrigation systems regardless of the size of their plots, thereby rendering this variable irrelevant.
[26] Irrigation systems represent the typical case of a capital input that is not possible to rent (since it is not a mobile factor) and whose acquisition entails high fixed costs that can only be recovered if it has a minimum scale.
[27] Pérez Zamorano (2007) identifies three reasons why a structure of small farms inhibits greater farm mechanization. First, the cost is prohibitive relative to the gain that can be extracted by exploiting a small plot. Second, the equipment usually has a capacity that exceeds the requirements of smallholders. And third, there is reluctance to mechanize farm work to replace manual work (in which family may participate in some cases).

The economies of scale, which turn investments in production inputs profitable, can be listed as a plausible explanation behind the more intensive use of inputs in large sugarcane parcels.[28] This same argument can even be extended to a scenario of highly atomized land plots given that one of the main reasons why land fragmentation has remained (in some cases even exacerbated) lies in the division and distribution of land among the children of cane producers (Pérez Zamorano, 2007). In this context, we would observe small contiguous parcels whose managers are relatives, which produces social capital that facilitates de facto consolidation of farms, thereby generating economies of scale. Other mechanisms which could be fostering a greater consolidation of parcels are the renting of plots and other partnership schemes among smallholders.

One additional factor that may also be driving the more intensive use of inputs in large and small farms is that medium-sized producers neither have the support (e.g., subsidies) that small farmers get for the acquisition of inputs, nor they have the same financial capacity of large producers towards the same purpose.

IV.B Operation of the land market

As documented by Appendini (2010), about 60% of farmland in Mexico operates under communal ownership (community or ejido). Therefore, any discussion about the agricultural land market should focus on the legal framework that determines the operation of the market for communal lands. In this section we show that there are legal and extra-legal factors that hinder the free functioning of this market.

After the Mexican Revolution, and until 1992, communal lands were by constitutional mandate property of the nation. During this period the sale or lease of communal lands was banned in order to keep them tied to the community. The inheritance of land was allowed, though it was still owned by the state (OECD, 1997). The constitutional reform of Article 27, carried out in 1992, allowed to modify the land tenure to transform it into private property and thus facilitate the sale of land.[29] This reform aimed to promote a land market in which land would serve as an asset that could be used as collateral for credit (Yúnez Naude, 2010). Conceptually, the land market would promote the consolidation of land plots in productive units of greater extent, as the market would foster a more efficient allocation and exploitation of this resource.[30] However, the reform has fallen short

[28] Besides the stronger incentives for capital investment, Pérez Zamorano (2011) discusses other mechanisms (not explored in this research) through which the consolidation of land plots into larger farms has positive impact on the development of Mexican agriculture. He asserts that less fragmentation facilitates the access to credit and more efficient trading channels. Additionally, production subsidies are less likely to become consumption subsidies, and it reduces the environmental impact of farming as well as the risk of agrarian conflicts.

[29] A comprehensive description and discussion of the 1992 reform can be found in Appendini (2010) and Pérez Zamorano (2007).

[30] The Agrarian Law allows alternative schemes to the sale or lease of parcels meant to promote the merge of plots in production units of larger scale: association for productive purposes (Articles 45 and 50); concession to community members or others for the use or enjoyment, through sharecropping, partnership, lease, or any

in achieving its goals, in a way that the high fragmentation of Mexican farmland persists to day.[31] Appendini (2010) finds that by 2007, only 4.4% of communal land had become private property.

Three important reasons can be enlisted for these outcomes. First, the entry barriers that potential buyers who do not belong to the ejido face if they seek to participate in the land market. The first step in the process of switching from communal to private ownership is the regularization of property rights. This was done under the under the Certification Program of Communal Land Rights (PROCEDE), whose protocol is illustrated in Figure 10.[32] The certification of communal lands is sine qua non condition for parcels to be sold or leased, which, however, does not guarantee full domain of landholders over their plots (Article 81 of the Agrarian Law)—only 7% of all certified communal property had adopted the full domain regime which does grant landholders the authority to sell or lease their plots (Appendini, 2010). One restriction to the exercise of full domain rights, and thus the smooth functioning of the land market, results from the legal disposition that the sale of land to non-ejido members is subject to the ejido assembly's authorization and the right of preference (known as "right of first refusal") for family, people who have worked on the plots for over a year, and other ejido members (see Section 6 of the Agrarian Law, Articles 81 and 84).[33] With these provisions, the law creates entry barriers to the land market for people who do not belong to the ejido.

The lack of legal certainty over the ownership of land plots is plausibly a second explanation behind the limited impact of the reform. This issue came up repeatedly in our interviews with stakeholders in the sugar industry. Among the anecdotes shared by our interviewees, we can cite situations in which the new owners suffered the invasion of their lands and received an unsatisfactory response from the authorities; or cases in which ejido authorities approved the sale of the same plot multiple times.[34]

---

other scheme not prohibited by law (Article 79); and transferring the domain of communal lands to mercantile or civil organizations in way that ejido members participate in the project (Article 75). In none of these schemes, landholders give up their ejido rights.

[31] According to the 2002 National Rural Households of Mexico Survey (ENHRUM), the average cotton parcel had a size of 14 hectares, rice 2.5 ha, coffee 1.2 ha, sugarcane 4.2 ha, barley and oats 3.2 ha, beans 1.9 ha, vegetables 1.6 ha, corn 1.9 ha, orange 1.7 ha, sorghum, 3.7 ha, soybeans 8 ha, tobacco 1.5 ha and wheat 1.7 ha.

[32] PROCEDE operated from 1993 through 2006, when it closed having certified 95% of communal lands. After PROCEDE, the government implemented the Agrarian Organization Program (FOMAR) and the Support Fund for Agrarian Nuclei without Regularization (FANAR). FOMAR focuses on mediating conflicts that had prevented certification under PROCEDE. FANAR assists uncertified communal lands seeking to regularize their situation. See Appendini (2010).

[33] Article 80 of the Agrarian Law grants landholders the right to sell their land to fellow ejido members or residents of the community where the ejido locates without the approval of the ejido assembly, although this article does preserve the right of first refusal to the spouse, concubine and the children of the seller.

[34] An additional factor that came up recurrently in our interviews that might curb the operation of the land market is the culture of attachment to farmlands. Elizondo Mayer-Serra (2011) also reckons that the unawareness by ejido members about the process to change the tenure of their lands could be helping to keep land out of the market.

A third factor that hampers the operation of the land market is the fact that, besides tobacco, sugarcane is the only crop that allows producers and their economic dependents access social security—health care and the right to a pension—under the mandatory scheme of the Mexican Social Security Institute, IMSS (Articles 12 and 236 of the Social Security Law).[35, 36] To receive social security benefits, sugarcane producers must pay their contributions to IMSS and maintain their status as sugarcane farmers regardless of the size of their parcel (laborers are also eligible during harvest). This feature of the sugarcane sector hampers the operation of the land market because it provides incentives for producers to retain some or all of their land and thus their status as sugarcane farmers. It can even be argued that this distinction of the cane sector encourages a greater fragmentation of land plots because: (a) sugarcane producers would seek that their descendants also have access to social security, which may be achieved by subdividing the land; or (b) if a farmer decides to switch crops, she has incentives to keep a swath of land producing sugarcane.

IV.C Payment system for sugarcane

Sugarcane is a crop that is paid according to the procedure established in the Law for the Sustainable Development of Sugarcane (LDSCA), which we describe in more detail in Appendix A5. Although the LDSCA contemplates the payment for sugarcane based on uniform quality as well as on individual or group quality (Art. 62 of the LDSCA), one of our interviewees from the sugarcane producer union asserted that this crop is mostly paid based on uniform quality.[37] In this context, it can be argued that the system governing payments for sugarcane creates perverse incentives that encourage free-riding among sugarcane farmers. This is because the formula does not allow them to fully appropriate the profits generated by their efforts to improve the quality of their crop. Instead, these benefits are distributed among all providers as the average quality of all cane received by the mill improves (Pérez Zamorano, 2007). According to this reasoning, the system governing the payment for sugarcane has negative effects on cane quality since it discourages

[35] The Social Security Law establishes two schemes for social security, one mandatory and another voluntary (Art. 6). Although both schemes provide the same benefits, the mandatory scheme has priority over the voluntary one. For example, some benefits under the voluntary scheme do not proceed when they could compromise IMSS's financial standing, or the effectiveness of services provided under the mandatory scheme (Art. 226); or IMSS is allowed to establish waiting periods for the enjoyment of in-kind benefits for sickness and maternity (Art. 225). Producers of crops other than tobacco and sugarcane can only enroll under the voluntary scheme.

[36] As explained by Pérez Zamorano (2007), the collection of contributions to IMSS is done by sugarcane producers' organizations or sugar mills by deducting from suppliers' final payment for the cane delivered to the mill. This represents 25% of the contribution of producers to IMSS. The rest is paid by the mill (50%) and the government (25%). Within the Special Concurrent Program (PEC) of the federal government's budget, Branch 19 earmarks resources to subsidize sugarcane producers' social security contributions. This subsidy is not available to growers of any other crop.

[37] Prior to the LDSCA (enacted in 2005), the uniform payment for cane had been implemented under the decree declaring of public interest the planting, growing, harvesting and industrialization of sugarcane, published in the Official Gazette of the Federation on May 31, 1991, Articles 11-13.

sugarcane producers to seek mechanisms to improve their crop.[38] We now subject this conjecture to empirical tests examining the relationship between the number of providers and the average quality of the cane received by mills (measured by the concentration of sucrose). Evidence in favor of this hypothesis would be observed through a negative association between these variables.

Figure 11 provides a first illustration of the nonlinear association between the number of cane providers and the quality of sugarcane, which is confirmed by the non-parametric regression shown in Figure 12. A simple way to evaluate econometrically the relationship that takes into account the nonlinearity of the relationship suggested in Figure 12 is by estimating different specifications of the following fourth-degree polynomial:

$$sucrose\ content_{ist} = c + \sum_{k=1}^{4} \beta_k (cane\ providers_{ist})^k + X'_{ist}\delta + \varphi_t + \varphi_s + u_{ist}, \quad (2)$$

where $sucrose\ content_{ist}$ denotes the concentration of sucrose contained in the sugarcane harvested by providers of sugar mill i located in the state s during the cycle $t =$ 2000/01,..., 2010/11; c is a constant; $cane\ providers_{ist}$ is the number of cane providers of mill i; X_{ist} is a vector of control variables; φ_t and φ_s represent cycle and state fixed effects, respectively; and u_{ist} is the error term. The conjecture would imply that $\beta_1 < 0$ and $\beta_2 = \beta_3 = \beta_4 = 0$.[39]

Table 7 displays the results of the regressions. Panel A presents the estimates of the model that only includes the linear term of the variable $cane\ providers$, while Panel B shows the estimates of the fourth-degree polynomial. Panel C shows the controls included in each specification; for example, the cycle and state fixed effects were included in the estimates shown in columns (A2) and (B2).

Column (A1) provides evidence of a positive correlation between the number of cane providers and the cane quality, which is preserved against the inclusion of the fixed effects, as shown in column (A2). Under these first two specifications, we can reject the null hypothesis $\beta_1 < 0$ with a confidence of at least 97%. However, the relationship loses its statistical significance when controlling for mill administration, rainfall, and amount of cane obtained per hectare (column (A3)). Under this specification, we continue to reject the null hypothesis at a 94% confidence level. The next two columns show that the association between sugarcane suppliers and cane quality is not robust to the inclusion of controls on the availability of irrigation, fertilizer application, mechanical lifting, vehicles, and

[38] IMCO (2007) argues that since the payment for cane is defined by the volume of individual amounts and the quality of all cane received by the mill, providers have incentives to add materials (e.g., rocks) that increase the weight of their load and thus their payment.

[39] For similar reasons to the situation we face with equation (1), equation (2) excludes sugar mill fixed effects to avoid the problem of not being able to identify the coefficients of interest, as the key variable, the number of sugarcane providers, does not exhibit enough variation over the time.

cane cutters (column (A4)); and mechanical harvesting (column (A5)). In these last two cases, we cannot reject the null hypothesis at conventional confidence levels, but it is not possible to reject the alternative hypothesis $\beta_1 \geq 0$ either. Thus, the results reported in Panel A lead us to conclude that the evidence does not support the conjecture that a larger number of cane providers will always be associated with a lower quality of sugarcane received by sugarcane mills.

Panel B shows that the fourth-degree polynomial has greater explanatory power than the model that only includes the linear term. As shown in columns (B1) through (B5), estimates of the polynomial coefficients maintain their statistical significance across all specifications. Similarly, p-values derived from a likelihood ratio test and a heteroskedasticity-adjusted Wald test allow us to reject at a 99% confidence level the null hypothesis $\beta_2 = \beta_3 = \beta_4 = 0$.[40] We use the estimates to calculate the critical points at which the direction of the relationship changes. (See Figure 13 to facilitate the understanding of the following description.) Our calculations indicate that a larger number of cane suppliers will be associated with higher cane quality insofar as the number of providers is less than about 2,500. The relationship becomes negative when the number of cane providers exceeds 2,500, reversing again when the number of suppliers exceeds approximately 4,000. From this point, and up to about 6,800, once again a larger number of sugarcane suppliers is associated with a higher concentration of sucrose. The last segment of the relationship, observed from 6,800 suppliers and on, indicates a negative correlation between the number of sugarcane growers and the crop's quality.

Summing up, we do not find strong evidence in support of the notion that the formula defining the payment for sugarcane dissuades farmers from finding ways to increase cane quality.

V Productivity of sugar mills

The processing of sugarcane into sugar is carried out by sugar mills. As shown in Figure 13, their productivity—measured by the efficiency and yield of factories—has remained relatively stable over the 2000/01-2010/11 period, showing a slight upward trend (excluding the 2009/10 harvest) in the most recent cycles. In the case of factory efficiency, the difference between its maximum and minimum is 1.3 percentage points; the yield of factories has a range of 0.9 percentage points. Both indicators hit their minimum in 2006/07 and peaked during the last triennium.

[40] The results of regressions weighted by sugarcane or sugar production show that the significant estimates reported in Panel A (columns (A1) and (A2)) are not robust to the use of weights. This contrasts with the results shown in Panel B, which hold in weighted regressions.

Internationally, the factory yield recorded in the 2010/11 cycle puts Mexico in seventh place among the leading producers of sugarcane (see Figure 14). [41]

In this section we study the relationship between factory efficiency and various potential drivers. Our focus lies in the administration (public or private) of sugar mills and the efficiency with which they generate different sugar products, specifically alcohol and electric power.

Our analysis is based on the estimation of different variants of the equation

$$\begin{aligned} factory\ efficiency_{it} = c &+ \beta_1(sugar\ mill\ admin.)_{it} \\ &+ \beta_2(electricity\ generation)_{it} \\ &+ \beta_3(alcohol\ production\ )_{it} \\ &+ X_{it}'\delta + \varphi_i + \varphi_t + u_{it}, \qquad (3) \end{aligned}$$

where $factory\ efficiency_{it}$ represents the efficiency of sugar mill i during the cycle $t = 2000/01,..., 2010/11$; c is a constant; $sugar\ mill\ admin._{it}$ denotes ownership (public or private) of sugar mill; $electricity\ generation_{it}$ and $alcohol\ production_{it}$ indicate the production of electricity and alcohol obtained per ton of cane; X_{it} is a vector of controls; φ_i and φ_t represent mill and cycle fixed effects, respectively; and u_{it} is the residual. We estimate various specifications in which the variables of interest are included separately or simultaneously, while the control variables and fixed effects are introduced gradually.

Table 8 shows the results of the econometric exercise. The first three columns are the estimates of our simplest specifications that only include (apart from a constant) each of the variables of interest separately. We note that neither the administration of mills nor the production of alcohol have a significant impact on factory efficiency. Instead, the generation of electricity displays (prima facie) a significant negative association with factory efficiency. Column (4) confirms the previous results in a specification that includes simultaneously the three variables of interest. Columns (5) through (8) extend the specifications estimated in the first four columns introducing the mill and cycle fixed effects, and find that the results from columns (1)-(4) are robust to the inclusion of fixed effects.

Next, we proceed with the introduction of control variables. A first control group comprises the fraction of lost work time due to different circumstances. Column (9) shows that under this specification the aforementioned results are preserved, namely, only the generation of electricity holds a statistically significant relationship with factory efficiency. Moreover, our estimates indicate that mills with greater periods of lost time exhibit lower efficiency, being the downtime

[41] No data are available to make an international comparison on the factory efficiency gauge.

attributed to factory and festivities especially harmful for the productivity of mills. The magnitude of these associations is nonetheless small; for instance, a coefficient of -0.2 implies that an increase in lost time by one percentage point (a substantial increase considering that the average loss for factory issues is almost 10%) is associated with a 0.2 percentage point drop in factory efficiency, a tiny fraction of the 82% average.

The negative correlation of electricity generation with factory efficiency may seem surprising since it is intuitive to think that those mills that are capable of generating greater amounts of electricity per ton of sugarcane should also be capable of extracting sugar more efficiently. However, one can think that the negative relationship could be capturing mills' need for electric energy—which produce their own electricity—in a way that mills with higher energy requirements tend to be less productive because they have worse or even obsolete equipment. To test this hypothesis we include mills' energy consumption controls (electricity, oil, and steam) per ton of industrialized cane. The results presented in column (10) give empirical support to our hypothesis. Sugar mills with higher energy requirements show lower levels of factory efficiency. Controlling for the energy consumption, the coefficient β_2 reverses its direction, indicating that mills with a greater capacity to generate electricity exhibit higher productivity in the manufacturing of sugar. The magnitude of the coefficient is nontrivial: mills that are able to increase their productivity in generating electricity by 10% tend to have higher factory efficiency by 4%, on average.

Finally, we include simultaneously the full battery of controls. The estimates reported in column (11) show that under our most complete specification the main results described above are maintained, which we now summarize.[42] First, neither the public or private administration of mills, nor their ability to produce alcohol, seem to have an impact on their productivity. Second, having controlled for operating consumption of electricity, mills that generate electricity more efficiently also tend to transform sucrose into sugar at higher rates. And third, less efficient mills tend to have heftier losses of time and greater energy consumption.

VI Conclusions

Despite the importance of the sugar industry in Mexico, and the number of people that depend on it, this industry has structural features that potentially inhibit greater competitiveness. In interviews we held with various stakeholders in the sugar industry, most of our interviewees cited the atomization of sugarcane farms

[42] Regressions weighted by sugar production offer very similar results.

as one of the most pernicious obstacles to the development of the sector. This under the argument that small landholdings are unable to generate economies of scale that render the investment in production inputs profitable. In turn, the lack of inputs erodes the capacity of farms to produce a greater volume of high quality of the industry's basic crop, sugarcane. This research provides empirical support for the view that—starting at approximately 8 hectares—larger parcels tend to be more productive. This result is complemented by the finding that small farms also tend to have high yields compared to medium-sized plots. The evidence we have presented suggests that this non-monotonic relationship between farm size and productivity stems from a more intensive use of inputs in both smaller and larger farms. However, further research is still needed to advance our understanding of the relationship between the size of sugarcane plots and their productivity. In particular, the more intensive use of inputs in small plots is an issue that deserves deeper analysis.

This study, furthermore, provides evidence to suggest incentive schemes meant to encourage investment by mills in equipment, which may increase their yields in the production of sugar.

It is be valuable to conduct studies with a scope similar to this research in order to assess whether the structural features identified here are also observed in other agricultural sectors. These studies would help achieve a better understanding of the institutional components of the price formation of products that are relevant for inflation dynamics, and would provide guidance for the design of public policies aimed at enhancing the competitiveness of the Mexican agricultural industry.

References

Ahmad, Munir and Sarfaz Khan Qureshi, 1999, "Recent Evidence on Farm Size and Land Productivity: Implications for Public Policy," *The Pakistan Development Review*, 38(4): 1135-1153.

Appendini, Kirsten, 2010, "La Regularización de la Tierra después de 1992: La \`Apropiación´ Campesina de PROCEDE," en *Los Grandes Problemas de México Vol. XI: Economía Rural*, editado por Antonio Yúnez Naude, El Colegio de México.

Artís Espriu, Gloria, 1997, "Minifundio y Fraccionamiento de la Tierra Ejidal Parcelada," *Estudios Agrarios*, 3(8): 11-31.

Bardhan, Pranab, 1973, "Size, Productivity, and Returns to Scale: An Analysis of Farm-Level Data in Indian Agriculture," *Journal of Political Economy*, 81(6): 1370-1386.

Bhalla, S. S. and Roy, P., 1988, "Misspecification in Farm Productivity Analysis: The Role of Land Quality," *Oxford Economic Papers*, 40(1): 55-73.

Carter, M. R., 1984, "Identification of the Inverse Relationship between Farm Size and Productivity: An Empirical Analysis of Peasant Agricultural Production," *Oxford Economic Papers*, 36(1): 131-145.

CEMA, 2002, *Manual Azucarero Mexicano 2002*, México, D.F.

CEMA, 2003, *Manual Azucarero Mexicano 2003*, México, D.F.

CEMA, 2004, *Manual Azucarero Mexicano 2004*, México, D.F.

CEMA, 2005, *Manual Azucarero Mexicano 2005*, México, D.F.

CEMA, 2006, *Manual Azucarero Mexicano 2006*, México, D.F.

CEMA, 2007, *Manual Azucarero Mexicano 2007*, México, D.F.

CEMA, 2008, *Manual Azucarero Mexicano 2008*, México, D.F.

CEMA, 2009, *Manual Azucarero Mexicano 2009*, México, D.F.

CEMA, 2010, *Manual Azucarero Mexicano 2010*, México, D.F.

CEMA, 2011, *Manual Azucarero Mexicano 2011*, México, D.F.

CEMA, 2012, *Manual Azucarero Mexicano 2012*, México, D.F.

CEFP, 2005, *El Impacto de las Importaciones de Fructosa en la Industria Azucarera*, Cámara de Diputados.

Chen, Zhou, Wallace Huffman and Scott Rozelle, 2011, "Inverse Relationship between Productivity and Farm Size: The Case of China," *Contemporary Economic Policy*, 29(4): 580-592.

Cornia, G.A., 1985, "Farm Size, Land Yields and the Agricultural Production Function: An Analysis for Fifteen Developing Countries," *World Development*, 13(4): 513-534.

Fan, Shengen, and Chan-Kang Connie, 2005, "Is Small Beautiful? Farm Size, Productivity, and Poverty in Asian Agriculture," *Agricultural Economics*, 32(1): 135-146.

FAO, 2012, *Sistema de Información de los Recursos del Pienso*, disponible en: http://www.fao.org/ag/AGA/AGAP/FRG/AFRIS/espanol/Document/tfeed8/Data/474.HTM

Fernández y Fernández, Ramón, 1946, "Problemas Creados por la Reforma Agraria en México," *El Trimestre Económico*, 13(3): 463-494.

FIRA, 2009, *Competitividad de la Industria del Azúcar en México,* México, D.F.

FIRA, 2010, *Producción Sostenible de Caña de Azúcar en México*, México, D.F.

FIRA, 2011, *Panorama Agroalimentario: Azúcar 2011/12*, México, D.F.

Helfand, Steven and Edward Levine, 2004, "Farm size and the determinants of productive efficiency in the Brazilian Center-West," *Agricultural Economics*, 31(2-3): 241-249.

Heltberg, Rasmus, 1998, "Rural Market Imperfections and the Farm Size-Productivity Relationship: Evidence from Pakistan," *World Development*, 26(10):1807-1826.

Elizondo Mayer-Serra, Carlos, 2011, *Por Eso Estamos Como Estamos: La Economía Política de un Crecimiento Mediocre*, Editorial Debate.

IMCO, 2007, *The Integration of the North-American Sugar Market: Consequences for Mexican Producers and Consumers*, Mimeo.

Kagin, Justin, J. Edward Taylor and Antonio Yúnez Naude, 2012, "Inverse Productivity or Inverse Efficiency? Evidence from Mexico," Mimeo.

Koo, Won and Richard Taylor, 2011, "2011 Outlook of the U.S. and World Sugar Markets, 2010-2020," Agribusiness & Applied Economics Report 679.

OCDE, 1997, *Examen de las Políticas Agrícolas de México*, París.

Pérez Zamorano, Abel, 2007, *Tenencia de la Tierra e Industria Azucarera*, Editorial Porrúa.

Pérez Zamorano, Abel, 2011, "Estructura Agraria y Sector Agrícola en México," Mimeo.

SAGARPA, 2007a, *Programa Nacional de la Agroindustria de la Caña de Azúcar 2007-2012*, México, D.F.

SAGARPA, 2007b, *Programa Sectorial de Desarrollo Agropecuario y Pesquero 2007-2012*, México, D.F.

SAGARPA, 2010, *Bases Técnicas para el Fomento a la Producción de Biocombustibles en el País a partir de la Caña de Azúcar*, México, D.F.

Sen, Amartya, 1962, "An Aspect of Indian Agriculture," *Economic Weekly*, 14, 243–246.

Thapa, Sridhar, 2007, "The relationship between farm size and productivity: empirical evidence from the Nepalese mid-hills," documento presentado durante el 106th Seminar of the European Association of Agricultural Economists.

UNC-CNPR, 2010, *Estadísticas de la Agroindustria de la Caña de Azúcar 2001-2010*, México, D.F.

UNC-CNPR, 2011, *Estadísticas de la Agroindustria de la Caña de Azúcar 2002-2011*, México, D.F.

Warman, Arturo, 2003, "La Reforma Agraria Mexicana: Una Visión de Largo Plazo," *Land Reform, Land Settlement and Cooperatives*, 2003/2: 84-94.

Yúnez Naude, Antonio 2010, "Las Políticas Públicas Dirigidas al Sector Rural: El Carácter de las Reformas para el Cambio Estructural," en *Los Grandes Problemas de México Vol. XI: Economía Rural*, editado por Antonio Yúnez Naude, El Colegio de México.

Appendix

A1 High Fructose Corn Syrup

The high fructose corn syrup (HFCS) is a sweetener that is produced from yellow maize. As a lower cost substitute of sugar for the food and soft drink industries, HFCS has gradually entered the Mexican market displacing sugar as an input in these industries. As shown in Figure A1.1, domestic consumption of sweeteners (sugar and fructose) has been increasing steadily from an average of 4.94 million tons per year during 2000-2005 to an average of 5.57 million in 2006-2012. During the first half of the decade, total consumption of sweeteners was dominated by sugar, with the share of fructose reaching a minimum of 2.7% in 2003.[43] In contrast, the second part of the decade was characterized by a substantial growth in the demand for HFCS, which led total consumption of sweeteners to maximum levels despite the reduction in the consumption of sugar. For 2012, fructose consumption amounted to 1.72 million tons, representing 30% of total consumption of sweeteners.

The decision of industrial consumers to replace sugar with HFCS as an input is largely due to the latter's lower cost. Figure A1.2 compares wholesale prices between fructose, standard sugar, and refined sugar. The figure shows that the price of fructose is usually below the price of both types of sugar. Note that the dramatic increase in the demand for HFCS observed between 2009 and 2010 coincides with the sharp uptick in the price of the two types of sugar during the same period.

About three-quarters of HFCS consumed in Mexico comes from overseas. Fructose enters our country duty-free if it comes from the U.S., Canada, Chile or Uruguay as part of the trade agreements that Mexico has signed with these nations. To the rest of the world Mexico applies an ad valorem tariff of 175%.[44] Of the total HFCS that Mexico imports, approximately 80% comes from the U.S.

---

[43] Mexico has tried in the past to curb imports of HFCS. In 1997, Mexico filed a demand promoted by CNIAA accusing the U.S. of dumping. As a result of this, in 1998 SE determined that there was indeed dumping, so it imposed a compensatory duty on imports of high fructose. Meanwhile, U.S. companies that were affected by this policy filed their complaint with the World Trade Organization (WTO). The WTO ruling was in favor of Mexico. Later, in December 2001 Mexican authorities implemented a special tax for the production and services (IEPS) of 20% on soft drinks that were sweetened with products different to sugar. Additionally, in 2002 the ad valorem tariff on fructose was raised to 210% (see CEFP, 2005). These events resulted in a decrease in imports of fructose. U.S. companies filed again a complaint with the WTO. This time the ruling favored them, so in 2007 Mexico was forced to eliminate the IEPS on soft drinks.

[44] Starting on November 24, 2012, the import tariff for the fructose fell from 210% to 175%, and will decrease each January 1st by 25 percentage points until reaching 75% ad valorem in 2017 (see the *Decreto por el que se modifican la Tarifa de la Ley de los Impuestos Generales de Importación y de Exportación y el diverso por el que se modifican diversos aranceles de la Tarifa de la Ley de los Impuestos Generales de Importación y de Exportación, del Decreto por el que se establecen diversos Programas de Promoción Sectorial y de los diversos por los que se establece el esquema de importación a la Franja Fronteriza Norte y Región Fronteriza*, published in DOF on November 23, 2012).

A2 Contribution of sugar to inflation dynamics, 2000-2012

In this appendix, we describe the behavior of sugar prices and their contribution to headline inflation during the 2000-2012 period. We use the incidence of this product as well as the percentage it represents of annual headline inflation recorded in each month during the aforementioned period.[45]

Figure A2.1 shows that prior to the second half of 2006, the impact of sugar on inflation dynamics remained stable and relatively low, averaging 1.4 basis points, which amounts to a 0.28% mean contribution to headline inflation. From the second half of 2006, the contribution of sugar to inflation has increased both in level and volatility. In fact, from July 2006 to December 2012, sugar has contributed on average 2.8 basis points, or 0.69% of overall inflation; indeed, while the incidence of sugar showed a standard deviation of 1.3 units through the first semester of 2006, this measure of volatility rose to 6.83 units thereafter. During this period, there are three episodes in which the contribution of sugar to the dynamics of inflation was particularly high.

The first of them started at the beginning of the second half of 2006, reaching a peak in October of that year when the incidence of sugar reached 9 basis points, or 2% of the annual inflation rate. This behavior coincides with the increase in international commodity prices. Additionally, increases in oil prices led countries such as Brazil and the U.S. to boost ethanol production from crops like sugarcane and yellow corn, a situation that exacerbated the rise of sugar prices worldwide.[46]

The second episode began to form during the second quarter of 2009, attaining an incidence of 19.9 basis points by the end of that year, and contributing 5.2% to inflation in December. This increase was largely due to: (a) a lower production of the sweetener in the 2008/09 and 2009/10 cycles; and (b) the substantial increase in sugar exports to the U.S. that resulted from the elimination in January 2008 of tariffs on sugar trade with that country and the exchange rate depreciation recorded at the end of the same year.[47] The rise in international prices of many commodities can also be cited as a factor that contributed to the increase in sugar prices in Mexico.

The most recent episode occurred during the last quarter of 2011, when sugar reached an incidence of 3.7 basis points in December and a contribution of 1% to headline inflation in November. This increase in prices is mainly explained by the following two supply shocks. First, the weather conditions that delayed the start of the 2011/12 harvest (cumulative production by the end of 2011 exhibited a

[45] Incidence refers to the percentage point contribution of each component of the CPI to general inflation. This is calculated using the weights of each generic good/service, relative prices and their respective annual percentage changes.
[46] Martínez, Verónica, 2006, "Reconoce SAGARPA Escasez de Azúcar," *Reforma,* September 20.
[47] Official Gazette of the Federation, *Acuerdo por el que se da a conocer el cupo y mecanismo de asignación para importar azúcar en 2009*, published on August 6, 2009.

decrease of 31% relative to the same period of the previous year). And second, a significant increase in sugar exports (by November exports had registered an annual increase of 55%).[48]

A3 Relationship between quantity and quality of sugarcane

In this appendix, we document the positive association between the amount (volume of cane per hectare) and quality (sugar content) of sugarcane harvested in Mexico. Figure A3.1 illustrates the relationship between these two variables for the 2009/10 and 2010/11 cycles. As one can observe, sugarcane providers to the mills Atencingo, Casasano La Abeja, and Emiliano Zapata produced large volumes of high quality cane per hectare. This contrasts with the less productive supply of bad quality cane to mills Aaron Saenz, Los Mochis, and San Francisco El Naranjal.

In order to establish econometrically the correlation between the quantity and quality of cane, we estimate equation

$$sucrose\ content_{it} = c + \beta(cane_{it}) + X_{it}'\delta + \varphi_i + \varphi_t + u_{it}, \qquad \text{(A3.1)}$$

where $sucrose\ content_{it}$ represents the sucrose concentration (expressed in percentage points) of the sugarcane industrialized at mill i in cycle $t =$ 2000/01,..., 2010/11; c is a constant; $cane_{it}$ indicates the volume of cane per hectare obtained by cane providers of mill i; X_{it} is a vector of controls that includes data about mills' ownership (public or private), rainfall, irrigation, use of fertilizer, mechanical lifting, vehicles, cutters, and mechanical harvesting; φ_i and φ_t are mill and cycle fixed effects, respectively; and u_{it} is the residual term. The coefficient of interest is β.

Column (1) in Table A3.1 shows that one additional ton per hectare is associated with a higher sucrose content by 0.013 percentage points. Columns (2) to (4) indicate that the inclusion of control variables does not significantly alter the direction, magnitude, or statistical significance of this estimate.[49] The size of the coefficient is small when one considers that for the 2010/11 harvest, cane's sucrose content was 14.1%.

In order to examine further the magnitude of the positive relationship between the quantity and quality of sugarcane, we estimate an equation similar to (A3.1), with the difference that we express both the dependent variable, $sucrose\ content_{it}$, and the regressor of interest, $cane_{it}$, in logarithmic terms; this

[48] Banco de Mexico, Inflation Report October – December 2011, p. 13.

[49] The drop in the number of observations results from the lack of data on the control variables. The empirical strategy remains valid to the extent that the lack of such data is not due to some factor related to the residual term having controlled for the explanatory variables included in (A3.1). We consider this scenario plausible.

empirical strategy allows us to estimate the elasticity between these variables. Columns (5) to (8), which differ from each other for the controls included in the estimation, show an elasticity ranging from 0.05 to 0.06, which implies that a 10% increase in the volume of cane per hectare is associated with an increase of 0.4% to 0.6% in the crop's quality.

A4 Robustness tests applied to equation (1)

In this appendix, we present the results of a battery of robustness tests that we apply to the functional form of equation (1) and the estimates that stem from it. The results of these tests are shown in Table A4.1. In order to facilitate the comparison with the base results, Panel A replicates the key estimates shown in Table 5.

The first test evaluates the quadratic form of equation (1). To do this we estimate the model excluding the quadratic term in order to examine whether the inclusion of this term represents a statistically significant improvement. The results are reported in Panel B. Given that: (a) the critical size of sugarcane plots where the direction of the relationship of interest changes is large relative to the size of most plots, and (b) sucrose yields achieved by the largest parcels do not exceed the yields of the small plots, it is not surprising that for several of our specifications (described in Panel G) the linear term coefficient turns out negative and statistically significant. However, in various specifications where we control for the use of production inputs, the negative linear relationship loses significance (columns (6), (8) and (10)), and even changes direction in a couple of cases (columns (12) and (13)). This is consistent with the argument that the use of some inputs determines the relationship between the size of sugarcane plots and their productivity, such that once we control for the use of these inputs, the size of plots becomes a redundant component of the model.

Panel B also presents the p-values of robust Wald tests performed to assess whether the inclusion of the quadratic term improves significantly the econometric model. The results show that under the specifications without controls for the use of inputs, the inclusion of the quadratic component represents a statistically significant improvement over the model that only considers the linear term. Instead, under the specifications that control for the use of inputs, the inclusion of the quadratic element does not significantly improve the model. In this case, not only does the quadratic term become irrelevant, but in general the size of parcels becomes redundant. This is shown with the p-values of the null hypothesis $\beta_1 = \beta_2 = 0$, which we fail to reject in those specifications that include controls for the use of inputs; i.e., in those specifications where the linear and quadratic terms do not jointly represent a significant improvement over the model that excludes the variable concerning the size of sugarcane plots.

The rest of the robustness tests are alternative ways of estimating equation (1). First, we explore whether the exclusion of outliers alters our basic results. The justification for this exercise arises from the concern that because of their atypical values, some observations may be driving our results. Panel C reports the estimates excluding observations of sugar mill La Primavera (PRI), while Panel D shows the analogous results by excluding the observations of sugar mills La Primavera and El Higo (HIG). The second exercise is to examine whether the use of weights in the estimation of (1) changes our results. The motivation for this exercise comes from the differences in the volumes of sugarcane and sugar that each mill processes and produces, respectively. As an example of a concern that may arise from these differences, one might think that the non-monotonic relationship would disappear if it is the case that the farms that supply the smaller mills (judged by the volume of sugarcane they process and sugar they produce) are the ones located on either extreme of the distribution of plot sizes. In Panels E and F, we present, respectively, the results of the regressions weighted by the volume of industrialized cane and the volume of sugar produced. It can be readily seen in Panels C-F that in all these robustness tests our basic results are preserved: a U-shaped relationship with a critical value of around 8 hectares, which dissipates once we control for the use of inputs.

A5 Formula used to determine the price of sugarcane

According to Chapter II (Articles 57 to 66) of the Law for the Sustainable Development of Sugarcane (LDSCA) and Minutes of the Group for Increased Investment and Employment (November 9, 2010), the payment of cane is carried out in three phases. During the first one, known as pre-settlement, sugarcane providers are paid 80% of the value of net cane delivered to the mill from October through May. This payment is made on the 15th of each month when cane is harvested in the second half of the previous month, and paid on the last day when cane is cut in the first half of the month. These payments are calculated based on the price agreed on by stakeholders for the final adjustment of payments for cane delivered during the previous cycle. This price, which is published in October (i.e., at the beginning of the new harvest) in DOF, is multiplied by the average of the so-called Kilogram of Recoverable Standard Base Sugar (KARBE) extracted per ton of cane recorded throughout the five previous harvests.[50] The pre-settlement price is 57% of that product. Formally, the pre-settlement price can be expressed as

[50] KARBE is a theoretical measure of the amount of sugar that mills are expected to recover per ton of cane based on the characteristics of the cane delivered to the mill and the mill's productivity. According to Article

$$P^{pre}_{cane,t} = 0.57(K_5)P_{ref,t-1},$$

where $P^{pre}_{cane,t}$ denotes the price of sugarcane in the pre-settlement stage of the ongoing cycle; K_5 represents the average KARBE per ton of cane in the five previous harvests; and $P_{ref,t-1}$ is the reference price used for the final adjustment of the preceding cycle.[51]

The second stage is known as final settlement. In this phase, which begins in June, providers are paid 100% of net cane delivered during the ongoing harvest. The reference price of sugar is the weighted average of the price of sugar in the domestic and foreign markets during the ongoing cycle through May. In turn, KARBE is computed from the characteristics of sugarcane delivered to the mill during the harvest. The settlement price corresponds to 57% of the product of KARBE/TCN and reference price of sugar. Formally, the formula can be expressed as

$$P^{sett}_{cane,t} = 0.57\left(\frac{KARBE}{TCN}\right)P_{ref,t},$$

where $P^{sett}_{cane,t}$ is the price used in the settlement phase; $\frac{KARBE}{TCN}$ denotes the kilogram of standard base recoverable sugar obtained per net ton of cane; and $P_{ref,t}$ represents the reference price of sugar that is used countrywide, which is calculated as the weighted average of the domestic wholesale price of standard sugar and the average price of exports in the ongoing cycle. That is,

$$P_{ref,t} = \alpha P_{n,t} + (1-\alpha)P_{ex,t},$$

where $P_{n,t}$ denotes the average wholesale price of standard sugar reported by SNIIM using data collected from 23 supply centers since the start of the cycle

---

62, Section II of the LDSCA, KARBE is calculated taking into account the cane's sucrose content, its juice purity and the fiber in cane, considering a factory efficiency not lower than 82.37%, that is,

$$\frac{KARBE}{TCN} = \frac{\left(\frac{KARBE}{TCB}\right) * TCB}{TCN},$$

where

$$\frac{KARBE}{TCB} = Pol\%C * EBF * FP * FF * \frac{10}{99.40},$$

where $KARBE$ = kilogram of recoverable standard base sugar; TCN = net ton of cane (obtained by deducting from raw cane the weight of trash or foreign material); TCB = ton of raw cane; $Pol\%C$ = percentage of sucrose in cane; EBF = baseline factory efficiency of 82.37%; FP = purity factor of juice taking as benchmark a purity level of 81.23%; FF = fiber content taking as reference a value of 14.21%; and the 10/99.4 factor is used to normalize this gauge to kilograms of Pol from standard basis sugar per ton of raw cane.

[51] According to one of our interviewees from the sugarcane sector, in practice, the payment made in the pre-settlement phase is usually lower than the amount calculated with the formula. This is because sugarcane organizations seek to prevent farmers from having to reimburse money in the final settlement due to a drastic fall in sugar prices.

through May[52]; $P_{ex,t}$ is the average price of exports, equivalent to the average of Contract 16 (price of futures contracts of raw sugar in the U.S. market) plus 6% less 50 dollars if exports are U.S. bound, and the average of Contract 11 (price of futures contracts of crude sugar in the international market) plus 6% less 30 dollars in the case of exports to third countries; and α captures the share of domestic consumption relative to the national production, so $(1-\alpha)$ is equivalent to the fraction of domestic production destined for foreign markets, according to data from the National Sweeteners Balance published by the National Committee for the Sustainable Development of Sugarcane (CONADESUCA).

The third phase of settlement, known as final adjustment begins in October and ends in December of the following harvest. This phase uses the same formula as the settlement stage, with the difference that the information used in the calculations is updated through September, so data reflect the behavior of the entire cycle. This price is published in DOF in October and serves as reference during the pre-settlement phase of the next harvest.

A6 Acronyms

CEFP	Center for the Study of Public Finances (Centro de Estudios de las Finanzas Públicas)
CEMA	Sugar Manual Editing Company (Compañía Editora del Manual Azucarero, S.A. de C.V.)
CNIAA	National Chamber of the Sugar and Alcohol Industries (Cámara Nacional de las Industrias Azucarera y Alcoholera)
CONADESUCA	National Committee for the Sustainable Development of Sugarcane (Comité Nacional para el Desarrollo Sustentable de la Caña de Azúcar)
CONAGUA	National Water Commission (Comisión Nacional del Agua)
DOF	Official Gazette of the Federation (Diario Oficial de la Federación)
ENHRUM	National Rural Households of Mexico Survey (Encuesta Nacional de Hogares Rurales de México)
FANAR	Support Fund for Agrarian Nuclei without Regularization

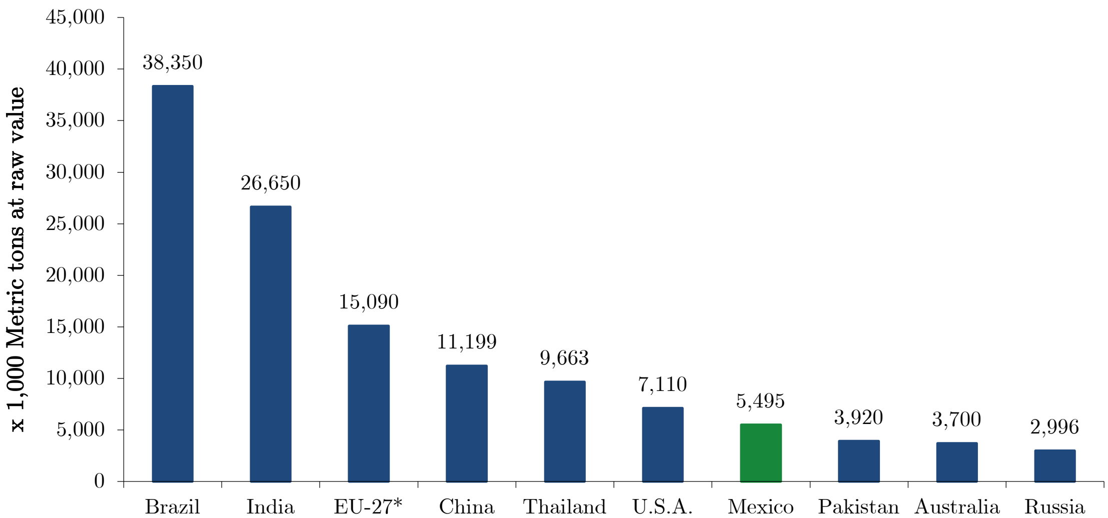
[52] This price is cut by 6.4% and the result is the reference price for the domestic market.

	(Fondo de Apoyo a Núcleos Agrarios sin Regularización)
FAO	Food and Agriculture Organization of the United Nations
FIRA	Trust Funds Related to Agriculture (Fideicomisos Instituidos en Relación con la Agricultura)
FEESA	Fund of Expropriated Companies in the Sugar Sector (Fondo de Empresas Expropiadas del Sector Azucarero)
FOMAR	Agrarian Organization Program (Fomento a la Organización Agraria)
IMCO	Mexican Institute for Competitiveness (Instituto Mexicano para la Competitividad)
INEGI	National Institute of Statistics and Geography (Instituto Nacional de Geografía y Estadística)
INPC	National Consumer Price Index (Índice Nacional de Precios al Consumidor)
INPP	National Producer Price Index (Índice Nacional de Precios al Productor)
HFCS	High Fructose Corn Syrup
KARBE	Kilogram of Recoverable Standard Base Sugar (Kilogramo de Azúcar Recuperable Base Estándar)
LDSCA	Law for the Sustainable Development of Sugarcane (Ley de Desarrollo Sustentable de la Caña de Azúcar)
GDP	Gross Domestic Product
OECD	Organization for Economic Cooperation and Development
PROCEDE	Certification Program of Communal Land Rights (Programa de Certificación de Derechos Ejidales y Titulación de Solares)
SAGARPA	Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación)
SE	Ministry of Economy (Secretaría de Economía)

SIAP	Agrifood and Fishery Information Service (Servicio de Información Agroalimentaria y Pesquera)
SNIIM	National Information and Market Integration System (Sistema Nacional de Información e Integración de Mercados)
UNC-CNPR	National Sugarcane Union of the National Confederation of Rural Growers (Unión Nacional de Cañeros de la Confederación Nacional de Productores Rurales)
USDA	U.S. Department of Agriculture
WTO	World Trade Organization

Figures and tables

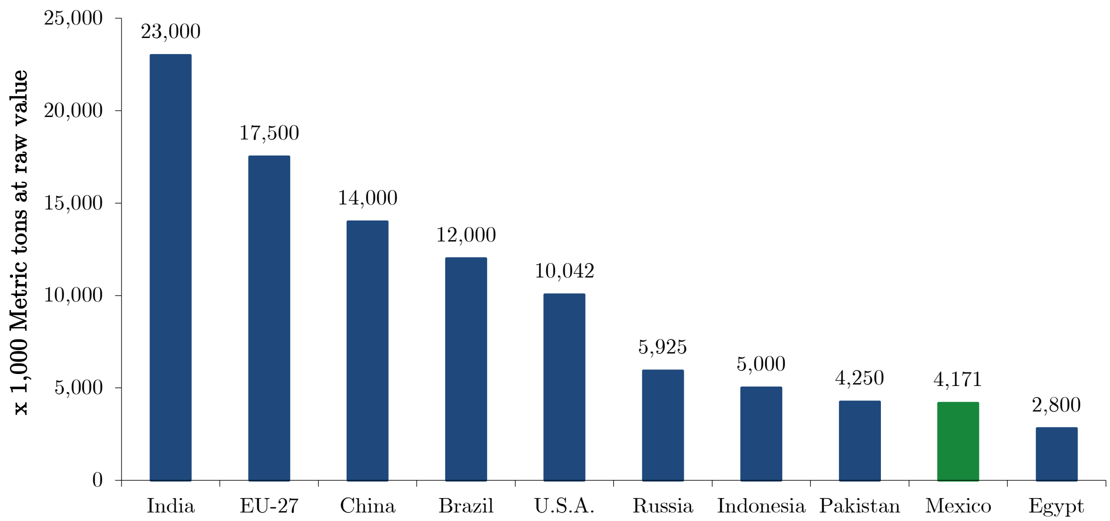
Figure 1. Main producers of centrifugal sugar, cycle 2010/11



Source: USDA.

* EU-27: Germany, Austria, Belgium, Bulgaria, Cyprus, Denmark, Slovakia, Slovenia, Spain, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, UK, Czech Republic, Romania and Sweden.

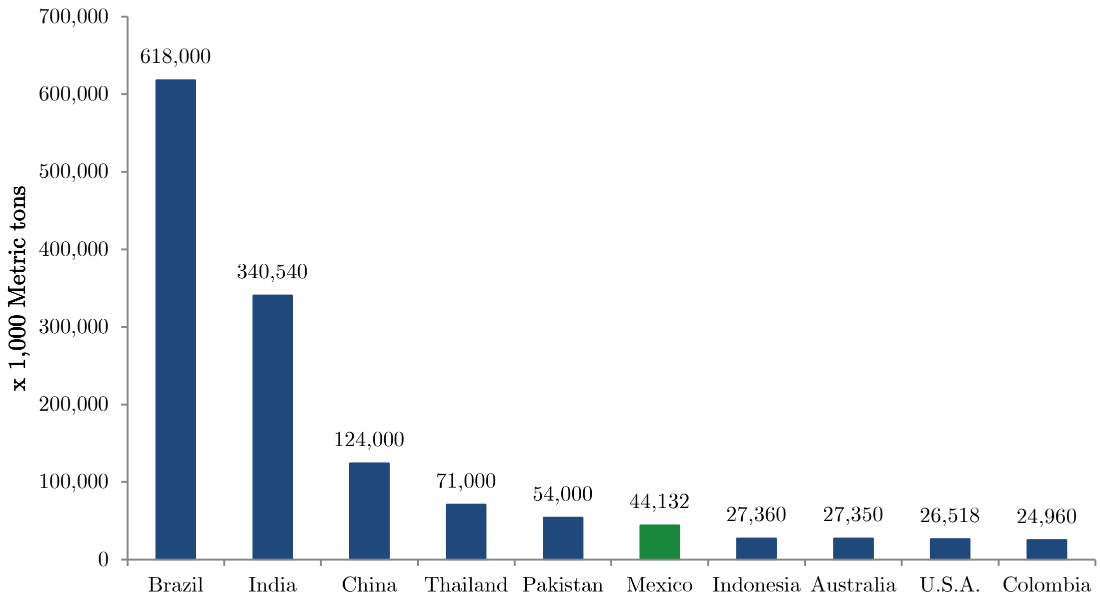
Figure 2. Main consumers of centrifugal sugar for human use, cycle 2010/11



Source: USDA.

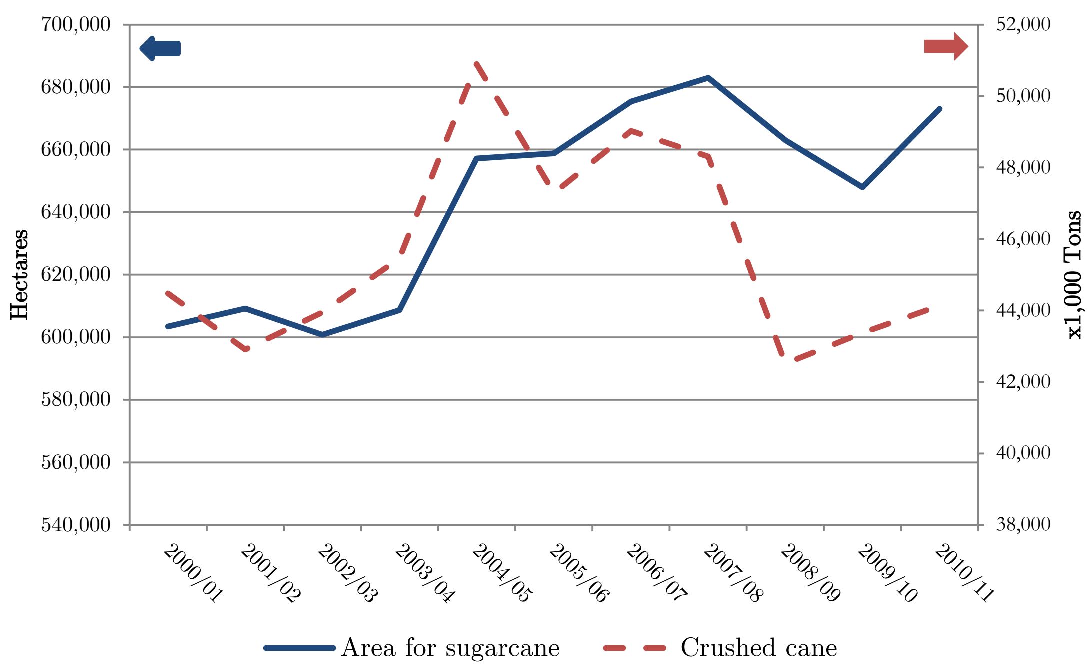
* EU-27: Germany, Austria, Belgium, Bulgaria, Cyprus, Denmark, Slovakia, Slovenia, Spain, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, UK, Czech Republic, Romania and Sweden.

Figure 3. Main producers of sugarcane in 2011



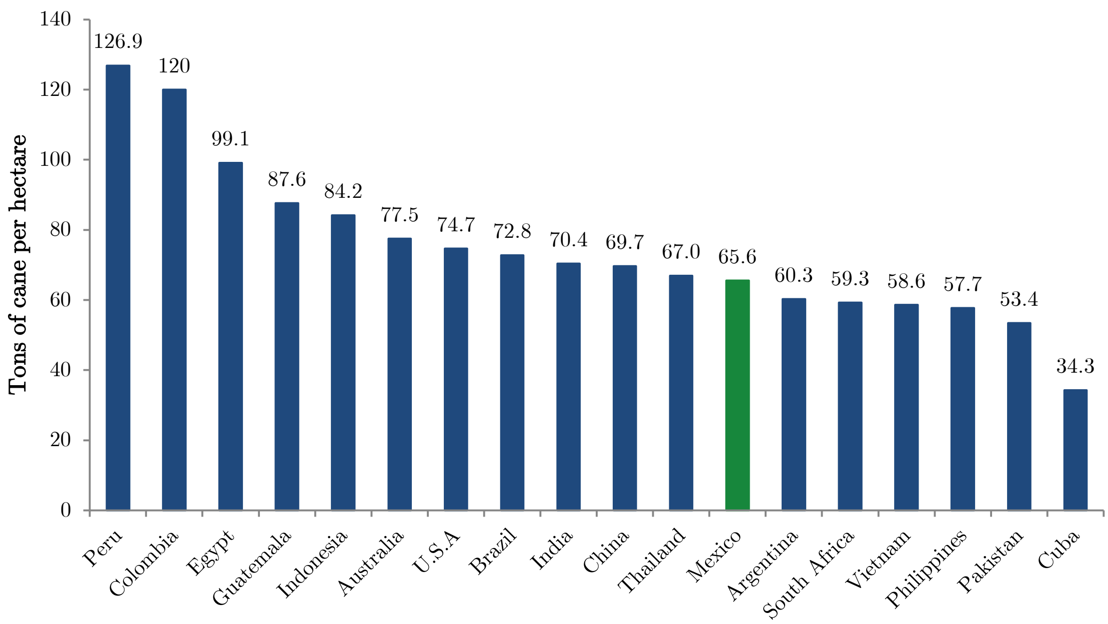
Source: UNC-CNPR (2011) based on USDA data.

Figure 4. Area devoted to sugarcane and production of sugarcane, 2000/01-2010/11



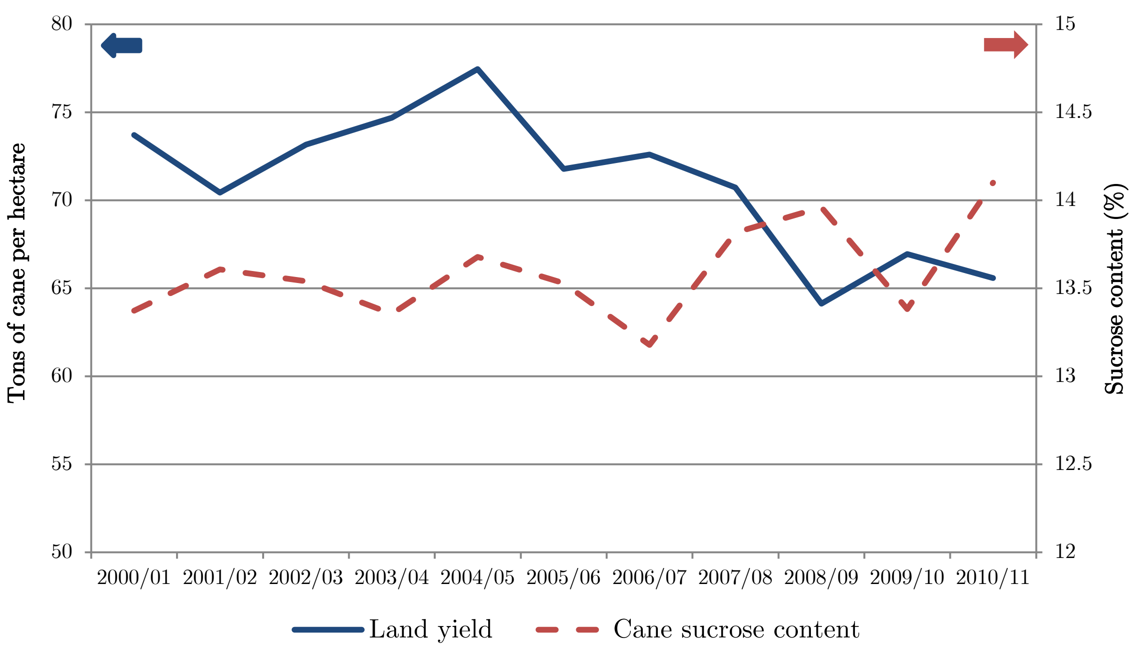
Source: UNC-CNPR (2010, 2011).

Figure 5. International comparison of yields of sugarcane landplots in 2011



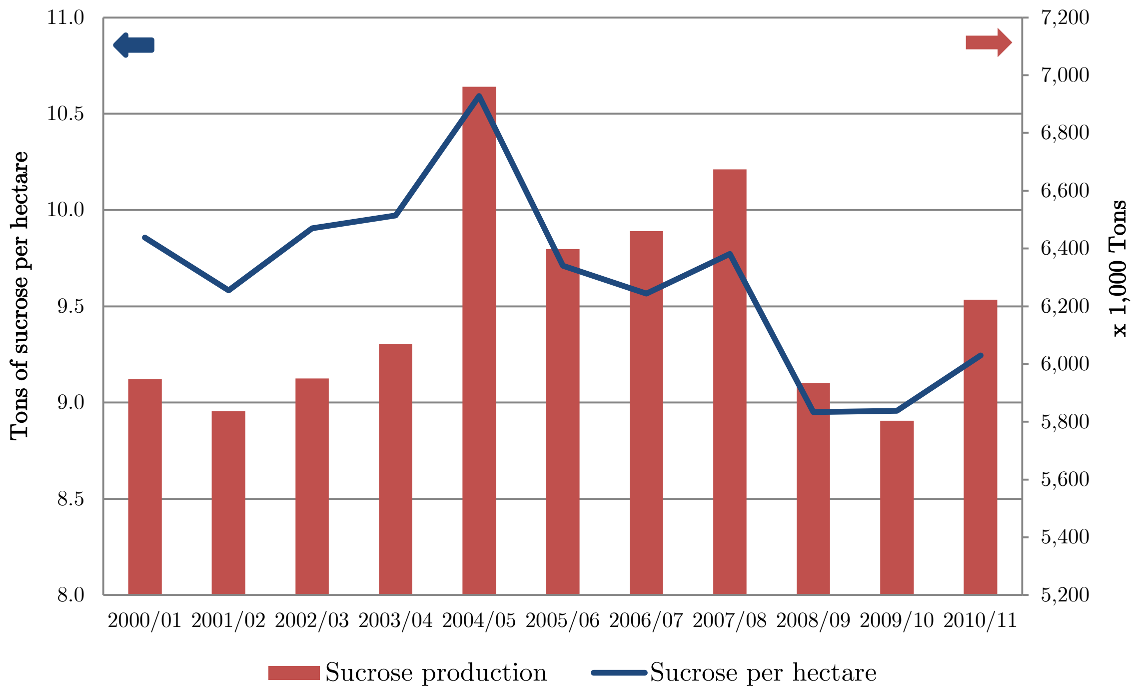
Source: UNC-CNPR (2011) based on USDA data.

Figure 6. Landplot yields and cane sucrose content, 2000/01-2010/11



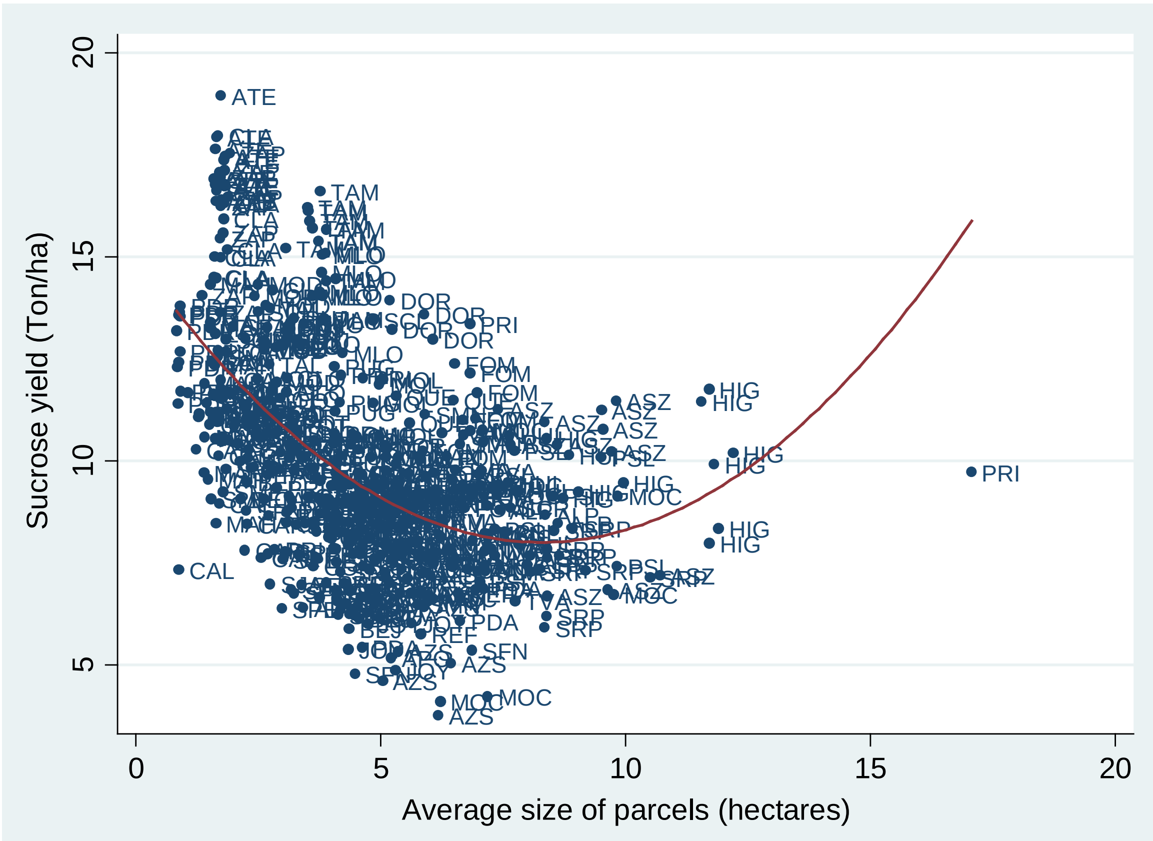
Source: UNC-CNPR (2010, 2011).

Figure 7. Sucrose production, 2000/01-2010/11



Source: UNC-CNPR (2010, 2011).

Figure 8. Size of sugarcane parcels and sucrose yield



The abbreviations correspond to the following mills: ALP-Adolfo López Mateos; APO-Alianza Popular; ASZ-Aarón Sáenz; ATE-Atencingo; AZS-Azsuremex (Tenosique); BEJ-Benito Juárez; BEL-Bellavista; CAL-Calipam; CAR-El Carmen; CLA-Casasano La Abeja; CMO-Central Motzorongo; CON-Constancia; CPR-Central Progreso; CUA-Cuatotolapam (Cía. Industrial Azucarera); DOR-El Dorado; FOM-Fomento Azucarero del Golfo (Zapoapita-Pánuco); GLO-La Gloria; HIG-El Higo; HUI-Huixtla; IND-Independencia; JMM-José María Morelos; JOY-La Joya; LCA-Lázaro Cárdenas; LCO-La Concepción; MAH-Mahuixtlan; MAN-El Mante; MLO-Melchor Ocampo; MOC-Los Mochis; MOD-El Modelo; MOL-El Molino; PAM-Pablo Machado (La Margarita); PDA-Plan de Ayala; PDR-Pedernales; POT-El Potrero; PRI-La Primavera; PRO-La Providencia; PSL-Plan de San Luis; PUG-Puga; PUJ-Pujiltic; QUE-Quesería; REF-El Refugio; SCL-Santa Clara; SCR-San Cristóbal; SDO-Santo Domingo; SFA-San Francisco Ameca; SFN-San Francisco El Naranjal (Nuevo San Francisco); SGA-San Gabriel; SJA-San José de Abajo; SMI-San Miguelito; SMN-San Miguel del Naranjo; SNC-San Nicolás; SPE-San Pedro; SRO-Santa Rosalía; SRP-San Rafael de Pucté; SSE-San Sebastián; TAL-Tala (José Ma. Martínez); TAM-Tamazula; TVA-Tres Valles; ZAP-Emiliano Zapata.

Figure 9. Non-parametric regression of sucrose yield on the size of sugarcane parcels

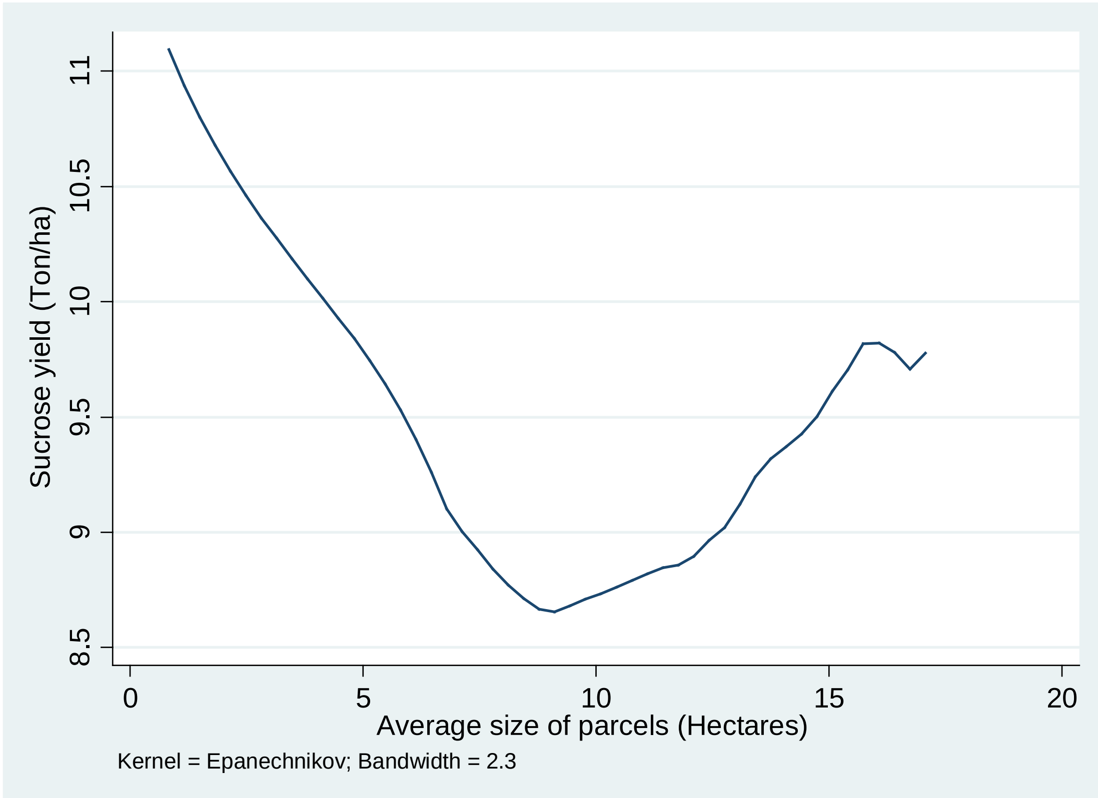
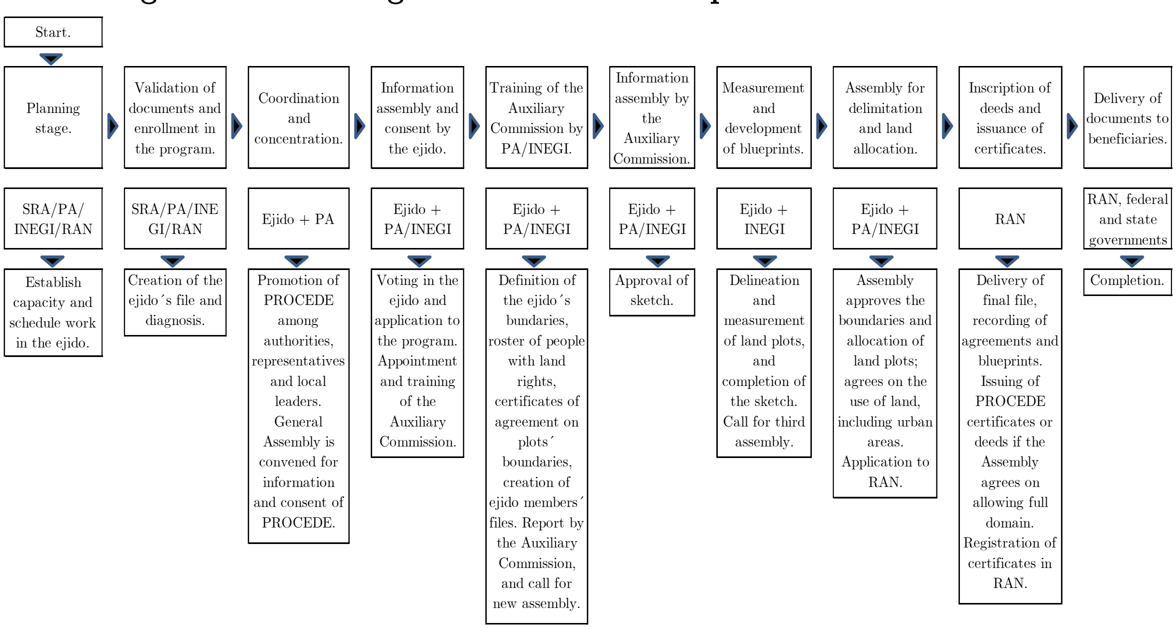


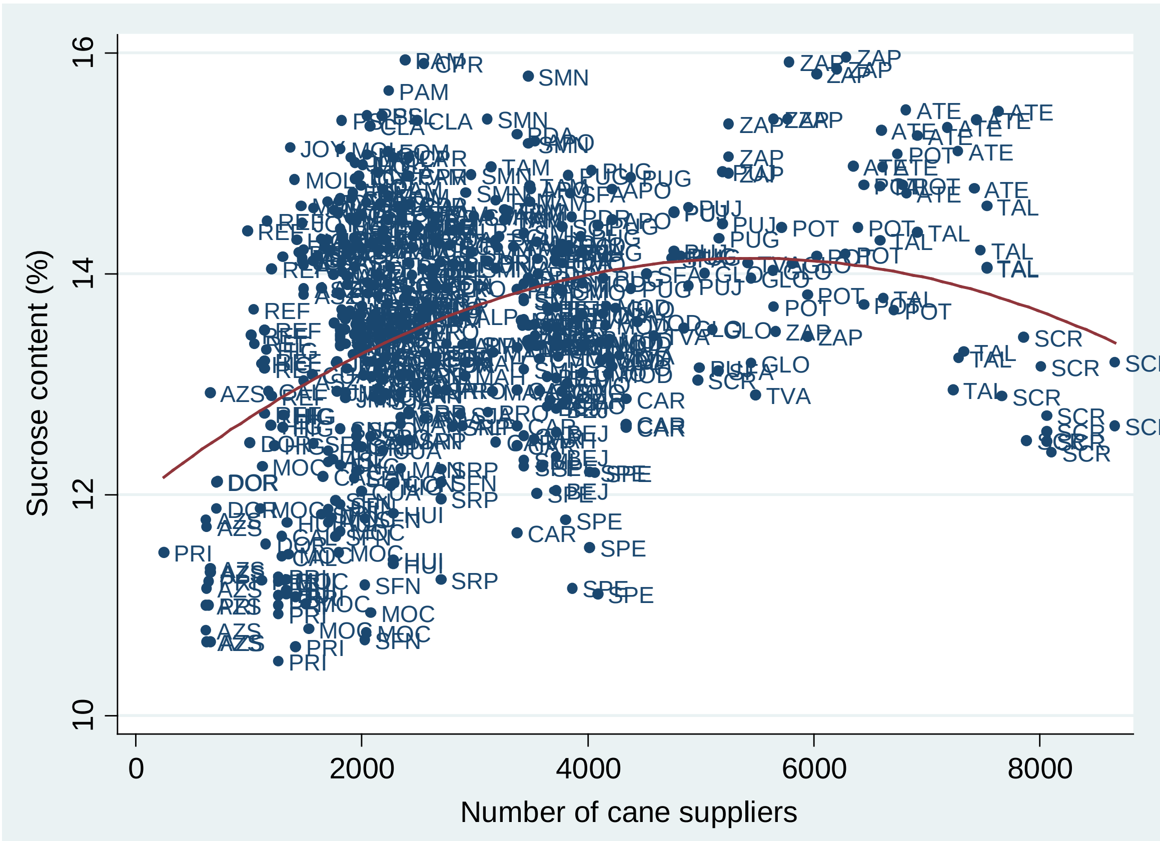
Figure 10. Main stages of the certification process under PROCEDE



PROCEDE - Certification Program of Communal Land Rights
PA - Agrarian Attorney Office
RAN - National Agrarian Registry
SRA - Agrarian Reform Secretariat

Source: Pérez Zamorano (2007, p. 90).

Figure 11. Number of sugarcane providers and cane quality



The abbreviations correspond to the following mills: ALP-Adolfo López Mateos; APO-Alianza Popular; ASZ-Aarón Sáenz; ATE-Atencingo; AZS-Azsuremex (Tenosique); BEJ-Benito Juárez; BEL-Bellavista; CAL-Calipam; CAR-El Carmen; CLA-Casasano La Abeja; CMO-Central Motzorongo; CON-Constancia; CPR-Central Progreso; CUA-Cuatotolapam (Cía. Industrial Azucarera); DOR-El Dorado; FOM-Fomento Azucarero del Golfo (Zapoapita-Pánuco); GLO-La Gloria; HIG-El Higo; HUI-Huixtla; IND-Independencia; JMM-José María Morelos; JOY-La Joya; LCA-Lázaro Cárdenas; LCO-La Concepción; MAH-Mahuixtlan; MAN-El Mante; MLO-Melchor Ocampo; MOC-Los Mochis; MOD-El Modelo; MOL-El Molino; PAM-Pablo Machado (La Margarita); PDA-Plan de Ayala; PDR-Pedernales; POT-El Potrero; PRI-La Primavera; PRO-La Providencia; PSL-Plan de San Luis; PUG-Puga; PUJ-Pujiltic; QUE-Quesería; REF-El Refugio; SCL-Santa Clara; SCR-San Cristóbal; SDO-Santo Domingo; SFA-San Francisco Ameca; SFN-San Francisco El Naranjal (Nuevo San Francisco); SGA-San Gabriel; SJA-San José de Abajo; SMI-San Miguelito; SMN-San Miguel del Naranjo; SNC-San Nicolás; SPE-San Pedro; SRO-Santa Rosalía; SRP-San Rafael de Pucté; SSE-San Sebastián; TAL-Tala (José Ma. Martínez); TAM-Tamazula; TVA-Tres Valles; ZAP-Emiliano Zapata.

Figure 12. Non-parametric regression of cane quality on the number of sugarcane providers

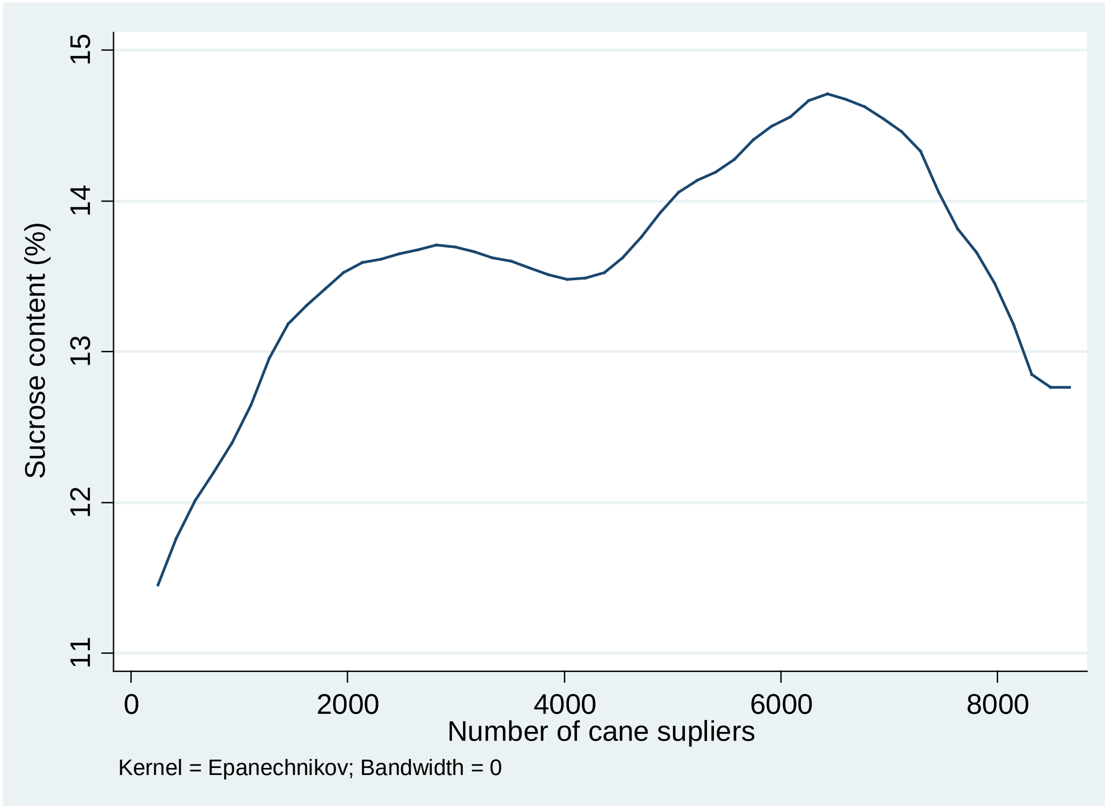
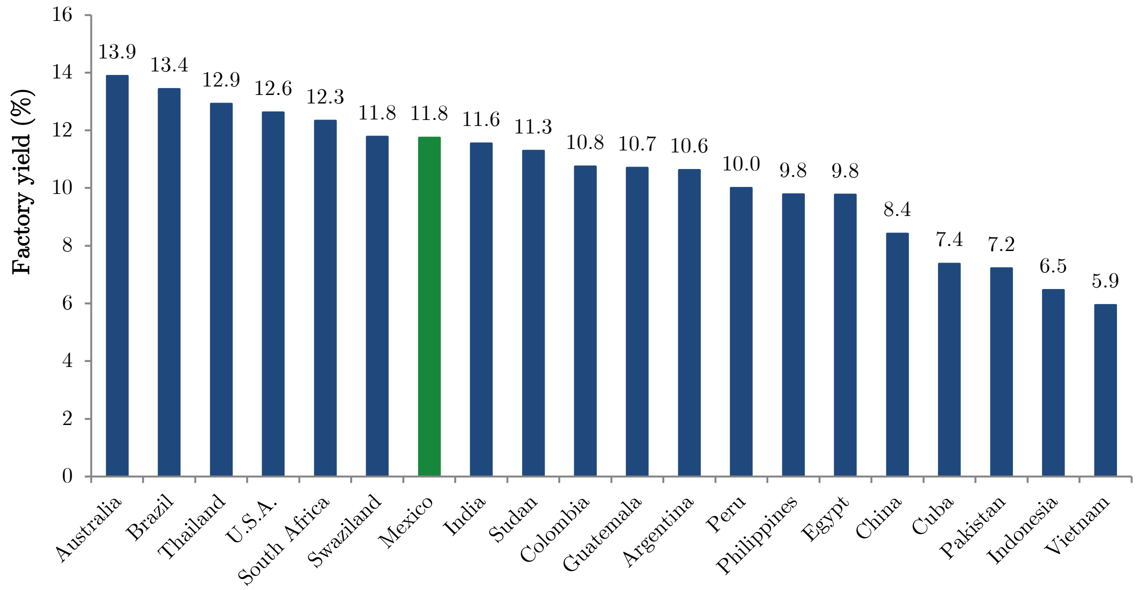


Figure 13. Productivity of sugar mills

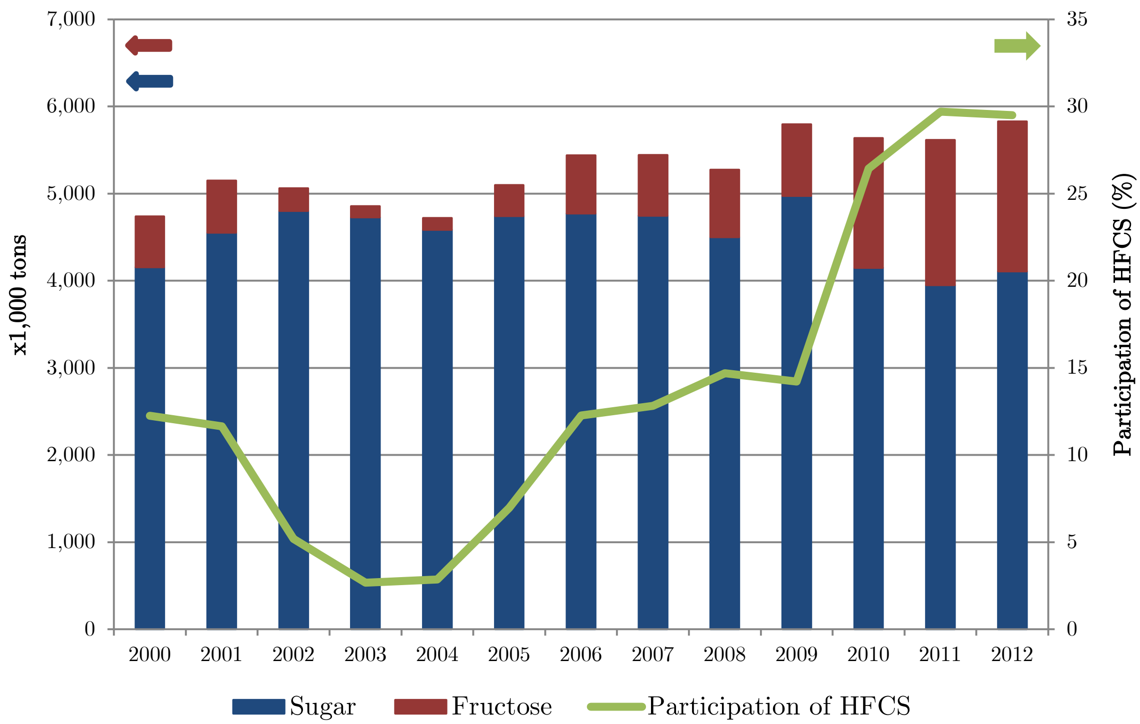
Source: UNC-CNPR (2010, 2011).

Figure 14. International comparison of factory yields in 2011



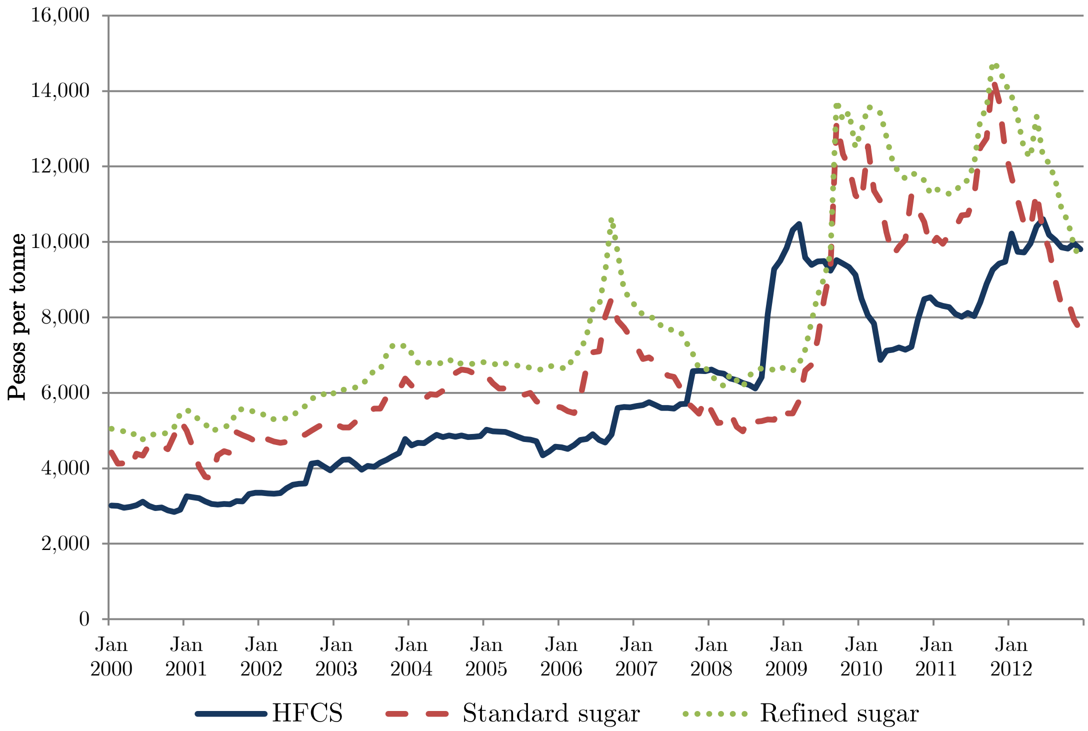
Source: UNC-CNPR (2011) based on USDA data.

Figure A1.1. Consumption of sugar and HFCS in Mexico



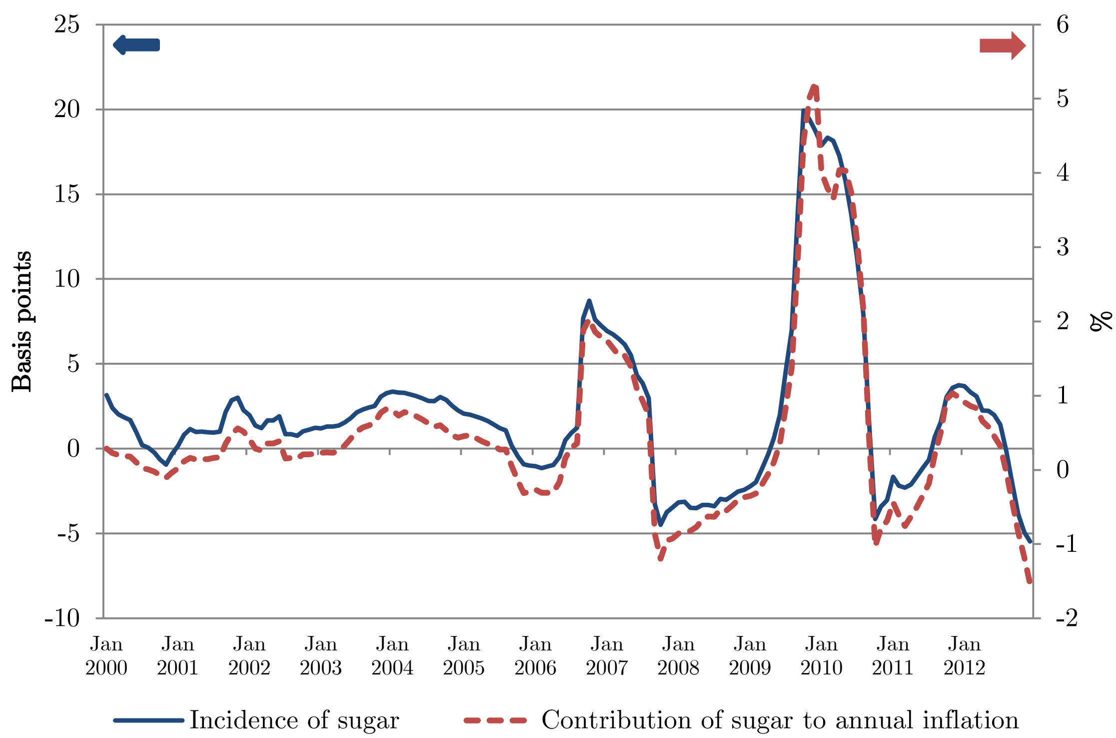
Source: Data through 2008 was obtained from the study entitled "Market Analysis of Sweeteners in Mexico" prepared by Luis Ramiro Garcia Chavez. For data after 2009 we use the data reported in the National Balance of Sugar and Sweeteners prepared by the CONADESUCA.

Figure A1.2. Comparison of wholesale prices of sugar and HFCS



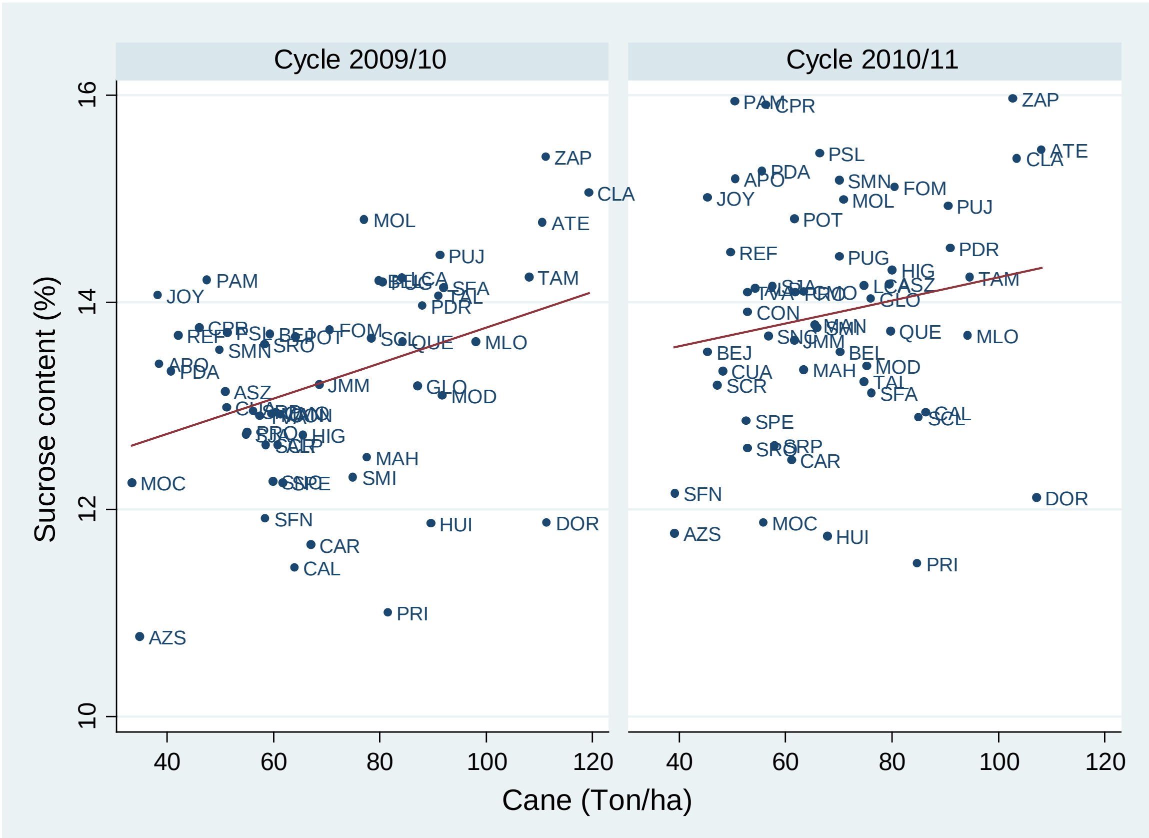
Source: SNIIM and USDA.

Figure A2.1. Contribution of sugar to inflation



Source: Banco de México and INEGI.

Figure A3.1. Quantity and quality of sugarcane, cycles 2009/10 and 2010/11



The abbreviations correspond to the following mills: ALP-Adolfo López Mateos; APO-Alianza Popular; ASZ-Aarón Sáenz; ATE-Atencingo; AZS-Azsuremex (Tenosique); BEJ-Benito Juárez; BEL-Bellavista; CAL-Calipam; CAR-El Carmen; CLA-Casasano La Abeja; CMO-Central Motzorongo; CON-Constancia; CPR-Central Progreso; CUA-Cuatotolapam (Cía. Industrial Azucarera); DOR-El Dorado; FOM-Fomento Azucarero del Golfo (Zapoapita-Pánuco); GLO-La Gloria; HIG-El Higo; HUI-Huixtla; IND-Independencia; JMM-José María Morelos; JOY-La Joya; LCA-Lázaro Cárdenas; LCO-La Concepción; MAH-Mahuixtlan; MAN-El Mante; MLO-Melchor Ocampo; MOC-Los Mochis; MOD-El Modelo; MOL-El Molino; PAM-Pablo Machado (La Margarita); PDA-Plan de Ayala; PDR-Pedernales; POT-El Potrero; PRI-La Primavera; PRO-La Providencia; PSL-Plan de San Luis; PUG-Puga; PUJ-Pujiltic; QUE-Quesería; REF-El Refugio; SCL-Santa Clara; SCR-San Cristóbal; SDO-Santo Domingo; SFA-San Francisco Ameca; SFN-San Francisco El Naranjal (Nuevo San Francisco); SGA-San Gabriel; SJA-San José de Abajo; SMI-San Miguelito; SMN-San Miguel del Naranjo; SNC-San Nicolás; SPE-San Pedro; SRO-Santa Rosalía; SRP-San Rafael de Pucté; SSE-San Sebastián; TAL-Tala (José Ma. Martínez); TAM-Tamazula; TVA-Tres Valles; ZAP-Emiliano Zapata.

Table 1. Production of sugarcane and sugar by state (harvest 2010/11)

State	Mills	Land devoted to sugarcane (Hectares)	Net weight of grinded cane (Tons)	Share of the national cane production (%)	Sugar (Tons)	Share of the national sugar production (%)
Veracruz	19	268,516	15,618,455	36.72	1,892,096	36.50
San Luis Potosí	4	74,299	4,361,525	10.26	576,060	11.11
Jalisco	6	62,941	4,834,359	11.37	571,187	11.02
Oaxaca	3	46,777	2,357,495	5.54	305,765	5.90
Chiapas	2	30,115	2,357,689	5.54	288,573	5.57
Nayarit	2	27,107	1,868,606	4.39	233,053	4.50
Tamaulipas	2	28,320	1,900,592	4.47	231,022	4.46
Morelos	2	15,503	1,596,413	3.75	206,118	3.98
Puebla	2	15,291	1,596,305	3.75	204,923	3.95
Quintana Roo	1	25,723	1,364,920	3.21	153,312	2.96
Tabasco	3	29,081	1,316,025	3.09	140,156	2.70
Sinaloa	3	15,228	1,128,555	2.65	118,142	2.28
Colima	1	12,458	962,807	2.26	113,059	2.18
Michoacán	3	10,791	890,341	2.09	104,832	2.02
Campeche	1	8,514	375,135	0.88	45,202	0.87
Total	54	670,664	42,529,222		5,183,500	

Source: CNIIA.

Table 2. Sugar mills in operation during the 2010/11 cycle

Group/Mill	Production (Tons)	% of national
FEESA	**1,077,032**	**20.78%**
Atencingo	192,400	3.71%
San Cristobal	179,936	3.47%
El Potrero	166,831	3.22%
Emiliano Zapata	145,062	2.80%
Plan de San Luis	136,057	2.62%
El Modelo	79,060	1.53%
La Providencia	77,552	1.50%
Casasano La Abeja	61,056	1.18%
San Miguelito	39,078	0.75%
Beta San Miguel	**702,375**	**13.55%**
San Miguel del Naranjo	206,376	3.98%
San Rafael de Pucte	153,312	2.96%
Queseria	113,059	2.18%
San Francisco Ameca	92,771	1.79%
Constancia	89,192	1.72%
Santa Rosalia de la Chontalpa	47,665	0.92%
Zucarmex	**533,229**	**10.29%**
Pujiltic	199,287	3.84%
El Higo	163,533	3.15%
Melchor Ocampo	93,964	1.81%
Mahuixtlan	42,107	0.81%
La Primavera	34,338	0.66%

Group/Mill	Production (Tons)	% of national
PIASA	**402,864**	**7.77%**
Tres Valles	227,805	4.39%
Adolfo Lopez Mateos	175,059	3.38%
Sáenz Group	**369,850**	**7.14%**
Tamazula	138,828	2.68%
Aaron Saenz	127,506	2.46%
El Mante	103,516	2.00%
Santos Group	**350,583**	**6.76%**
Plan de Ayala	118,167	2.28%
Alianza Popular	115,460	2.23%
Cuatotolapam	47,077	0.91%
Bellavista	35,183	0.68%
Pedernales	34,696	0.67%
Azucarero Mexico Group	**316,512**	**6.11%**
Tala (Jose Maria Martinez)	159,808	3.08%
Benito Juarez	82,009	1.58%
El Dorado	48,478	0.94%
Lazaro Cardenas	26,217	0.51%
La Margarita	**217,837**	**4.20%**
La Margarita	89,013	1.72%
Central Progreso	78,191	1.51%
Jose Maria Morelos	50,633	0.98%

Group/Mill	Production (Tons)	% of national
Porres Group	**200,962**	**3.88%**
Huixtla	89,286	1.72%
San Pedro	67,757	1.31%
Santa Clara	43,919	0.85%
Azucarero del Tropico	**191,606**	**3.70%**
La Gloria	146,404	2.82%
La Joya	45,202	0.87%
Motzorongo Group	**170,674**	**3.29%**
Central Motzorongo	128,980	2.49%
El Refugio	41,694	0.80%
García González Group	**93,381**	**1.80%**
El Carmen	49,212	0.95%
Nuevo San Francisco	31,646	0.61%
Calipam	12,523	0.24%
Independent mills	**556,600**	**10.74%**
Panuco	152,275	2.94%
Puga	140,834	2.72%
El Molino	92,220	1.78%
San Nicolas	72,618	1.40%
San Jose de Abajo	52,845	1.02%
Los Mochis	35,326	0.68%
Azsuremex (Tenosique)	10,482	0.20%

Source: CNIIA.

Table 3. Description of variables

	Unit	Description	Source
Alcohol production	Lts/Ton	Liters of alcohol produced per ton of cane	UNC-CNPR (2010, 2011)
Altitude	MASL	Meters above sea level of the mill	CEMA (2002 to 2012)
Cane	Ton/ha	Tons of sugarcane produced per hectare	UNC-CNPR (2010, 2011)
Cane cutters	People/ha	Number of cane cutters normalized by harvested area	Own elaboration based on data from UNC-CNPR (2010, 2011)
Cane suppliers	People	Number of farmers supplying sugarcane to mills	CEMA (2002 to 2012)
Electricity consumption	kWh/Ton	Electricity consumption per ton of cane mills process	UNC-CNPR (2010, 2011)
Electricity generation	kWh/Ton	Electricity generation per ton of cane	UNC-CNPR (2010, 2011)
Factory efficiency	%	Transformation rate of sucrose into sugar	UNC-CNPR (2010, 2011)
Factory yield	%	Transformation rate of cane into sugar	UNC-CNPR (2010, 2011)
Fertilizer	Kg/ha	First dose of fertilizer per hectare	CEMA (2002 to 2012)
Irrigation	%	Fraction of harvested area with irrigation	CEMA (2002 to 2012)
Lost time factory	%	Fraction of time lost due to factory issues	UNC-CNPR (2010, 2011)
Lost time festivities	%	Fraction of lost time by festivities	UNC-CNPR (2010, 2011)
Lost time field	%	Fraction of time lost in parcels	UNC-CNPR (2010, 2011)
Lost time rain	%	Fraction of time lost due to rain	UNC-CNPR (2010, 2011)
Lost time staff	%	Fraction of time lost due to staff issues	UNC-CNPR (2010, 2011)
Mechanical harvest	%	Fraction of cane cut and lifted mechanically	UNC-CNPR (2010, 2011)
Mechanical lifting	%	Fraction of cane lifted mechanically and laid on trucks that bring it to the mill	UNC-CNPR (2010, 2011)
Mill administration	0=Government; 1=Private	Government or private ownership of the mill	CEMA (2002 to 2012)
Oil consumption	Lts/Ton	Liters of oil used per ton of cane mills process	UNC-CNPR (2010, 2011)

Table 3 (Cont.)

Plot size	ha/Producer	Hectares per sugarcane producer. In other words, average size of sugarcane parcels	Own elaboration based on data from UNC-CNPR (2010, 2011) about harvested area and the number of cane suppliers to each mill obtained from CEMA (2002 to 2012)
Rainfall	Millimeters	Cumulative rainfall during the 18 months before the start of each harvest	Own elaboration based on data from CONAGUA
Steam consumption	Ton/Ton	Tons of steam used per ton of cane mills process	UNC-CNPR (2010, 2011)
Sucrose	Ton/ha	Tons of sucrose produced per hectare	Own elaboration based on data from UNC-CNPR (2010, 2011)
Sucrose content	%	Concentration of sucrose in cane	UNC-CNPR (2010, 2011)
Total lost time	%	Total fraction of lost time	UNC-CNPR (2010, 2011)
Vehicles	Trucks/ha	Number of trucks to transport the cane from parcels to mills normalized by harvested area	Own elaboration based on data from UNC-CNPR (2010, 2011)

Table 4. Descriptive Statistics

	Unit	Cycles 2000/01-2010/11					Cycle 2010/11				
		N	Average	Std. Deviation	Minimum	Maximum	N	Average	Std. Deviation	Minimum	Maximum
Alcohol production	Lts/Ton	594	0.7	2.1	0	15.0	54	0.4	1.4	0	8.2
Altitude	MASL	594	481.9	491.0	3	1359	54	481.9	491.0	3	1359
Cane	Ton/ha	594	74.6	18.6	33.4	124.3	54	68.2	17.6	39.1	108.1
Cane cutters	People/ha	539	0.11	0.05	0.01	0.39	54	0.1	0.1	0.02	0.28
Cane suppliers	People	541	3,012	1,659	246	8,663	54	3,071	1,833	246	8,663
Electricity consumption	kWh/Ton	594	17.3	4.9	0	37.7	54	18.1	4.6	8.9	28.2
Electricity generation	kWh/Ton	594	17.3	4.9	0	37.7	54	18.1	4.6	8.9	28.2
Factory efficiency	%	594	82.3	3.1	64.2	88.4	54	82.5	3.2	72.1	87.9
Factory yield	%	594	11.1	1.1	7.5	13.2	54	11.5	1.1	8.5	13.2
Fertilizer	Kg/ha	553	602.2	137.6	150	1050	51	585.8	148.5	200	1000
Irrigation	%	577	47.9	44.0	0	100	53	48.5	43.9	0	100
Lost time factory	%	594	9.7	5.3	1.2	32.5	54	9.8	5.8	1.2	25.6
Lost time festivities	%	594	0.7	1.0	0	5.3	54	0.4	0.9	0	3.7
Lost time field	%	594	4.2	4.3	0	27.6	54	2.4	2.9	0	14.6
Lost time rain	%	594	4.2	5.0	0	39.8	54	1.8	3.3	0	17.2
Lost time staff	%	594	1.3	1.9	0	19.7	54	0.9	1.3	0	5.2
Mechanical harvest	%	376	21.7	19.9	0.03	100	42	23.4	23.8	0.04	100
Mechanical lifting	%	514	81.7	21.0	0.02	100	51	83.4	18.5	8.5	100
Mill administration	0=Gov.; 1=Priv.	594	0.7	0.5	0	1	54	0.8	0.4	0	1
Oil consumption	Lts/Ton	594	7.9	8.0	0	38.7	54	2.3	3.0	0	11.1
Plot size	ha/Producer	541	4.5	2.3	0.8	17.1	54	4.7	2.8	0.8	17.1
Rainfall	Millimeters	594	2,498	1,146	282	7,548	54	2,610	1,183	606	6,671
Steam consumption	Ton/Ton	594	0.6	1.3	0	31.5	54	0.5	0.1	0	0.7
Sucrose	Ton/ha	594	10.1	2.8	3.8	19.0	54	9.5	2.7	4.6	16.7
Sucrose content	%	594	13.5	1.1	10.3	16	54	13.9	1.1	11.5	16
Total lost time	%	594	20.2	8.5	3.3	53.6	54	15.4	8.5	3.3	47.7
Vehicles	Trucks/ha	534	0.02	0.01	0.003	0.13	53	0.0	0.0	0.01	0.05

Table 5. Size of sugarcane plots and sucrose yield

	Dependent variable: Production of sucrose per hectare												
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Plot size	-1.691***	-1.699***	-0.733**	-0.708**	-0.769***	-0.701*	-0.415	-0.549	-0.088	0.102	-0.781**	0.239	0.166
	(0.372)	(0.368)	(0.306)	(0.278)	(0.258)	(0.385)	(0.252)	(0.436)	(0.362)	(0.366)	(0.318)	(0.240)	(0.278)
Plot size^2	0.102***	0.103***	0.045**	0.041**	0.044**	0.045	0.018	0.028	-0.003	-0.017	0.051**	-0.018	-0.011
	(0.029)	(0.029)	(0.021)	(0.019)	(0.018)	(0.027)	(0.016)	(0.026)	(0.026)	(0.025)	(0.022)	(0.018)	(0.020)
Rainfall				-0.0004**	-0.001***	-0.001**	0.0003*	-0.001**	0.001***	0.0001	-0.003	0.001***	0.0004**
				(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Mill administration				-0.007	0.228	0.037	-0.204	0.658	0.223	0.529	-0.23	-0.789**	-0.758*
				(0.460)	(0.398)	(0.474)	(0.377)	(0.585)	(0.299)	(0.371)	(0.411)	(0.360)	(0.426)
Fertlizer					-0.016*				-0.008	-0.003	-0.027***	-0.013*	-0.01
					(0.008)				(0.008)	(0.008)	(0.006)	(0.007)	(0.007)
Fertilizer^2					0.000**				0.000	0.000	0.000***	0.000**	0.000**
					(0.000)				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Mechanical lifting						-0.013			-0.015*	-0.018		0.005	0.001
						(0.010)			(0.008)	(0.014)		(0.009)	(0.016)
Vehicles						15.301			20.807	13.093		8.136	5.62
						(19.839)			(13.086)	(14.007)		(14.474)	(13.484)
Cane cutters						-1.065			4.154	7.595		6.854	15.253**
						(7.206)			(3.801)	(6.404)		(4.990)	(6.092)
Irrigation							0.039***		0.037***	0.038***		0.042***	0.041***
							(0.006)		(0.006)	(0.006)		(0.006)	(0.006)
Mechanical harvest								0.035*		0.018			0.014
								(0.020)		(0.013)			(0.019)
Altitude											0.002***	0.002***	0.003***
											(0.001)	(0.0005)	(0.001)
Constant	15.010***	15.377***	8.824***	9.661***	14.384***	10.593***	7.231***	8.962***	8.844**	6.819*	19.810***	7.267**	6.052
	(1.090)	(1.094)	(1.086)	(1.069)	(3.052)	(1.650)	(1.026)	(1.853)	(3.385)	(3.630)	(2.156)	(3.024)	(3.732)
Cycle dummies	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
State dummies	no	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no
N	541	541	541	541	506	480	524	356	434	327	506	434	327
R^2	0.318	0.347	0.620	0.635	0.697	0.651	0.711	0.710	0.782	0.812	0.573	0.725	0.755
Critical size of parcels	8.3	8.2	8.1	8.6	8.7	7.8	irrelevant	irrelevant	irrelevant	irrelevant	7.7	irrelevant	irrelevant

Heteroskedasticity-robust standard errors clustered by municipality are shown in parentheses. Table 3 provides a description of variables. Stars denote statistical significance at the *10% , **5% and ***1% levels.

Table 6. Size of sugarcane plots and use of inputs

	Dependent variable											
	Fertilizer		Mechanical lifting		Vehicles		Cane cutters		Irrigation		Mechanical harvest	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Plot size	-1.3	-23.106*	-0.482	3.771	-0.002***	-0.003*	-0.008***	-0.024***	0.114	-7.261	1.518**	1.835
	(5.532)	(11.556)	(1.170)	(4.600)	(0.000)	(0.002)	(0.002)	(0.004)	(2.334)	(5.611)	(0.570)	(2.276)
Plot size^2		1.730**		-0.358		0.0001		0.001***		0.585		-0.023
		(0.809)		(0.317)		(0.0001)		(0.000)		(0.426)		(0.125)
Rainfall	-0.003	-0.002	-0.003*	-0.004*	0.000	0.000	-0.000**	0.000	-0.020***	-0.020***	0.001	0.001
	(0.008)	(0.008)	(0.002)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.004)	(0.001)	(0.001)
Mill administration	-20.424	-18.078	1.498	1.305	-0.008***	-0.008***	-0.001	0	3.734	4.68	-6.216**	-6.240**
	(19.026)	(18.772)	(4.965)	(4.840)	(0.002)	(0.002)	(0.007)	(0.006)	(7.004)	(6.794)	(2.814)	(2.785)
Constant	553.355***	614.569***	96.380***	84.564***	0.032***	0.036***	0.161***	0.203***	40.706***	61.704***	-2.505	-3.515
	(37.586)	(47.376)	(6.655)	(14.559)	(0.003)	(0.006)	(0.010)	(0.013)	(12.858)	(17.039)	(5.587)	(10.297)
Cycle dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
State dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
N	506	506	482	482	496	496	501	501	524	524	356	356
R^2	0.364	0.373	0.3	0.308	0.444	0.447	0.717	0.75	0.776	0.786	0.751	0.751
Critical size of parcels	-	6.7	-	5.3	-	15	-	12	-	6.2	-	39.9

Heteroskedasticity-robust standard errors clustered by municipality are shown in parentheses. Table 3 provides a description of variables. Stars denote statistical significance at the *10% , **5% and ***1% levels.

Table 7. Number of cane suppliers and cane quality

	Dependent variable: Sucrose content				
Panel A	(A1)	(A2)	(A3)	(A4)	(A5)
Cane suppliers	0.0002**	0.0001*	0.0001	0.0001	1.69E-06
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(4.34E-05)
Constant	12.889***	14.181***	14.176***	13.412***	13.939***
	(0.331)	(0.168)	(0.429)	(0.893)	(0.798)
R^2	0.094	0.54	0.592	0.595	0.651
H_0: $\beta_1<0$	0.014	0.028	0.054	0.126	0.485
Panel B	(B1)	(B2)	(B3)	(B4)	(B5)
Cane suppliers	0.0053***	0.0034***	0.0037***	0.0042***	0.0040***
	(0.0008)	(0.0011)	(0.0009)	(0.0011)	(0.0010)
Cane suppliers^2	-2.07E-06***	-1.36E-06***	-1.49E-06***	-1.67E-06***	-1.42E-06***
	(3.84E-07)	(4.63E-07)	(3.89E-07)	(4.40E-07)	(3.70E-07)
Cane suppliers^3	3.38E-10***	2.33E-10***	2.51E-10***	2.68E-10***	2.02E-10***
	(6.89E-11)	(7.82E-11)	(6.63E-11)	(7.34E-11)	(5.52E-11)
Cane suppliers^4	-1.91E-14***	-1.36E-14***	-1.45E-14***	-1.49E-14***	-1.01E-14***
	(4.05E-15)	(4.41E-15)	(3.76E-15)	(4.14E-15)	(2.83E-15)
Constant	8.821***	11.65***	11.353***	11.24***	11.719***
	(0.556)	(0.822)	(0.773)	(1.531)	(1.416)
R^2	0.238	0.588	0.645	0.651	0.71
H_0: $\beta_2=\beta_3=\beta_4=0$					
Likelihood ratio	<0.01	<0.01	<0.01	<0.01	<0.01
Heteroskedasticity adjusted Wald	<0.01	<0.01	<0.01	<0.01	<0.01
Critics numbers of sugarcane suppliers (max; min; max) =	(2,695; 3,776; 6,801)	(-; -; 6,892)[1/]	(2,533; 3,679; 6,771)	(2,472; 4,266; 6,752)	(2,690; 5,317; 6,993)
Panel C					
N	541	541	541	434	327
Controls					
Cycle dummies	no	yes	yes	yes	yes
State dummies	no	yes	yes	yes	yes
Administration, rainfall and cane	no	no	yes	yes	yes
Irrigation, fertilizer, mechanical lifting, vehicles and cutters	no	no	no	yes	yes
Mechanical harvest	no	no	no	no	yes

Heteroskedasticity-robust standard errors clustered by municipality are shown in parentheses. Table 3 provides a description of variables. Stars denote statistical significance at the *10% , **5% and ***1% levels. [1/] Under this specification there is only one global maximum, which occurs when number of cane suppliers amounts to 6,892.

Table 8. Factory efficiency

	Dependent variable: Factory efficiency										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Mill administration	0.979			0.844	-0.263			-0.368	0.118	-0.266	0.135
	(0.680)			(0.626)	(0.534)			(0.510)	(0.481)	(0.513)	(0.490)
Electricity generation		-0.193**		-0.194**		-0.159***		-0.162***	-0.102**	1.948***	1.747***
		(0.090)		(0.087)		(0.050)		(0.049)	(0.042)	(0.380)	(0.552)
Alcohol production			0.063	0.091			0.031	0.05	0.044	0.063	0.052
			(0.127)	(0.103)			(0.079)	(0.073)	(0.059)	(0.076)	(0.058)
Lost time factory									-0.196***		-0.191***
									(0.024)		(0.025)
Lost time staff									-0.067		-0.06
									(0.043)		(0.044)
Lost time festivities									-0.273**		-0.238**
									(0.106)		(0.103)
Lost time field									-0.065**		-0.060**
									(0.028)		(0.029)
Lost time rain									-0.078***		-0.082***
									(0.024)		(0.023)
Electricity consumption										-2.088***	-1.836***
										(0.378)	(0.558)
Oil consumption										-0.066**	-0.031
										(0.031)	(0.027)
Steam consumption										-0.067***	-0.091***
										(0.017)	(0.017)
Constant	81.610***	85.586***	82.215***	84.988***	82.106***	84.732***	81.933***	84.910***	86.811***	85.312***	86.872***
	(0.572)	(1.508)	(0.341)	(1.372)	(0.427)	(0.830)	(0.262)	(0.832)	(0.765)	(0.859)	(0.783)
Cycle fixed effect	no	no	no	no	yes	yes	yes	yes	yes	yes	yes
Sugar mill fixed effect	no	no	no	no	yes	yes	yes	yes	yes	yes	yes
N	594	594	594	594	594	594	594	594	594	594	594
R^2 (within)	0.023	0.093	0.002	0.116	0.043	0.097	0.042	0.100	0.247	0.124	0.256

Heteroskedasticity-robust standard errors clustered by sugar mill are shown in parentheses. Table 3 provides a description of variables. Stars denote statistical significance at the *10%, **5% and ***1% levels.

Table A3.1. Quantity and quality of sugarcane

	Dependent variable							
	Sucrose content				ln(Sucrose content)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cane	0.013***	0.013***	0.012***	0.014**				
	(0.003)	(0.003)	(0.004)	(0.006)				
ln(Cane)					0.061***	0.061***	0.045**	0.049*
					(0.016)	(0.016)	(0.020)	(0.027)
Constant	12.285***	12.290***	13.552***	13.939***	2.324***	2.323***	2.450***	2.508***
	(0.268)	(0.316)	(0.771)	(1.086)	(0.072)	(0.074)	(0.106)	(0.145)
Controls								
Cycle fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Sugar mill fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Mill administration and rainfall	no	yes	yes	yes	no	yes	yes	yes
Irrigation, fertilizer, mechanical lifting, vehicles and cutters	no	no	yes	yes	no	no	yes	yes
Mechanical harvest	no	no	no	yes	no	no	no	yes
R^2 (within)	0.248	0.248	0.312	0.32	0.236	0.236	0.301	0.306
N	594	594	462	343	594	594	462	343
Number of sugar mills	54	54	54	45	54	54	54	45
Increase in sucrose content associated to a 10% increase in the volume of cane obtained per hectare =					0.58%	0.58%	0.43%	0.47%

Heteroskedasticity-robust standard errors clustered by sugar mill are shown in parentheses. Table 3 provides a description of variables. Stars denote statistical significance at the *10%, **5% and ***1% levels.

Table A4.1. Robustness tests applied to equation (1)

	Dependent Variable: Production of sucrose per hectare												
Panel A: Baseline results	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Plot size	-1.691***	-1.699***	-0.733**	-0.708**	-0.769***	-0.701*	-0.415	-0.549	-0.088	0.102	-0.781**	0.239	0.166
	(0.372)	(0.368)	(0.306)	(0.278)	(0.258)	(0.385)	(0.252)	(0.436)	(0.362)	(0.366)	(0.318)	(0.240)	(0.278)
Plot size^2	0.102***	0.103***	0.045**	0.041**	0.044**	0.045	0.018	0.028	-0.003	-0.017	0.051**	-0.018	-0.011
	(0.029)	(0.029)	(0.021)	(0.019)	(0.018)	(0.027)	(0.016)	(0.026)	(0.026)	(0.025)	(0.022)	(0.018)	(0.020)
Critical size of parcels	8.3	8.2	8.1	8.6	8.7	7.8	irrelevant	irrelevant	irrelevant	irrelevant	7.7	irrelevant	irrelevant
Panel B: Tests on the quadratic specification													
Plot size	-0.560***	-0.562***	-0.17	-0.190*	-0.211**	-0.136	-0.187**	-0.153	-0.126*	-0.13	-0.14	0.002	0.015
	(0.139)	(0.141)	(0.111)	(0.095)	(0.086)	(0.108)	(0.079)	(0.125)	(0.068)	(0.087)	(0.124)	(0.076)	(0.080)
H_0: $\beta_2=0$	<0.01	<0.01	0.036	0.035	0.018	0.102	0.273	0.281	0.910	0.496	0.026	0.314	0.58
H_0: $\beta_1=\beta_2=0$	<0.01	<0.01	0.055	0.018	<0.01	0.172	0.038	0.349	0.134	0.186	0.058	0.596	0.837
Panel C: Results excluding sugar mill La Primavera (PRI)													
Plot size	-2.035***	-2.025***	-1.000***	-0.934***	-0.935***	-0.735*	-0.428	-0.941*	-0.078	0.164	-0.993**	0.237	0.173
	(0.403)	(0.404)	(0.329)	(0.306)	(0.298)	(0.408)	(0.338)	(0.516)	(0.371)	(0.369)	(0.377)	(0.237)	(0.273)
Plot size^2	0.137***	0.135***	0.068***	0.061***	0.060***	0.047	0.017	0.057	-0.003	-0.021	0.072**	-0.018	-0.012
	(0.032)	(0.032)	(0.023)	(0.022)	(0.021)	(0.028)	(0.025)	(0.034)	(0.027)	(0.025)	(0.027)	(0.018)	(0.020)
Critical size of parcels	7.4	7.5	7.4	7.7	7.8	7.8	irrelevant	8.3	irrelevant	irrelevant	6.9	irrelevant	irrelevant
Panel D: Results excluding sugar mills La Primavera (PRI) and El Higo (HIG)													
Plot size	-2.140***	-2.126***	-0.958**	-0.906**	-0.976***	-0.686	-0.585	-1.048	-0.287	-0.125	-0.996**	0.238	0.091
	(0.501)	(0.505)	(0.367)	(0.362)	(0.354)	(0.475)	(0.401)	(0.629)	(0.451)	(0.478)	(0.473)	(0.325)	(0.402)
Plot size^2	0.148***	0.146***	0.061**	0.056*	0.065**	0.04	0.038	0.067	0.021	0.01	0.072*	-0.018	-0.005
	(0.044)	(0.045)	(0.030)	(0.031)	(0.029)	(0.038)	(0.034)	(0.049)	(0.035)	(0.037)	(0.040)	(0.028)	(0.035)
Critical size of parcels	7.2	7.3	7.9	8.1	7.5	irrelevant	irrelevant	irrelevant	irrelevant	irrelevant	6.9	irrelevant	irrelevant

Table A4.1 (Cont.)

Panel E: Results weighted by the production of sugarcane	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Plot size	-2.181***	-2.181***	-0.928**	-0.916***	-0.932***	-0.641	-0.327	-0.844	0.002	0.152	-1.153***	0.205	0.157
	(0.470)	(0.473)	(0.371)	(0.341)	(0.315)	(0.416)	(0.245)	(0.510)	(0.298)	(0.288)	(0.413)	(0.241)	(0.264)
Plot size^2	0.137***	0.137***	0.060**	0.056**	0.056**	0.043	0.011	0.047	-0.009	-0.019	0.075**	-0.015	-0.011
	(0.035)	(0.036)	(0.025)	(0.023)	(0.021)	(0.028)	(0.018)	(0.032)	(0.022)	(0.020)	(0.029)	(0.018)	(0.018)
Critical size of parcels	8.0	8.0	7.7	8.2	8.3	irrelevant	irrelevant	irrelevant	irrelevant	irrelevant	7.7	irrelevant	irrelevant
Panel F: Results weighted by the production of sugar													
Plot size	-2.260***	-2.257***	-0.934**	-0.920**	-0.930***	-0.622	-0.313	-0.868*	0.008	0.151	-1.217***	0.182	0.132
	(0.479)	(0.483)	(0.380)	(0.349)	(0.324)	(0.423)	(0.253)	(0.515)	(0.301)	(0.297)	(0.426)	(0.245)	(0.265)
Plot size^2	0.143***	0.142***	0.061**	0.057**	0.056**	0.042	0.01	0.049	-0.009	-0.019	0.079**	-0.013	-0.009
	(0.036)	(0.036)	(0.026)	(0.024)	(0.022)	(0.028)	(0.018)	(0.032)	(0.022)	(0.021)	(0.030)	(0.018)	(0.019)
Critical size of parcels	7.9	7.9	7.7	8.1	8.3	irrelevant	irrelevant	8.9	irrelevant	irrelevant	7.7	irrelevant	irrelevant
Panel G: Controls													
Constant	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Cycle dummies	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
State dummies	no	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no
Irrigation, Mill administration	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Fertilizer (linear and quadratic)	no	no	no	no	yes	no	no	no	yes	yes	yes	yes	yes
Mechanical lifting, vehicles and cutters	no	no	no	no	no	yes	no	no	yes	yes	no	yes	yes
Irrigation	no	no	no	no	no	no	yes	no	yes	yes	no	yes	yes
Mechanical harvest	no	no	no	no	no	no	no	yes	no	yes	no	no	yes
Altitude	no	no	no	no	no	no	no	no	no	no	yes	yes	yes

Heteroskedasticity-robust standard errors clustered by municipality are shown in parentheses. Table 3 provides a description of variables. Stars denote statistical significance at the *10% , **5% and ***1% levels.