Ethanol and sugarcane expansion in the Brazilian *Cerrado*: Farm, industry, and market analyses

by

Ana Cláudia Sant'Anna

B.A., University of Brasilia, 2008
M.Sc., University of São Paulo - ESALQ, 2011

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2017

Abstract

Brazil is one of the leading producers of ethanol, sugar, and sugarcane. Increasing demand for biofuels aligned with public policies prompted the expansion of sugarcane into the Brazilian *Cerrado*, particularly, into the states of Goiás and Mato Grosso do Sul. The overall purpose of this dissertation, comprised of three essays, is to understand the impacts from the sugarcane expansion on farmers, processors, and the market. At the market level, the first essay, estimates the impacts of public policies and market factors on ethanol and sugar, supply and demand, in Goiás and Mato Grosso do Sul, using three-stage least squares. Results show that ethanol supply is sensitive to public policies whereas the sugar supply is sensitive to market prices. Sugar and ethanol were found to be complementary outputs. For ethanol expansion to be sustainable the ethanol market must be developed to the extent that it relies on market factors and is no longer dependent on public policies.

At the farmer level, the second essay, examines farmers' willingness to sign a sugarcane contract with a mill in the Brazilian *Cerrado*. A hypothetical stated choice experiment was conducted with farmers in Goiás and Mato Grosso do Sul. Respondents choose between three contracts (land rental, agricultural partnership, and supply) and two optout options ("keep current contract" or "not grow sugarcane"). A single and a two opt-out random parameters models were estimated. The two opt-out model allowed for a better interpretation of the status quo. Willingness to pay, direct and cross-elasticity measures for contract attributes were calculated. Results showed that farmers prefer contracts with higher returns, shorter duration and a lower probability of late payments. Farmers seemed to prefer to renting out their land to the mill than to produce sugarcane themselves, which could lead to consequences for rural development and the sustainability of sugarcane expansion.

At the processor level, the third essay investigates the impact of vertical coordination on input-oriented technical efficiency using data envelopment analysis (first stage) and a Tobit censored model (second stage). 204 Brazilian mills were considered. The second stage controlled for vertical integration as well as other characteristics of the mill. Vertical integration was measured as the percentage of total sugarcane used, supplied by mills. A negative, though minimal, relationship between vertical integration and technical efficiency was found. Hence, technical efficiency is not the major driver of vertical integration. Other vertical coordination strategies may bring more benefits in terms of technical efficiency (e.g. contracts). Drivers of vertical integration seem to vary according to the characteristics of the location of the mill.

Ethanol and sugarcane expansion in the Brazilian *Cerrado*: Farm, industry, and market analyses

by

Ana Cláudia Sant'Anna

B.A., University of Brasilia, 2008
M.Sc., University of São Paulo - ESALQ, 2011

A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2017

Approved by:

Co-Major Professor
Jason Scott Bergtold

Approved by:

Co-Major Professor
Tian Xia

Copyright

Abstract

Brazil is one of the leading producers of ethanol, sugar, and sugarcane. Increasing demand for biofuels aligned with public policies prompted the expansion of sugarcane into the Brazilian *Cerrado*, particularly, into the states of Goiás and Mato Grosso do Sul. The overall purpose of this dissertation, comprised of three essays, is to understand the impacts from the sugarcane expansion on farmers, processors, and the market. At the market level, the first essay, estimates the impacts of public policies and market factors on ethanol and sugar, supply and demand, in Goiás and Mato Grosso do Sul, using three-stage least squares. Results show that ethanol supply is sensitive to public policies whereas the sugar supply is sensitive to market prices. Sugar and ethanol were found to be complementary outputs. For ethanol expansion to be sustainable the ethanol market must be developed to the extent that it relies on market factors and is no longer dependent on public policies.

At the farmer level, the second essay, examines farmers' willingness to sign a sugarcane contract with a mill in the Brazilian *Cerrado*. A hypothetical stated choice experiment was conducted with farmers in Goiás and Mato Grosso do Sul. Respondents choose between three contracts (land rental, agricultural partnership, and supply) and two optout options ("keep current contract" or "not grow sugarcane"). A single and a two opt-out random parameters models were estimated. The two opt-out model allowed for a better interpretation of the status quo. Willingness to pay, direct and cross-elasticity measures for contract attributes were calculated. Results showed that farmers prefer contracts with higher returns, shorter duration and a lower probability of late payments. Farmers seemed to prefer to renting out their land to the mill than to produce sugarcane themselves, which could lead to consequences for rural development and the sustainability of sugarcane expansion.

At the processor level, the third essay investigates the impact of vertical coordination on input-oriented technical efficiency using data envelopment analysis (first stage) and a Tobit censored model (second stage). 204 Brazilian mills were considered. The second stage controlled for vertical integration as well as other characteristics of the mill. Vertical integration was measured as the percentage of total sugarcane used, supplied by mills. A negative, though minimal, relationship between vertical integration and technical efficiency was found. Hence, technical efficiency is not the major driver of vertical integration. Other vertical coordination strategies may bring more benefits in terms of technical efficiency (e.g. contracts). Drivers of vertical integration seem to vary according to the characteristics of the location of the mill.

Table of Contents

List of Figures

List of Tables

Acknowledgements

I am eternally grateful for my mother, my pillar, who has helped me through the highs and the lows. I am thankful for the advice and support of my major advisor and friend, Dr. Jason Scott Bergtold. I am also grateful for the constructive comments and encouragement from my co-chair Dr. Tian Xia. I thank Dr. Marcellus Caldas for his support and motivation right from the start of my PhD and Dr. Aleksan Shanoyan for always being there to help me and give me advice. I also thank my outside chair Dr. Spencer Wood. I am thankful for my master's adviser Ricardo Shirota for connecting me to Professor Marcellus at Kansas State University. A special thanks to my friends, old and new, far and near. You are always in my thoughts. Thanks to Gabriel Granço, my coauthor and friend.

I also thank my K-State Family who helped throughout my time here. I thank the faculty and staff of the Econ and AgEcon Departments who helped me navigate through the PhD course, living in Kansas and my future career path. In particular, I thank Terry Griffen for his advice and friendship. Orlen Grunewald, Jeff Williams, Brian Briggman and Sean Fox for the teaching opportunities and their teaching advice. I also thank Terry Teske for all the computer help, as well as, Judy, Deanna, Amy and Mary for all their assistance. I thank the Graduate School Council, the Student Government Association and the Western Agricultural Economics society for the travel grants they awarded me, making it possible to receive feedback on sections of this research.

I am grateful for farmers and landowners in Goiás and Mato Grosso do Sul, for welcoming us into their farms and dedicating their time to answer our survey. I would also like to thank the rural syndicates in Goiás and Mato Grosso do Sul, sugarcane producer organizations (including Acaer, AFC, APMP, Aprocana, Sulcanas, Coplacana), the Federation of Agriculture and Livestock in Goiás (Faeg) and the Foundation MS for their help in connecting us with sugarcane growers and landowners. I also thank all the students that helped out with the survey in Brazil, as well as, Pedro Masi for helping out with survey design and application.

I would like to thank the researchers and colleagues that provided me with information, help in survey application and feedback on my research, such as Gesmar Rosa dos Santos, Professors Wagner and Ana Elisa Lourenzani, Professor Heloisa Burnquist, Professor Ferenc Istvan Bankuti and Professor Sandra Schavi. I thank the Brazilian Department of Agriculture for the printed material on sugarcane they shared with me. I thank Talia Guzman-Gonzalez for her help navigating through the Library of Congress to gather the data on the Brazilian mills, and Gabriel Blair for his help with entering the data on to the computer.

This dissertation was part of a National Science Foundation grant entitled "Collaborative Research: Land Change in Brazil's Cerrado: Ethanol and Sugar Cane Expansion at the Farm and Industry Scale" [NSF BSC-1227451].

Funding this dissertation also came through the University Distinguished Professor Graduate Student Award I received in 2016.

Dedication

I dedicate this dissertation to my grandparents (Norma and Claudio) who are no longer with us.

Chapter 1 - Introduction

Brazil has produced sugarcane ever since 1532 (BNDES 2008). Since its introduction, sugarcane production has expanded from the North-Northeast regions of the country to the Center-South, becoming, over the past decades, a dominant crop in the state of São Paulo (Sant'Anna, Shanoyan, et al. 2016). Sugarcane is a main input in producing sugar, ethanol and even electricity. Brazil is not only a major sugarcane and ethanol producer, but also, a large sugar and ethanol exporter (MAPA 2013). The sugar-energy sector in Brazil is approximately 2% of the country's Gross Domestic Product (Neves, Trombin and Consoli 2011), generating 900,000 direct and indirect jobs (Fagundes de Almeida, Bomtempo and de Souza e Silva 2008).

From 2000 to 2013 the number of operating sugarcane mills in Brazil increased by 171% and the country's daily sugarcane processing capacity reached 3.6 million metric tons (Reinhardt, Maurer and de Pinho 2009; Sant'Anna, Shanoyan, et al. 2016). There are three types of mills in Brazil (their distribution in percentage is in brackets): sugar mills (5%), ethanol mills (35%) and mixed mills (65%), which produce sugar and ethanol (Sant'Anna, Shanoyan, et al. 2016). A ton of sugarcane produces, on average, 140 kg of sugar or 86 liters of ethanol (State of São Paulo Government 2014).

During the 21st century, Brazil increased its ethanol production capacity by expanding into the *Cerrado* region, located in the center of the country. The sugarcane expansion was more significant in the states of Goiás and Mato Grosso do Sul. The availability of cheaper and flatter land in these two states allowed for easy expansion and greater mechanization (Granco et al. 2015). From 2000 to 2012 over 40 mills have been constructed in these states (Procana 2013), such that Goiás and Mato Grosso do Sul, are catching up to São Paulo in terms of sugarcane production. Sugarcane expansion into Goiás and Mato Grosso do Sul has changed lands once known for livestock and soybean production (Granco et al. 2015). Degraded areas, pasture and crop lands, as well as, *Cerrado* areas are being converted to produce sugarcane (Sant'Anna, Shanoyan, et al. 2016). Figure 1.1 illustrates the increase in sugarcane areas and in mills from 2005 to 2012 in these two states.

Goiás and Mato Grosso do Sul have increased their contribution to the Brazilian supply of sugarcane from 2% in 2000 to 10% in 2013 (IBGE 2014). Meanwhile São Paulo's participation in the country's sugarcane production has remained constant (Table 1.1). Data on the percentage distributions of planted areas, quantity and value of production in selected states illustrates the sugarcane expansion in the *Cerrado* region (Table 1.1).

Among the drivers of sugarcane expansion are international demand for sugar and ethanol, national policies, technological changes in production and vertical integration by mills, from agricultural production into processing (Fischer et al. 2008; Shikida 2013). The Brazilian government has encouraged sugarcane expansion as it prompts rural development and economic growth. Given the role of public policies in the sugarcane expansion, it is important to estimate the impact of these policies on ethanol and sugar supply and demand. In addition to the impact of market prices on ethanol and sugar demand and supply, other factors that impact ethanol and sugar markets include: changes to the blending ratio of anhydrous ethanol with gasoline; the introduction of flex-fuel cars in 2004, allowing consumers to choose freely between ethanol and gasoline at the pump; the reduction to zero of the CIDE-fuel tax (Contribution of Intervention in the Economic Domain); variations in sugar and ethanol prices; and the launch of the Sugarcane Agroecological Zoning in 2009 (Brazil 2009; Manzatto et al. 2009) (Figure 1.2).

The geographic expansion in sugarcane production driven by public policies, as well as market factors has instigated a competitive dynamic in the Brazilian ethanol industry (Sant'Anna, Shanoyan, et al. 2016). In Brazil, sugarcane used in the production of ethanol is grown either by independent farmers (40%) or by the mills (60%) (MAPA 2013). Thus, processors expanding into the *Cerrado* must decide on the sugarcane procurement (i.e. from suppliers or to produce it themselves. Farmers, wanting to enter the sugarcane sector must decide between growing sugarcane or renting out their lands to mills. An evolution of the amount of sugarcane supplied by farmers and by mills can be seen in Figure 1.3.

It is common for contracts to be signed between mills and farmers or landowners. Three types of contracts are currently used in Brazil: (1) land rental contracts – which give the local mill use of the land for sugarcane production for a fixed rental rate; (2) agricultural partnership contracts – which give the local mill use of the land for sugarcane production for a percentage of the harvested crop; and (3) supply contracts – by which farmers agree to supply sugarcane to the local mill for an agreed price and quantity (Brazil 1966). Mills may decide to sign a contract to guarantee their supply of sugarcane (Picanço Filho and Marin 2012a). On average contracts are signed for the duration of one or two sugarcane planting cycle (i.e. 6 or 12 years) (Picanço Filho and Marin 2012a). It is important to identify farmers' and landowners' preferences for contract attributes, as well as their willingness to pay for those contract attributes. This information can help farmers with contract selection and negotiation. Mills can be informed about ways to reduce their current transaction costs incurred during contract negotiation.

As mentioned the mill may also decide to produce their own sugarcane, taking on the strategic decision to vertically integrate (backwards). In these cases, a land rental or agricultural partnership contract is usually negotiated. According to Picanço Filho (2010) landowners may prefer to rent the land to mills instead of growing sugarcane themselves for various reasons, including: high costs to form and maintain a sugarcane plantation; lack of stamina to migrate into a new sector; restrictive labor regulations; and the guarantee of a fixed periodical payment with reduced risks. From the mills' perspective, distance and harvest timeline limitations, along with the desire to guarantee sugarcane supply or to create barriers of entry to competing firms, make vertical integration enticing. Lower levels of vertical integration in Brazil are witnessed in the states with a longer tradition of growing sugarcane (e.g. São Paulo) while higher levels of vertical integration are present in states where sugarcane is a new crop (e.g. Goiás). Understanding the impact of vertical integration on mill production and efficiency can help mills with strategic planning and provide policy makers guidance on ethanol and sugar industry expansion.

1.1 Research objectives

The overall purpose of this dissertation, comprised of three essays, is to understand the impacts from the expansion of sugarcane production on farmers, mills, and markets in the Brazilian *Cerrado*. Each essay constitutes a chapter with its own objective, focusing on a level of the supply chain:

1. Market level: To estimate the impact of public policies and market factors on ethanol and sugar supply and demand.
2. Processor level: To assess the impact of vertical coordination strategies on efficiency.
3. Farmer/Supplier level: To assess the incentive structure at the processor and producer interface of the sugarcane supply chain.

Below is an overview of each the three essays. A summary of the methods used to achieve the objectives listed afore as well as the results are presented.

1.1.1 First essay: What is driving the sugarcane expansion in Brazil? The impact of internal and external factors

Brazil is one of the leading countries in the production of ethanol, sugar and sugarcane. Increasing demand for biofuels aligned with public policies prompted the expansion of sugarcane into the Brazilian *Cerrado*, particularly into the states of Goiás and Mato Grosso do Sul. This study estimates ethanol and sugar supply and demand elasticities for these states. It uses a system of equations and three-stage least squares method to estimate the impacts from market and policy drivers on sugar and ethanol markets. Results show that policies aimed at increasing ethanol production have a statistically significant impact on ethanol supply but little impact on sugar supply. Successful programs were the blend mandate, subsidized credits and mapping of areas suitable to grow sugarcane. The sugar industry was greatly impacted by market factors, though changes in prices of sugar and sugarcane affected exports more than domestic sugar supply. Sugar and ethanol were found to be complementary outputs. Results suggest that for ethanol expansion to be sustainable the ethanol market must be developed such that it relies on market factors and is no longer dependent on public policies.

1.1.2 Second essay: Sugarcane contracts in Brazil: How sweet is the deal?

This essay examines farmers' and landowners' willingness to sign a contract with a local ethanol mill in the Brazilian *Cerrado* to produce sugarcane. This study contributes to the understanding of the extensive expansion in sugarcane production that has occurred in this region. A hypothetical stated choice experiment was conducted with farmers and landowners in Goiás (GO) and Mato Grosso do Sul (MS). The experiment involved them choosing between three contract options (land rental contract, an agricultural partnership contract, a supply contract) and a status quo option. If the status quo option was chosen, individuals had to indicate the reason for this choice ("keep current contract" or "not grow sugarcane"). We ran a single opt-out model with one opt-out option and a two opt-out model. The two opt-out model is a novel approach that has not been used in past stated choice studies and has the advantage of allowing for a better interpretation of the single opt-out model, generally found in the literature. The two opt-out model was further extended to include the modeling of the random parameters with trust and welfare. Data from the stated choice experiment was analyzed using a random parameter model and the respondent's willingness to pay for contract attributes was estimated. Elasticity measures were also calculated to interpret contract preferences due to changes in contract attributes. Results made it possible to identify which attributes gave farmers and landowners' utility and disutility. Results showed that farmers and landowners are more likely to sign contracts that offer higher returns, are shorter in length and have a lower probability of late payments. Farmers and landowners seem to prefer land rental contracts over other contract options (except the option to keep their current contract). This, in turn, could have damaging consequences to rural development and the sustainability of sugarcane expansion.

1.1.3 Third essay: Assessing the relationship between vertical coordination strategy and technical efficiency: Evidence from the Brazilian ethanol industry

The purpose of this essay is to estimate the impact of upstream vertical integration on input-oriented technical efficiency using data envelopment analysis and a Tobit censored model. Inputs considered in the DEA model were the amount of crushed sugarcane and the daily sugarcane crushing capacities of the mill. Outputs were the quantities of ethanol and sugar produced. A sample of 204 Brazilian mills were considered in this study. In 2013, they produced half of total amount of sugar and ethanol produced in the country. The Tobit censored model controlled for the percentage of crushed sugarcane produced on lands owned or rented by mills, if the mill could produce two goods, the age of the mill, dummies for locations of the mill and interaction terms. The interaction terms consisted of percentage of crushed sugarcane produced by the mill interacted with different locations (São Paulo, Center West region and Alagoas and Pernambuco).

Vertical integration, by itself, has a, but minimal, negative marginal effect on efficiency. Vertical integration seems to be motivated by strategic reasons instead of operational purposes. The strategic reasons to vertically integration seam to vary between the locations. In areas with tradition in growing sugarcane, vertical integration may be used a strategy to increase the mills bargaining power with sugarcane suppliers. In the Cerrado region, where sugarcane has recently expanded into, vertical integration may be used to create barriers to entry to new mills. In areas where little sugarcane is grown, vertical integration may be a strategy to establish a procurement base. The industry should seek partnerships with farmers while policy makers can motivate input markets by offering extension services, financial incentives for the adoption of cutting edge technology, as well as, motivation for the institution of producer organizations. Findings from this study provide guidance to industries highly dependent on one input and with high location specificity. It provides policy makers with information to guide policies aimed at limiting vertical integration and on assuring farmer's welfare.

1.2 References

BNDES ed. 2008. *Sugarcane-based bioethanol energy for sustainable development*. Rio de Janeiro: Coordination BNDES and CGEE - BNDES.

Brazil. 2009. Decreto No. 6,961 of Setember 17th 2009. Aprova o zoneamento agroecológico da cana-de-açúcar e determina ao Conselho Monetário Nacional o estabelecimento de normas para as operações de financiamento ao setor sucroalcooleiro, nos termos do zoneamento. Brasilia: Presidência da República. Available at: http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2009/Decreto/D6961.htm [Accessed March 20, 2017].

Fagundes de Almeida, E., J.V. Bomtempo, and C.M. de Souza e Silva. 2008. "The performance of Brazilian biofuels." In *ITF Round Tables*. Organization for Economic Co-operation and Development, pp. 151–188. Available at: http://www.oecd-ilibrary.org/content/chapter/9789282101803-6-en [Accessed May 20, 2015].

Fischer, G., E. Teixeira, E. Tothne Hizsnyik, and H.T. van Velthuizen. 2008. "Land use dynamics and sugarcane production." In P. Zuurbier and J. van de Vooren, eds. *Sugarcane ethanol: contributions to climate change mitigation and the environment*. Netherlands pp.29-62: Wageningen Academic Publishers. Available at: http://www.wageningenacademic.com/sugarcane-e [Accessed March 20, 2017].

Granco, G., M.M. Caldas, J.S. Bergtold, and A.C. Sant'Anna. 2015. "Exploring the policy and social factors fueling the expansion and shift of sugarcane production in the Brazilian Cerrado." *GeoJournal* 82(1):63–80.

IBGE, Brazilian Institute of Geography and Statistics. 2014. "Produção Agrícola Municipal – PAM." Available at: www.ibge.gov.br [Accessed May 20, 2015].

Manzatto, C.V., E.D. Assad, J.F.M. Baca, M.J. Zaroni, and S.E.M. Pereira. 2009. "Zoneamento agroecológico da cana-de-açúcar: expandir a produção, preservar a vida, garantir o futuro." *Embrapa Solos. Documentos*.

MAPA, Ministry of Agriculture, Live Stock and Supply. 2013. *Anuário estatístico da agroenergia 2012: Statistical yearbook of agrienergy.* Brasília: Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Produção e Agroenergia.

Neves, M.F., V.G. Trombin, and M. Consoli. 2011. "The sugar-energy map of Brazil." In E. L. Leao de Sousa and I. de C. Macedo, eds. *Etanol and bioelectricity: sugarcane in the future of the energy matrix*. São Paulo: UNICA, pp. 14–43.

Picanço Filho, A.F., and J.O.B. Marin. 2012. "Contratos de fornecimento de cana-de-açúcar: as assimetrias de poder entre os agentes." *INTERAÇÕES* 13(n.2):191–202.

Picanço Filho, F.A. 2010. "Contratos agrários na agroindústria canavieira em Goiás: legalidades e conflitos." Available at: http://ppagro.agro.ufg.br/up/170/o/DISSERTA%C3%87%C3%83O_FINAL_ART%C3%8AMIO_2008.pdf?1354556732 [Accessed December 9, 2014].

Procana. 2013. *Brazilian Sugar and Ethanol Guide 2013*. Ribeirão Preto: ProCana Brasil.

Reinhardt, F., N. Maurer, and R.R. de Pinho. 2009. "Cosan: thinking outside the barrel." *Harvard Business Review* (710017):35.

Sant'Anna, A.C., G. Granco, J.S. Bergtold, M.M. Caldas, T. Xia, P. Masi, T. Link, and W. Lorenzani. 2016. "The challenges of the sugarcane expansion: How do producers and land owners think and act?" In G. R. Santos, ed. *Forty years of ethanol in Brazil: Hide or confront the crises?* Brasilia: IPEA, pp. 113–142.

Sant'Anna, A.C., A. Shanoyan, J.S. Bergtold, M.M. Caldas, and G. Granco. 2016. "Ethanol and sugarcane expansion in Brazil: what is fueling the ethanol industry?" *International Food and Agribusiness Management Review* 19(4):163–182.

Shikida, P.F.A. 2013. "Expansão canavieira no Centro-Oeste: limites e potencialidades." *Revista de Política Agrícola* 22(2):122–137.

State of São Paulo Government. 2014. "Fabricação de açúcar e etanol a partir da cana-de-açúcar." *Portal do Biogás*. Available at: http://www.portaldobiogas.com/fabrica cao-de-acucar-e-etanol-partir-da-cana-de-acucar/ [Accessed June 13, 2015].

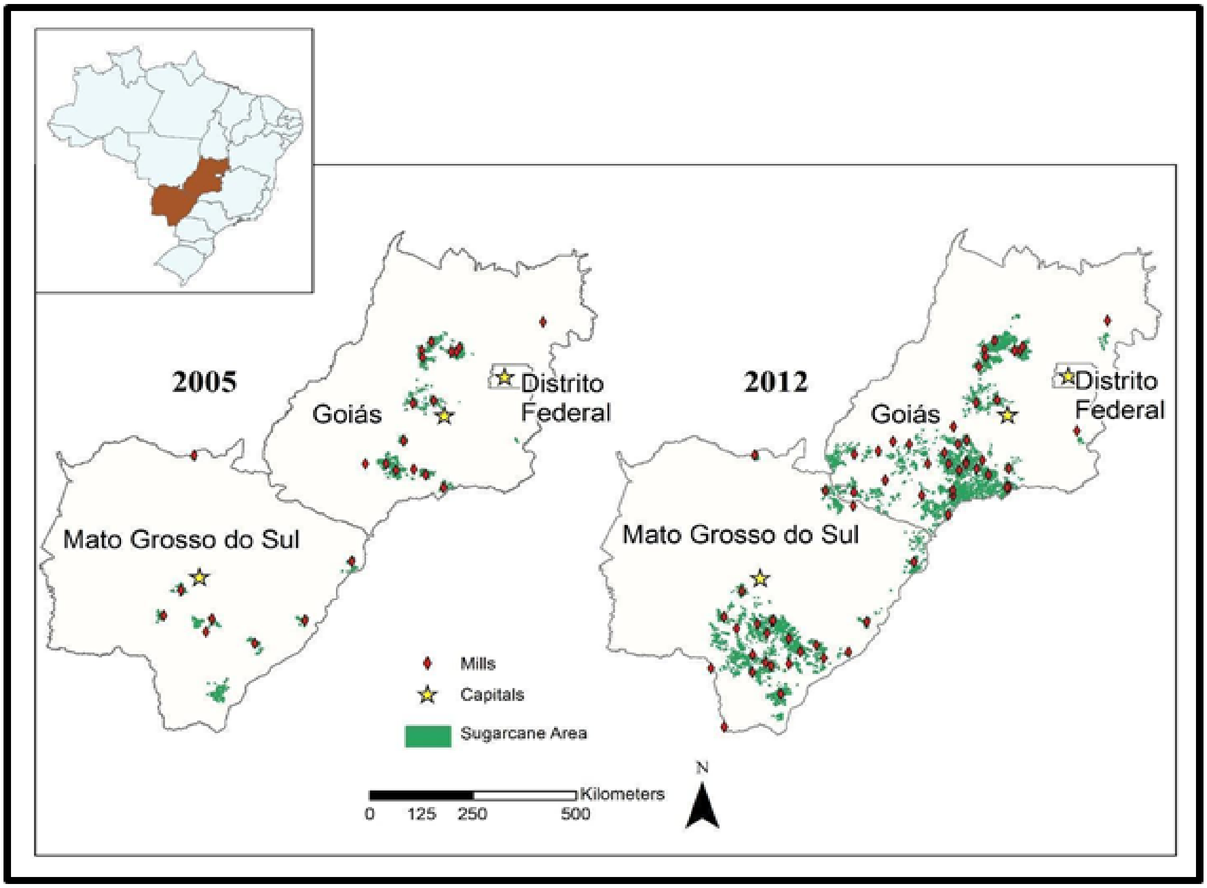


Figure 1.1: Expansion of the area with sugarcane from 2005 to 2012 in Goiás and Mato Grosso do Sul. Source: Sant'Anna, Granco, et al. (2016)

Table 1.1: Percentage of the area planted, quantity produced and the value of production in relation to the total produced in Brazil in 2000 and 2013.

State	Crop	(%) Area Planted		(%) Quantity Produced		(%) Value of Production	
		2000	2013	2000	2013	2000	2013
Goiás	Soybeans	10,9	10,5	12,5	10,9	12,0	10,5
Goiás	Sugarcane	2,9	8,4	3,1	9,0	2,5	10,1
Goiás	Corn	6,7	7,8	11,3	9,6	10,6	9,6
Mato Grosso do Sul	Soybeans	8,1	7,1	7,6	7,1	7,3	6,9
Mato Grosso do Sul	Sugarcane	2,0	6,3	1,8	5,5	1,6	5,5
Mato Grosso do Sul	Corn	4,1	9,8	3,3	9,4	3,1	7,2
São Paulo	Soybeans	3,9	2,2	3,6	2,3	4,0	2,4
São Paulo	Sugarcane	50,9	53,0	58,0	56,5	50,7	53,8
São Paulo	Corn	8,6	5,2	9,5	5,5	10,9	6,5

Source: IBGE 2014

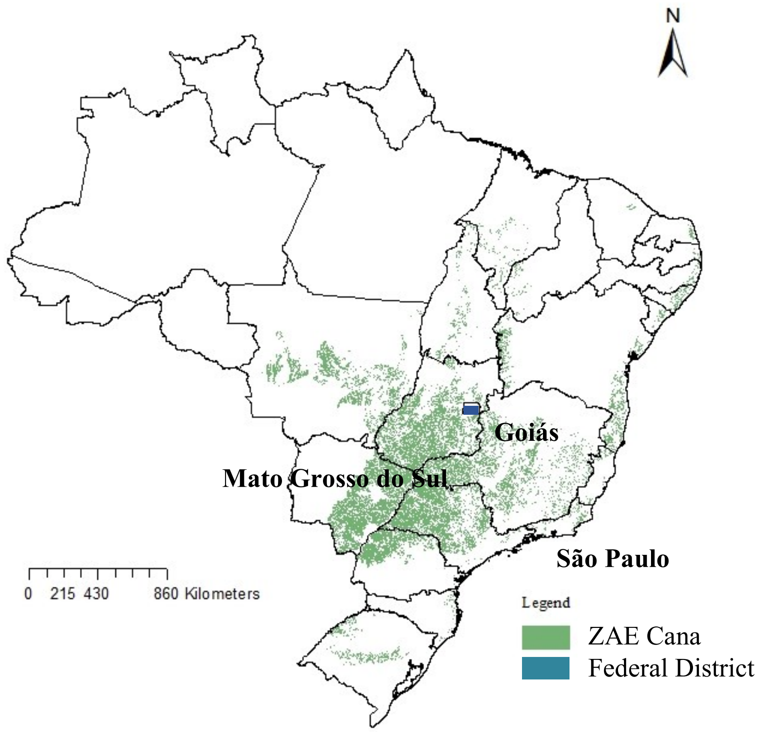


Figure 1.2: Map of Brazil with Goiás, Mato Grosso do Sul and São Paulo states and the Sugarcane Agroecological Zoning (ZAE-cana). Source: Sant'Anna, Shanoyan, et al. 2016

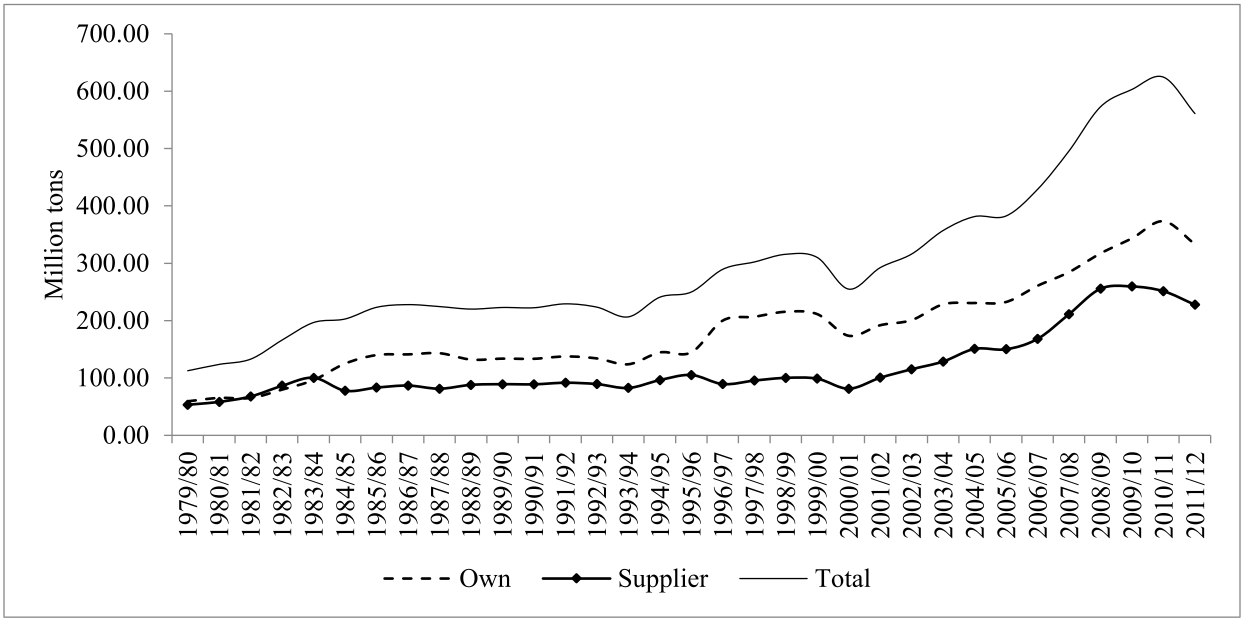


Figure 1.3: Origin of the sugarcane supplied to the mills per harvest year in million tons. Source: MAPA 2013.

Chapter 2 - What is driving the sugarcane expansion in Brazil? The impact of internal and external factors

2.1 Introduction

Brazil is one of the world's leading countries in the production of ethanol, sugar and sugarcane (MAPA 2013). The sugar-energy sector in Brazil accounts for approximately 2% of the country's Gross Domestic Product (Neves, Trombin and Consoli 2011). In Brazil, ethanol and sugar are produced from sugarcane, a crop that since its introduction in the country, has expanded from the North-Northeast region to the Center-Southeast region of the country. An increasing demand for biofuels in conjunction with public policies has prompted this expansion into the *Cerrado*, the country's second largest biome, especially in the states of Goiás (GO) and Mato Grosso do Sul (MS) (Shikida 2013). The Sugarcane Agro-ecological Zoning, launched in 2010, maps 12.6 million hectares in GO and 10.8 million hectares in MS as suitable areas for sugarcane production, promoting further expansion (Manzatto et al. 2009). Since the year 2000, more than 40 mills have been constructed in these states (Procana 2013). In 2014, these states, once large producers of grains and livestock, contributed to 22% of Brazil's total ethanol production and 9% of Brazil's total sugar production (UNICA 2015). In 2014, producers in the two states planted a total of 1.5 million hectares of sugarcane and contributed to 15% of total sugarcane production in Brazil (IBGE 2016).

As mentioned, the sugarcane/ethanol expansion into the *Cerrado* is the result of forces, internal and external, brought by government policies and regulations, technological innovations, and changes in domestic and global demand, among others (Fischer et al. 2008; Granco et al. 2015). Although sugarcane expansion in the *Cerrado* region has been the focus of many studies (Silva and Miziara 2011; CONAB 2013; Shikida 2013), few discuss its drivers (Granco et al. 2015). That is not to say that there have not been studies on the Brazilian sugar and ethanol markets. Studies can be found describing the Brazilian ethanol economy (Barros 2013), analyzing the relationship among ethanol, sugar and gasoline prices (Balcombe and Rapsomanikis 2008), estimating ethanol demand (de Freitas and Kaneko 2011), ethanol and sugarcane supply (Costa et al. 2015), the impact of ethanol policies on land use (Nuñez, Önal and Khanna 2013) and import demand for Brazilian ethanol (Farinelli et al. 2009). In addition, there are studies that analyze the impacts from changes in public policies on ethanol markets. Drabik et al. (2015) use simulations to determine the effects on the price of ethanol from trade liberalization between Brazil and the U.S., as well as, from U.S. federal tax credit removals and changes in Brazilian public policies. Gorter et al. (2013) have conducted simulations involving sugar and ethanol markets to analyze the impact of polices and sugarcane supply on ethanol, sugar and sugarcane prices. They find that removing ethanol tax exemptions and blend mandates reduces ethanol prices by 21%. Elobeid and Tokgoz (2008) analyze the impact of trade liberalization between the U.S. and Brazil. They find that trade liberalization decreases U.S. ethanol and corn prices. In this paper, we propose a model that differs from past studies by: (i) estimating both supply and demand as a system of equations to capture interactions between markets; and (ii) using time series data instead of simulation analysis to estimate elasticities for two states in the Brazilian *Cerrado*, Goiás (GO) and Mato Grosso do Sul (MS), where sugarcane has predominantly expanded over the past decade.

This study contributes to the discussion of sugarcane/ethanol expansion into the *Cerrado* by identifying and estimating the impact from the drivers of sugarcane expansion into the states of

MS and GO. These drivers are domestic and international market prices, as well as, public policies aimed at promoting sugar and ethanol markets. The novelty of this study arises from the estimation of supply and demand elasticities at the state level in Brazil, considering the interactions of national and international sugar and ethanol markets. This study also considers a longer time period, as well as using monthly time-series data over a ten-year period to estimate a system of equations modeling ethanol and sugar markets at the state level. Knowing how these forces impact the demand and supply of ethanol and sugar in Goiás and Mato Grosso do Sul is vital to understanding their role in ethanol and sugarcane expansion. Results from this study can pinpoint which policies or market factors have greater impact on sugarcane expansion within these states. This information can, not only, serve as a basis for future public policy debates, but also, facilitate the development of public programs aimed at the ethanol industry. It also aids the selection of public policies when financial resources are scarce. Results from this study will, furthermore, allow policy makers to analyze spillover effects from ethanol oriented policies on sugar production, as well as, the effect from changes in ethanol prices on sugar production and vice versa. Sugar and ethanol demand and income elasticities will provide the ethanol and sugar industry with information needed to better implement their marketing strategies.

2.2 Drivers of the sugarcane-ethanol-sugar expansion in the *Cerrado*

The *Cerrado* is Brazil's second largest biome, occupying 98% of the state of Goiás and 60% of the state of Mato Grosso do Sul (Granco et al. 2015). Sugarcane expansion in the *Cerrado* is driven by national and international demand for sugar and ethanol, as well as national policies promoting ethanol production and commercialization (Fischer et al. 2008). These national policies include: the setting of a blending ratio of anhydrous ethanol with gasoline; the introduction of flex-fuel cars in 2004, allowing consumers to choose freely between ethanol and gasoline at the pump; the reduction to zero, in 2004, of the CIDE-fuel tax (Contribution of Intervention in the Economic Domain) applied to ethanol; the increase of credit offered by the National Development Bank to sugar and ethanol producing mills; and the launch of the Sugarcane Agroecological Zoning in 2009 (Manzatto et al. 2009; Granco et al. 2015). New technology has also facilitated the expansion of the sugar and ethanol industries (Fischer et al. 2008). Modern mixed mills in Brazil can easily switch between the production of ethanol and sugar from sugarcane within the same year (Gorter et al. 2013). In 2012, Goais and Mato Grosso do Sul had together 28 mixed mills, 27 plants that only produced ethanol and 1 that only produced sugar (CONAB 2013).

Market factors that impact the production of ethanol and sugar are the prices of ethanol, sugar and gasoline, as well as interest rates. The prices of hydrous ethanol in Brazil have varied between US$0.26/L in 1999 and US$0.58/L in 2014. Anhydrous ethanol prices always have been higher than hydrous ethanol though, following the same pattern (Figure 2.1). A similar story occurs with domestic and international sugar prices (Figure 2.2). In the same period, the prices of sugar varied between US$0.13/Kg in 1999 and US$0.42/Kg in 2014. The national prices of sugar have followed the same trajectory as international prices. In 1999, a kilo of sugar cost US$0.14, whereas in 2014 the same kilo cost US$0.38. Prices of gasoline in Brazil are controlled by the Brazilian government with the intention of curving inflation. This policy, though, affects the ethanol industry by reducing the competitiveness of ethanol fuel prices, which are not regulated (Granco et al. 2015). Keeping gasoline prices below international prices prevents ethanol being sold at higher prices. As substitute goods, one would expect ethanol and gasoline prices to be related. Balcombe and Rapsomanikis (2008) find that oil prices are the principal long-run drivers of ethanol and sugar prices. The ethanol industry has benefitted when the prices of gasoline in Brazil are higher than international prices (Granco et al. 2015).

Another market factor is the Brazilian interest rate, which is based on the Special System for Settlement and Custody (SELIC). Set by the Brazilian Central Bank, variations in the SELIC affect the level of interest rates used in banking loans (BCB 2016). The interest rate was at its highest in the year of 1999, decreasing overtime (Figure 2.3). When analyzing agricultural commodity producers in Brazil, de Castro and Teixeira (2012) argue that greater access to rural credit allows farmers to increase output. Similarly, we expect that increases in interest rates may decrease mills' access to loans reducing their sugar and ethanol supply.

In Brazil, hydrous ethanol (E100) is demanded as a substitute for gasoline in flex-fuel cars, which entered the market in 2004, and currently make up more than 60% of the country's fleet (UNICA 2015). Before 2004, two types of cars were sold, those that ran on ethanol and those that ran on gasoline. Flex-fuel cars allow gasoline and E100 to be used interchangeably. Due to ethanol's lower mileage, consumers choose E100 over gasoline when the price of ethanol is 70% or less than that of gasoline (Granco et al. 2015). Anhydrous ethanol is demanded by fuel distributers to be mixed into gasoline in order to fulfill the blend mandate set by the government (Granco et al. 2015). Hydrous consumption varied more than that of anhydrous in the period considered. Greater variations in hydrous ethanol consumptions occur between 2010 and 2013, possibly due to changes in gasoline prices and oscillations in ethanol production. Anhydrous consumption increased from 20 million liters to 40 million liters from 1999 to 2014 (Figure 2.4).

A number of public policies in Brazil have motivated the expansion and production of ethanol and sugar. Through the National Development Bank, the Brazilian government provides subsidized loans to the sugar and ethanol industry. The loans for ethanol production increased from

US$1.3 million in 1999 to US$385 million in 2014. Loans to the sugar industry were also higher, increasing from US$1.8 in 1999 to US$135 million in 2014 (BNDES 2015) (Figure 2.5). In particular, new lines specifically directed towards the sugar and ethanol sector were created: the PRORENOVA (Program to support the renovation and implementation of new sugarcane fields), directed towards the renewal or expansion of sugarcane fields, and the Pass program (Program to Support the Sugar and Ethanol Sector), directed towards ethanol storage (Granco et al. 2015). Complementing the subsidized loans is the blend mandate. The blend mandate began in Brazil in the 1930s with the requirement of a mixture of 5% of ethanol with gasoline fuel (Sant'Anna, Shanoyan, et al. 2016). The blend mandate is set by the government making it mandatory that all gasoline sold in Brazil has a determined percentage of anhydrous ethanol in it (Figure 2.6). In 2015, the federal government increased the mandated amount of ethanol to be mixed into gasoline from 25% to 27% (Amato and Matoso 2015).

A further public policy aimed at benefitting the ethanol industry was the removal of the CIDE-fuels tax (Contribution of Intervention in the Economic Domain) applied on ethanol. The CIDE, a tax applied on commercialized fuel, was created in 2001 by law #10,336. In 2004 the CIDE-fuels tax applied on ethanol was reduced to zero, while that applied on gasoline varied between US$96.91/$m^3$ in 2004 to US$54.62/$m^3$ in 2011 (Maciel 2011). After 2011, the CIDE was removed from gasoline until the end of 2014. Figure 2.7 presents the CIDE fuel taxes per liter on both fuels (i.e. ethanol and gasoline).

Lands suitable to sugarcane production were delimited by the Sugarcane Agroecological Zoning program in 2009. The program was developed to avoid the conversion of native *Cerrado* regions into sugarcane plantations, while identifying areas suitable for sugarcane cultivation and mechanization (Granco et al. 2015). Farmers that produce sugarcane in this delimited area have easier access to governmental programs, such as subsidized loans from BNDES.

2.3 Ethanol and sugar markets – A general modeling framework

The supply and demand model for the markets of sugar and ethanol follows the set up proposed by Lin (2005). These markets are interconnected, through the prices of sugar, ethanol and sugarcane prices, to account for the effects of the ethanol market on the sugar market and vice versa. There are *M* markets of sugar and *N* of ethanol occurring at times $t = 1,..,T$. Although markets of sugar and ethanol are modelled we suppress the index for each market to simplify notation. At each time t, p_t is the price of the product, q_t the quantity transacted, and x_t a vector of market characteristics, including direct and cross-price effects. The quantity demanded of each product is q_t^d while the quantity supplied is q_t^s. Both quantities are a function of prices and market characteristics. It is assumed that both producers and consumers are price-takers. In equilibrium, markets clear, such that:

$$q_t^d(p_t, x_t) = q_t^s(p_t, x_t) \tag{2.1}$$

At each time period t only equilibrium prices and quantities are observed in each market. Prices and quantities are determined simultaneously making it hard to identify supply and demand (functions) independently. Let the structural equations for supply and demand in each market, with ε_t^d and ε_t^s representing residuals, be given by (Lin 2005):

$$\text{Demand: } q_t^d = f(p_t^d, x_t^d, x_t^m, \varepsilon_t^d) \tag{2.2}$$

$$\text{Supply: } q_t^s = f(p_t^s, x_t^s, x_t^m, \varepsilon_t^s) \tag{2.3}$$

$$\text{Market Clearing: } q_t^d = q_t^s = q_t \text{ and } p_t^d = p_t^s = p_t \tag{2.4}$$

where x_t^d are factors that only shift market demand (e.g. income), x_t^s are factors that only shift market supply (e.g. input prices), and x_t^m are factors that affect both market supply and demand. These factors are elements of the vector x_t (i.e. $x_t = (x_t^d, x_t^s, x_t^m)$), which allows for the identification of supply and demand functions (Lin 2005). Substituting in the market clearing conditions, equations (2.2) to (2.4) can be further simplified to:

$$\text{Demand: } q_t = f(p_t, x_t^d, x_t^m, \varepsilon_t^d) \tag{2.5}$$

$$\text{Supply: } q_t = f(p_t, x_t^s, x_t^m, \varepsilon_t^s) \tag{2.6}$$

Following economic theory, we expect the coefficient related to the price in the demand equation to be negative, so that demand is downward sloping, and the coefficient related to the price in the supply equation to be positive, so that supply is upward sloping. Since x_t^d only impacts supply through its effect on the equilibrium price p_t it can be used to instrument the price in the supply equation (Lin 2005). Analogously, x_t^s can be used as an instrument for the price in the demand equation. The exogenous vector of components that affect both equations x_t^m, serves as instruments to both equations. It is assumed that these instruments have a non-zero correlation with price and a monotonic effect on price to obtain estimates of the coefficients of the structural system that are consistent and identified (Lin 2005).

2.4 Empirical model

A multi-equation, multi-product economic model was developed to study the impact of the various factors on the supply and demand for sugar and ethanol in Mato Grosso do Sul and Goiás. The model is composed of six equations: three for the ethanol market and three for the sugar market (Equations 2.8 to 2.12). The empirical model can be represented as:

Sugar Demand:

$$lnscons_t = \alpha_1 + \alpha_2 lnpsugrow_t + \alpha_3 lngdp_t + \alpha_4 dummyfeb + \alpha_5 lnscons_{t-2} + \alpha_6 lnscons_{t-3} + \alpha_7 trend^2 + \varepsilon_t \quad (2.8)$$

Sugar Supply:

$$lnssup_t = \beta_1 + \beta_2 lnpsugrow_t + \beta_3 lnphyd_t + \beta_4 Dsbndes + \beta_5 lnselic_t + \beta_6 lnpcane_t + \beta_7 zone + \beta_8 lnssup_{t-1} + \beta_9 dsugsup * lnssup_{t-1} + \beta_{10} dum3 + \beta_{11} dsugsup + \varepsilon_t \quad (2.9)$$

Sugar Supply to the Rest of the World:

$$lnsexp_t = \gamma_1 + \gamma_2 lnpsugrow_t + \gamma_3 lnpcane_t + \gamma_4 lnsexp_{t-1} + \gamma_5 dum3 + \gamma_6 dum4 + \gamma_7 dum7 + \gamma_8 Dsbndes + \gamma_9 zone + \varepsilon_t \quad (2.10)$$

Ethanol Supply:

$$lnesup_t = \delta_1 + \delta_2 psugrow_t + \delta_3 pcane_t + \delta_4 phyd_t + \delta_5 phyd_t^2 + \delta_6 zone + \delta_7 Debndes + \delta_8 lnselic + \delta_9 diffcide + \delta_{10} lnblend + \varepsilon_t \quad (2.11)$$

Demand for Anhydrous Ethanol:

$$lnacons_t = \mu_1 + \mu_2 lngdp_t + \mu_3 lnpgas_t + \mu_4 dumadem + \mu_5 trend^2 + \varepsilon_t \quad (2.12)$$

Demand for Hydrous Ethanol:

$$lnhycons_t = \varphi_1 + \varphi_2 ratio_t + \varphi_3 gdp_t + \varphi_4 dumhydem + \varepsilon_t \quad (2.13)$$

Table 2.1 provides definitions for all variables.

Sugar demand is a function of international sugar prices and the gross domestic product per capita. The international sugar price and the domestic price of sugar are highly correlated, such that the choice of one of them was made in order to avoid multicollinearity problems. The international price was chosen over the domestic price since over 50% of Brazilian sugar production is exported. Unfortunately, it was not possible to find domestic prices for sugar substitutes and therefore these were not considered.

Sugar supply is a function of international sugar prices, the price of ethanol, price of sugarcane, a dummy representing the years when subsidized loans were low or zero, the interest rate and a dummy representing the launch of the Sugarcane Agro-ecological Zoning in 2010. We consider only the price of hydrous ethanol since hydrous and anhydrous prices are highly correlated. Anhydrous ethanol prices are equivalent to the price of hydrous ethanol plus the extra cost of dehydration (Elobeid and Tokgoz 2008). Sugar supply to the rest of the world relates sugar exports from these states with international sugar prices, sugarcane prices, and public policies (i.e. subsidized credit and zoning).

Turning to the ethanol market, ethanol supply is a function of the international price of sugar, hydrous ethanol price, price of sugarcane, a dummy representing the launch of the zoning policy, a dummy representing when the amount of subsidized credits was low or zero, the blending requirement of ethanol into gasoline, the interest rate and the difference between the fuel tax applied on ethanol and the fuel tax applied on gasoline.

Ethanol demand is split between demand for hydrous and demand for anhydrous ethanol. Demand for anhydrous ethanol is a function of the gross domestic product per capita and gasoline prices. Since anhydrous ethanol can only be consumed through gasoline consumption, consumers ultimately look at gasoline prices when deciding how much anhydrous ethanol to consume.

Demand for hydrous ethanol is a function of the ratio of hydrous ethanol prices to gasoline prices and the gross domestic product per capita.

Although mills in Brazil produce and sell electricity, this product was not considered in this study. Supply of electricity is not considered since energy in these states are mostly used as an input by the mill in sugar and ethanol production. The price of other crops, such as soybeans, were not considered as a factor since the farmer cannot easily switch from sugarcane production to grain production. Sugarcane is a perennial crop with a cycle of up to six years. Furthermore, farmers that decide to produce sugarcane in the states of Goiás (GO) and Mato Grosso do Sul (MS), do so, usually, under contract, increasing the transaction cost of changing crops. In a survey conducted in GO and MS, Sant'Anna, Granco, et al. (2016) find that 89% of farmers and landowners agree that it is impossible to grow sugarcane in these states without a contract.

The excess supply of ethanol to the rest of the world is not modelled, since most of the ethanol production in Brazil is for domestic consumption. Brazil exports around 10% of its total ethanol production, whereas it exports over 50% of its sugar production (MDIC 2016). In particular, the states of MS and GO have a greater history of exporting sugar instead of exporting ethanol. Evidence of ethanol exports from these states is very sporadic, with most of the exports occurring from 2013 onwards (MDIC 2016) (Figure 2.8). In contrast, sugar exports in these states have ranged from 154 million kilos in 1999 to 160 million kilos in 2014. Thus, the excess supply of ethanol to the rest of the world is not believed to have a significant impact on the expansion of ethanol in MS and GO.

Supply and demand equations are traditionally estimated as simultaneous equation models using three stage least squares (3SLS) to correct for endogeneity. Endogeneity arises from the fact that prices and quantities are determined jointly with the dependent variable via an equilibrium mechanism (Wooldridge 2009). 3SLS is a method using structural disturbances from two stage least squares estimation to simultaneously estimate the coefficients of a whole system (Zellner and Theil 1962). 3SLS allows for gains in efficiency in the presence of contemporaneous covariance as long as the system has over-identified equations (Zellner and Theil 1962). It allows for endogenous variables on the right-hand side of the equations to be corrected by using generalized instruments made up of the exogenous variables in the model as well as additional exogenous variables chosen by the modeler. Prices of sugar, gasoline, anhydrous and hydrous ethanol, as well as the quantities of sugar and ethanol supplied and consumed are considered endogenous. Exogenous variables outside of the model are the population and the production of ethanol and flex-fuel cars in MS and GO. A detailed description of the variables and respective transformations is provided in Table 2.1.

Estimations were conducted in STATA 13. Prior to running the 3SLS, the single equations were run individually using ordinary least squares and misspecification tests were conducted. The normality of the residuals was tested using the Shapiro-Wilk and the Shapiro-Francia tests (Royston 1983; Royston 1993). Functional form was tested using the Ramsey regression specification-error test (Ramsey 1969) and the link test (Pregibon 1979). Heteroskedasticity was tested using a test which is built on three versions of the Breusch and Pagan (1979) and Cook and Weisberg (1983) tests and an information matrix test suggested by Cameron and Trivedi (1990). Autocorrelation was tested by estimating the correlation between the residuals in the current month and in the previous month using Kendall’s rank correlation (Kendall 1938). To correct for violations to these properties interactions, dummies, lags and trends were added to equations and/or the data was transformed by taking logs. For instance, *dsugsup* was added as a dummy to account for a structural change in the data. Graphical analysis of the relationships among the variables were also used when deciding on the inclusion of trends, interactions or data transformations. The objective was to properly represent the relationship between the dependent and independent variables with statistical reliability (McGuirk, Driscoll and Alwang 1993) (see Appendix A for full results and detailed explanations).

After the 3SLS system was estimated the residuals for each equation were checked for normality using the Shapiro-Wilk and the Shapiro-Francia tests (Royston 1983; Royston 1993). An over identification test was also conducted using Hansen-Sargen test coded by Baum et al. (2006). A Hausman's specification test was used to test for the importance of the instruments, as well (Hausman 1978).

Own-price, Cross-price, input and income elasticities were estimated for supply and demand markets, where applicable. When the equations had logarithmic values of the dependent and independent variables (e.g. equation 2.12), the elasticity will be equivalent to the value of the respective coefficient. In cases of log-linear specification such as equation (2.11) the coefficient was multiplied by the mean of the variable. For instance, the own price supply elasticity of ethanol is calculated as ($\delta_4 * \overline{phyd}$). Similarly, cross-price elasticities were calculated as the coefficient times the mean of the variable (e.g. cross-price supply elasticity of the price of sugar is ($\delta_2 * \overline{psugrow}$). Compensated demand elasticities are calculated following Deaton and Muellbauer (1980). For example, the sugar compensated demand is calculated as:

$$\left[\alpha_3 * \left(\frac{sugar\ prices * quantity\ supplied}{GDP}\right) + \alpha_2\right] \tag{2.14}$$

Standard errors for elasticities were estimated using the delta method (Greene 2008).

2.5 Data

This study considers the period from January 1999 to December 2014. Secondary data was collected for Goiás and Mato Grosso do Sul and summary statistics are presented in Table 2.2. The period considered is important since it encompasses the introduction of flex-fuel cars in 2004 and the implementation of national policies such as the Agro-ecological Zoning of Sugarcane and the elimination of the fuel tax on ethanol. In general, information that was only available on a yearly basis was transformed into monthly by dividing the yearly amount by twelve. In order to account for inflation, current values were converted into real values. Variables related to the consumption of sugar or ethanol (e.g. income or the price of ethanol) were converted using the consumer price index (Eurostat 2016). The prices of inputs (e.g. sugarcane) were converted into real values using the producer price index (Index of the Broad Producer – IPA) (IPEA 2015).

Data on gasoline prices and the consumption of hydrous ethanol comes from the Brazilian National Agency of Petroleum (ANP 2014). Data was gathered for both states and then the average of both prices were used in the final model. Consumption of anhydrous ethanol was estimated using the information on gasoline consumption and on the blend mandate. Gasoline consumption data is available at the Brazilian National Agency of Petroleum (ANP 2014). Sugar exports from both states were collected from the Brazilian Ministry of Industry, Foreign Trade and Services (MDIC 2016). Total sugar exports were calculated by adding monthly sugar exports from both states. The aggregated quantity of sugar consumed in Brazil per year was obtained from the Foreign Agricultural Service (FAS) from the U.S. Department of Agriculture (USDA 2017). Sugar consumption per capita was calculated by dividing the total sugar consumption by the Brazilian population (IBGE 2016). Sugar consumption per capita was then multiplied by the populations of the states of Goiás (GO) and Mato Grosso do Sul (MS) to calculate sugar consumption in these states. Monthly sugar consumption was calculated by dividing the total amount of yearly sugar consumption in MS and GO by 365 and then multiplying the daily sugar consumption by the number of days in each month. The amount of sugar and that of ethanol supplied were set as the equivalent to the quantities demanded. This equivalence was chosen since there is no information on storage of sugar and/or ethanol for the time period. We only had information on ethanol and sugar production and consumption. Thus, our model accounts for storage since it sets quantity supplied equal to quantity demanded. In other words, the amount of sugar supplied each month is the sum of sugar demanded and sugar exported. The total amount of ethanol supplied is the sum of the consumption of hydrous and that of anhydrous ethanol.

Sugarcane prices come from the Union of Bioenergy Producers (UDOP) and are in Reais (R$) per kilo of TRS (Total Recoverable Sugar). The TRS represents the quantity of sugar in the sugarcane minus the losses occurred during industrial processing (UNICA 2015). Information on foreign prices of sugar were collected from the U.S. Department of Agriculture sugar and sweetener tables (USDA 2013). Brazilian prices of ethanol, hydrous and anhydrous come from the Center for Advanced Studies in Applied Economics (CEPEA 2015). The prices for the state of Alagoas were chosen as a proxy for the price of both states as it was the longest time series available. The interest rate (SELIC – Special System of Liquidation and Custody) time series come from the Brazilian Institute of Applied Economics Databank (IPEA 2015). Information on gross domestic product per capita came from the Brazilian Institute of Geography and Statistics (IBGE 2016). Missing months were estimated as a percentage of the total population of Brazil. Information on the sales of flex-fuel and ethanol cars came from the National Association of Automotive Vehicle Producers (ANFAVEA 2015). This information is only available at a national scale therefore state level was estimated by calculating production per capita, using the country's population and then multiplying by the population of the states of MS and GO. The amount of subsidized loans received by ethanol and sugar producers was acquired from the Brazilian National Development Bank (BNDES 2015). A dummy variable (Debndes) was created where 1 represents the months with no or low amounts of subsidized credit. For the subsidized credit for the sugar industry Dsbndes = 1 from January 1999 to January 2006, while for the ethanol industry Debndes = 1 from January 1999 to March 2007. Information on the blend mandate came from the Brazilian Ministry of Agriculture, Livestock and Supply (MAPA 2010). This information was the same for the whole country and did not change monthly. It is set by the government. Information on the CIDE fuel tax came from the research conducted by Maciel (2011). From 2001 onwards ethanol fuel was not taxed with CIDE. After 2012 the CIDE tax was also removed from gasoline, returning after 2014. Similar to the case of the blend mandate, changes in these taxes are set by the government and do not necessarily change on a month to month basis.

2.6 Results

In general, the signs of the coefficients correspond to those expected from economic theory (Table 2.3 and 2.4). For instance, increases in the price of a good increase the quantity supplied, while decreasing the quantity demanded. Equations in the sugar and ethanol markets have R^2 of 0.75 up to 0.96 indicating a good fit for the data (Table 2.3 and 2.4). The Hausman test rejects the null hypothesis at a statistically significance level of 5% indicating that the 3SLS estimation explains better the model than an OLS estimation.

2.6.1 Public policies

According to Moraes and Zilberman (2014) the sugar market did not fully rely on public policies in the late 1990s due to its marketing mechanisms and product differentiation strategies. In turn, the same authors conclude that, ethanol markets are more dependent on public policies than either sugar or sugarcane markets. Results from this study point to similar conclusions. Public policies appear to have a greater impact on ethanol than on sugar supply. The Sugarcane Agro-ecological Zoning program (ZAE-Cana) has a statistically significant impact on ethanol supply but not on sugar supply (Table 2.5). It increases ethanol supply by 0.57%, which is equivalent to a growth of 284 thousand liters in the quantity supplied of ethanol. The fact that the ZAE-Cana only has a statistically significant impact on ethanol supply is not surprising. It was created by the Brazilian National Plan of Agro-energy 2006-2011 to map areas for agro-energy (Brazil 2006). ZAE-Cana was created with the intent of motivating ethanol production (Oliveira and Ramalho 2006; Brazil 2009).

Sugar and ethanol supply are both impacted by subsidies. Lack of available subsidized credit (i.e. BNDES) impacts ethanol supply more than sugar supply, in percentage terms. Lack of subsidized credit decreases ethanol supply by 0.84% or 419 thousand liters and sugar supply by 0.08% or 57 thousand kilos. This difference in impact may be due to the fact that incentives for sugarcane expansion towards the center of the country have focused on ethanol rather than sugar production. In the period considered, the total amount of subsidized loans assigned through the BNDES programs for sugar production was US$1 billion, while that for ethanol production was US$2.93 billion (BNDES 2015).

It is not surprising that ZAE-Cana and the BNDES subsidized credits do not have a statistically significant impact on the supply of sugar to the rest of the world since these programs are aimed at domestic production. Results show that sugarcane prices impact sugar supply to the rest of the world and sugar prices impact the quantity supplied (Table 2.3).

Apart from the ZAE-Cana and the BNDES subsidized loans there are other public policies in place to motivate ethanol supply (e.g. the blend mandate and the differences in taxes applied on ethanol and gasoline fuels). Results show that these policies do have an impact on ethanol supply. A one percent increase in the difference between the taxes applied on ethanol and the taxes applied on gasoline results in an increase in ethanol supply by 1.25% or 623 thousand liters. An increase in the blend mandate by one-percent, that is of 0.23%, results in an increase in ethanol supply by 3.14% equivalent to 1.6 million liters. Thus, among the policies studied the blend mandate has the greatest impact on ethanol supply. This is may be due to the fact that an increase in the blend mandate automatically increases demand for ethanol, for it is required to be mixed into gasoline. These results compliment Moraes and Zilberman (2014)'s argument for the blend mandate policy over the policy on eliminating the CIDE fuel tax. The same authors cite the complexity of simultaneously regulating gasoline and ethanol prices, such as the Brazilian government has done. The government has controlled gasoline prices to curb inflation while it has reduced fuel taxes on hydrous ethanol for it to be competitive with gasoline.

2.6.2 Sugar and ethanol supply

The own-price supply elasticities for domestic sugar and ethanol supply are inelastic, while sugar exports are elastic. There is larger fluctuation in the sugar quantities exported than in the quantities supplied domestically. This variation may be due to changes in the exchange rates. Another reason for the larger impact maybe due to the reduction of protectionist policies in importing countries in 1999 which increased Brazilian sugar exports (Moraes and Zilberman

2014). A one-percent increment in the sugar price leads to a 0.64% increase in the amount of sugar supplied, equivalent to 319 thousand kilos of sugar. This result is in the range of elasticities estimated in previous studies. These studies found short-run sugar own-price supply elasticities between 0.33 and 1.89 (Arend 2001; Caruso 2002). In terms of the ethanol market, a one-percent increase in the price of hydrous ethanol (i.e. R$0.01) results in an increase of 0.43% in the quantity of ethanol supplied. This coefficient, though, is not statistically significant. A similar result is also found in Shikida et al. (2007). They find the impact of sugar prices on sugar quantities supplied to be statistically significant, while the impact of ethanol prices on ethanol quantities supplied to be statistically insignificant. They attribute the statistical insignificance of the coefficient to the instability in ethanol prices during the 1980s. In our case, government control of gasoline prices, setting them below international prices, may be the cause of the statistical insignificance for the ethanol price coefficient. The own-price ethanol supply elasticity is close to those from previous studies. These range from 0.207 to 0.75 is the literature (Oliveira, Alencar and Souza 2008; Costa et al. 2015).

In terms of sugar exports, an increase of one percent in the price of sugar increases the quantity of sugar supplied to the rest of the world by 2.28%, or 751 thousand kilos of sugar. This impact may be due to changes in the exchange rate. Alves and Bacchi (2004) find that a one percent increase in the exchange rate in four months causes a variation of 2.18% in sugar exports. Sugar and sugarcane prices have a larger impact on foreign sugar supply and the quantity supplied than on the domestic supply and quantity supplied of sugar. An increase of R$0.01 (US$0.003) in the price of sugarcane decreases sugar supply by 0.87% or 617 thousand kilos and sugar supply to the rest of the world by 2.43% or 800 thousand kilos. The larger impact on export supply may come from extra transport costs involved in exporting sugar, such that increases in sugarcane prices cause greater impacts on production costs for exported sugar. The input price supply elasticity of sugarcane on ethanol lies between that of domestic sugar supply and sugar exports. A one percent increase in the price of sugarcane or a raise of US$0.003 decreases ethanol supply by 1.07% or 534 thousand liters. This elasticity is a little lower than that found by Marjotta-Maistro and Barros (2003) of -1.45, though not statistically significant.

Results indicate that ethanol and sugar are compliments in production in the sugar and ethanol industry. A one percent increase in the price of sugar increases the amount supplied of ethanol by 2.11% or 1.05 million liters. If the real price of hydrous ethanol increases from R$1.05 to R$1.06 (i.e. US$0.400 to US$0.403) the amount of sugar supplied grows by 0.35%, equivalent to 175 thousand kilos. This result can be explained by the fact that mixed mills, those that can produce both ethanol and sugar, usually produce a mix of both (Drabik et al. 2015). Also, mills can produce ethanol from molasses, a by-product of sugar (Elobeid and Tokgoz 2008). The percentage of ethanol and sugar that a mill produces is decided at the beginning of the year. Since our data is monthly, it would be expected these two outputs are complimentary instead of substitutes during a particular year. As there are more months than years in the data, the results pick up the positive correlation between the variables rather than the potential substitution relationship. In addition, the ratio of ethanol to sugar product does not exhibit much variation throughout the year. The ratio of sugar/ethanol production in Brazil is generally set to 40:60 (Barros 2015). In fact, in 2011/12 around 28% in GO and 37% in MS of the sugarcane produced was destined for sugar production and 72% in GO and 63% in MS of sugarcane went to produce ethanol (Santos 2013; CONAB 2013). The larger ratio in the production of ethanol to sugar may explain why increments in sugar prices appear to have a larger impact on ethanol supply than changes in ethanol prices have on sugar supply.

The preference for a higher percentage in the amount of ethanol supplied over that of sugar may be due to the lower variation in ethanol prices compared to that of sugar and, to the blend mandate ensuring that a minimum amount of ethanol is demanded. Another reason for mills preferring to produce more ethanol than sugar may be due to the fact that public policies motivating the sugarcane expansion into the *Cerrado* are aimed at expanding ethanol rather than sugar production. Nevertheless, it is important to notice how a growth in ethanol prices has spillover effects in the quantity of sugar supplied and vice versa (i.e. a growth in ethanol prices increases the quantity of sugar supplied). This result has important implications for public policies (i.e. you can invest in public policies in one industry and impact both industries).

2.6.3 Ethanol and sugar demand

Gasoline prices have a high influence on the demand for hydrous ethanol (Moraes and Zilberman 2014). Consumers make their decision about purchasing hydrous ethanol at the pump by looking at the ratio of the price of hydrous over that of gasoline. Employees at the gas station may also suggest which fuel customers should buy based on the prices. It is economic to purchase hydrous ethanol when its price is 70% or less of that of gasoline. An increase in the real ratio reduces the quantity demanded of hydrous ethanol by 2.58% or 691 thousand liters (Table 2.7). The use of flex-fuel cars, which currently accounts for 90% of the Brazilian fleet, allows gasoline and hydrous ethanol to be used interchangeably (Moraes and Zilberman 2014). This may explain why we find hydrous ethanol demand to be elastic. This result is comparable to Santos (2013), who finds that ethanol and gasoline are imperfect substitutes. The cross-price elasticity of gasoline to ethanol is 0.099 while that of ethanol to gasoline is 1.182. Santos (2013), also finds that ethanol has an own-price elasticity of -1.252, making our result of an elastic demand for ethanol plausible.

As can be seen by the result, consumers are very sensitive to fuel price changes. Brazilian consumers' purchasing decisions are constantly influenced by news reports on fuel prices and on when hydrous ethanol should be preferred (e.g. Estadão Conteúdo 2015). This result highlights the consequences of fuel pricing policies. The government's current aim of controlling gasoline prices irrespectively of the variation in international oil prices or production costs affects the competitiveness of hydrous ethanol prices (Moraes and Zilberman 2014). Moraes and Zilberman (2014) point to the complexity of trying to stabilize gasoline prices while influencing hydrous prices by eliminating CIDE fuel tazes.

In terms of consumer demand for anhydrous ethanol, it is the price of gasoline that influences their purchasing decision since anhydrous can only be demanded through gasoline consumption When the real price of gasoline increases by 1% (i.e. from R$2.89 to R$2.92 per liter or US$1.10 to US$1.11), the quantity of anhydrous demanded declines by 0.75% or 173 thousand liters. As Santos (2013) found, gasoline is a necessary good with a short-run price elasticity of -0.39. The inelastic demand for anhydrous ethanol compliments Moraes and Zilberman (2014)'s argument for the production of only anhydrous ethanol and no other ethanol. Moraes and Zilberman (2014) favor the public policy of the blend mandate over that of the pricing policy of the elimination of the CIDE fuel tax.

In terms of the sugar market, an increase of R$0.07 (US$0.03)[1] in real prices causes a decrease in 0.01% in the amount of sugar demanded (i.e. 3.8 thousand kilos of sugar). The uncompensated own price elasticity of the demand for sugar is -0.01 but is not statistically significant. Thus, demand for sugar appears not to be affected by its price. The values of the compensated (-0.009) and uncompensated own price elasticities are very close, and are both

[1] Exchange rate used is that of December 2014 where US$1=R$2.6387.

statistically insignificant. The value of the sugar demand elasticity, though inelastic, is smaller than that found in previous studies -0.08 (FAPRI 2016). In the month of February, the demand for sugar was lower, possibly because this month has less days than the rest. Demand for sugar in February decreases by 0.08% or 30 thousand kilos. Increases in sugar consumption in previous months, causes increases in the current month. There seems to be an increasing pattern in sugar consumption though lagged sugar consumption was added in the model to control for autocorrelation.

2.6.4 Expenditure elasticities

Expenditure elasticities for hydrous, anhydrous and sugar are varied (Table 2.8). An increase of one-percent in the real gross domestic product (GDP) per capita, or R$23.85 (US$9.04) results in an increase of 0.17% in the amount of sugar demanded, equivalent to 65 thousand kilos of sugar. The expenditure elasticity for sugar is 0.17 and is significant at the 1% level of significance (Table 2.8). It is only slightly larger than that found of 0.15 found by FAPRI (2016). Thus, sugar is a normal good.

In the ethanol market, a one-percent increase in real GDP reduces the demand for anhydrous ethanol by 0.63%. In other words, when GDP increases by R$23.85 (US$9.04) anhydrous demand falls by 145 thousand liters. An increase of one percent in GDP causes the consumption of hydrous ethanol to rise by 3.99% or 1.07 million liters. This impact is greater than that found by de Freitas and Kaneko (2011) of 0.944 for the Center-South region. De Freitas and Kaneko (2011), though, model ethanol demand without considering simultaneous effects from ethanol supply and sugar markets, which may explain the different results.

Moraes and Zilberman (2014) argue that low fuel prices are the concern of low and middle income consumers. Here we find hydrous ethanol to be a luxury good. Perhaps as consumers with flex-fuel cars move to an upper income class they become more concerned with the environment and opt for hydrous ethanol instead of gasoline. Similar to what Anderson (2012) finds for the U.S., where consumers are willing to pay a premium of US$0.24 to purchase E85, a mixture of 85% ethanol and 15% gasoline (Anderson 2012).

2.7 Conclusion

This study estimates the impacts from internal and external factors on the ethanol and sugar expansion in the *Cerrado* region, particularly in the state of Goiás and Mato Grosso do Sul. Once market and policies drivers were identified, a system of demand and supply equations for sugar and ethanol markets was estimated using 3SLS. Elasticities were then calculated using the estimated coefficients. Results show that ethanol supply is more sensitive to changes in public policies than sugar supply. From the public policies applied, the blend mandate had the largest impact in ethanol supply and the BNDES subsidized credit had the largest impact on domestic sugar supply. Sugar exports do not seem to depend on public policies and they are more sensitive to sugar and sugarcane prices than domestic sugar supply. Sugar and ethanol were found to be complimentary outputs, that is, positive changes in ethanol prices cause increases in sugar supply and vice versa. In terms of demand, demand for hydrous ethanol was found to be sensitive to changes in gasoline prices. While own price demand for hydrous ethanol was elastic, own price demand for anhydrous ethanol was inelastic. As consumer income increases the preference for hydrous ethanol increases instead of gasoline.

Spillovers from the sugar market into the ethanol market and inversely imply that policy makers must be cautious when deciding on pricing policies that should only impact one market. This spillover result is a consequence of technology allowing mills to produce both inputs simultaneously. Sugar markets not being sensitive to public policies points to the sustainability of the industry and to how appropriate the current sugar market structures might be. Therefore, we believe that in order to promote sugarcane expansion in Brazil the government should focus its resources on the ethanol industry. Results from this study help the Brazilian government to decide on which policy to invest in when faced with limited resources. Out of the programs analyzed the blend mandate had the largest impact and the zoning the smallest.

The dependence of ethanol supply on public policies can have serious implications for the sustainability of the ethanol expansion in the *Cerrado* region. The sustainability of the ethanol industry is important since it can bring rural development, environmental benefits and energy security to the country (Moraes and Zilberman 2014). Given limited financial resources, the sustainability of ethanol production in the *Cerrado* could be threatened by other competing policies (e.g. controlling of gasoline prices). Therefore, the Brazilian government should aim at developing a stable long-term demand for ethanol to ensure the sustainability of the ethanol market, making it is less dependent on public policies.

Ethanol exports could be a solution to the sustainability of ethanol production. Ethanol exports have been underutilized when compared to ethanol consumed domestically. Afterall this region has only started exporting ethanol since 2013 and only 10% of Brazil's total ethanol production is exported. Moraes and Zilberman (2014) believe that Brazilian ethanol has the potential of replacing around a quarter of the world's gasoline supply. For this to be feasible, Brazil must provide ethanol importers a constant ethanol supply allowing importing countries to implement blend mandates (Moraes and Zilberman 2014). To this end, Brazilian policies could aim at subsidizing ethanol storage costs, such that mills may be able to provide a constant flow of ethanol supply, as suggested by Moraes and Zilberman (2014). Another solution is the financial support for technological advances in second generation ethanol production or even the production of ethanol from other feedstocks (e.g. the use of corn as a feedstock in between sugarcane harvest seasons).

It appears the Brazilian government's act of juggling pricing policies (e.g. control of gasoline prices and the removal of CIDE fuel tax from ethanol) is not very beneficial to the ethanol industry and is impacting public revenue. There are policies that provide a higher impact on ethanol supply (e.g. blend mandate) than eliminating taxes. Perhaps efforts should be placed on the production of anhydrous ethanol instead of hydrous ethanol, as suggested by Moraes and Zilberman (2014). Nevertheless, if the government wishes to promote the production of hydrous ethanol then it should focus on policies that increase income. As shown, consumers become more willing to switch from gasoline to hydrous ethanol as they become more wealthy. In this sense, education on the environmental benefits of ethanol as a fuel could be beneficial.

Findings from this study can guide biofuels expansion in other countries (e.g. ethanol expansion in Mozambique). It was found that for ethanol expansion to be sustainable, the ethanol market must be developed up to the point where it is dependent on market factors and no longer sensitive to public policies. Therefore, potential markets may need to be identified (e.g. Brazil increasing its ethanol exports). The challenges of applying pricing policies at the same time to substitutable fuels (e.g. gasoline and hydrous ethanol), point to the benefits of potentially only producing one type of ethanol. In this case, the blend mandate would promote anhydrous ethanol production. Similarly, the implementation of blend mandates in other countries would guarantee a demand for ethanol promoting ethanol production. Further studies would be required to estimate the consequences of eliminating public policies, except for the blend mandate, on rural development and on the sustainability of the ethanol expansion into the *Cerrado*.

2.8 References

Alves, L.R.A., and M.R.P. Bacchi. 2004. "Oferta de exportação de açúcar do Brasil." *Revista de Economia e Sociologia Rural* 42(1):9–33.

Amato, F., and F. Matoso. 2015. "Mistura de etanol na gasolina sobe hoje." *G1-Economia*. Available at: http://g1.globo.com/economia/noticia/2015/03/mistura-de-etanol-na-gasolina-sobe-hoje.html [Accessed May 29, 2015].

Anderson, S.T. 2012. "The demand for ethanol as a gasoline substitute." *Journal of Environmental Economics and Management* 63(2):151–168.

ANFAVEA. 2015. "Tabelas estatísticas 2014." *National Association of Automatic Vehicle Producers*. Available at: http://www.anfavea.com.br/tabelas2014.html [Accessed June 2, 2015].

ANP - National Agency of Petroleum, Natural Gas and Biofuels. 2014. "Preços." Available at: http://www.anp.gov.br/wwwanp/precos-e-defesa-da-concorrencia/precos [Accessed March 29, 2017].

Arend, S.C. 2001. *O Instituto do Açúcar e do Álcool: os usineiros e a busca de rendas.* Master thesis. Porto Alegre: Universidade Federal do Rio Grande do Sul.

Balcombe, K., and G. Rapsomanikis. 2008. "Bayesian estimation and selection of nonlinear vector error correction models: the case of the sugar-ethanol-oil nexus in Brazil." *American Journal of Agricultural Economics* 90(3):658–668.

Barros, S. 2015. "Brazil: biofuels annual - biofuels-ethanol and biodiesel." *USDA Foreign Agricultural Service: GAIN.[cit. 2017-08-3]*.

Barros, S. 2013. "Brazil biofuels annual report." *Global Agricultural Information Network. Department of Agriculture, Foreign Agricultural Services, São Paulo*.

Baum, C.F., V. Wiggins, S. Stillman, and M.E. Schaffer. 2006. *OVERID: Stata module to calculate tests of overidentifying restrictions after ivreg2, ivreg29, ivregress, ivprobit, ivtobit, reg3*. Boston College Department of Economics. Available at: https://ideas.repec.org/c/boc/bocode/s396802.html [Accessed February 22, 2017].

BCB, Brazilian Central Bank. 2016. "Sistema Especial de Liquidação e de Custódia - Selic." Available at: http://www.bcb.gov.br/htms/novaPaginaSPB/selic.asp?IDPAI=SPBLIQTIT [Accessed March 29, 2017].

BNDES, Brazilian National Bank of Development. 2015. "Desembolso do setor sucroalcoleiro." Available upon request from http://www.bndes.gov.br/Ouvidoria.

Brazil. 2009. Decree No. 6961 of September 17th 2009. Aprova o zoneamento agroecológico da cana-de-açúcar e determina ao Conselho Monetário Nacional o estabelecimento de normas para as operações de financiamento ao setor sucroalcooleiro, nos termos do zoneamento.

Brasilia: Presidência da República. Available at: http://www.planalto.gov.br/ccivil_03 /_Ato2007-2010/2009/Decreto/D6961.htm [Accessed March 20, 2017].

Breusch, T.S., and A.R. Pagan. 1979. "A simple test for heteroscedasticity and random coefficient variation." *Econometrica* 47(5):1287–1294.

Cameron, A.C., and P.K. Trivedi. 1990. "The information matrix test and its implied alternative hypotheses." California Davis - Institute of Governmental Affairs. Available at: https://ideas.repec.org/p/fth/caldav/372.html.

Caruso, R.C. 2002. *Análise da oferta e demanda de açúcar no Estado de São Paulo.* Piracicaba-SP, Brazil: Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo.

de Castro, E.R., and E.C. Teixeira. 2012. "Rural credit and agricultural supply in Brazil." *Agricultural Economics* 43(3):293–302.

CEPEA - Centro de Estudos Avançados em Economia Aplicada, I. 2015. "Sugar." Available at: http://www.cepea.esalq.usp.br/en/indicator/sugar.aspx [Accessed March 29, 2017].

CONAB, Companhia Nacional de Abastecimento. 2013. *Perfil do setor do acucar e do etanol no Brasil* Yearly. Brasília: CONAB. Available at: http://www.conab.gov.br/OlalaCMS/ uploads/arquivos/13_10_02_11_28_41_perfil_sucro_2012.pdf [Accessed November 14, 2014].

Cook, R.D., and S. Weisberg. 1983. "Diagnostics for heteroscedasticity in regression." *Biometrika* 70(1):1–10.

Costa, C.C. da, H.L. Burnquist, C. Valdes, and M.J.P. de Souza. 2015. "Supply behavior of hydrous ethanol in Brazil." *Economia Aplicada* 19(4):731–748.

Deaton, A., and J. Muellbauer. 1980. *Economics and consumer behavior*. Cambridge university press.

Drabik, D., H. De Gorter, D.R. Just, and G.R. Timilsina. 2015. "The economics of brazil's ethanol-sugar markets, mandates, and tax exemptions." *American Journal of Agricultural Economics* 97(5):1433–1450.

Elobeid, A., and S. Tokgoz. 2008. "Removing distortions in the u.s. ethanol market: what does it imply for the United States and Brazil?" *American Journal of Agricultural Economics* 90(4):918–932.

Estadão Conteúdo. 2015. "Preço do etanol já equivale a 68% do valor da gasolina em SP, aponta Fipe." *G1-Economia*. Available at: http://g1.globo.com/economia/seu-dinheiro/noticia/ 2015/10/preco-do-etanol-ja-equivale-68-do-valor-da-gasolina-em-sp-aponta-fipe.html [Accessed April 17, 2017].

Eurostat. 2016. "G20 CPI all-items." Available at: http://ec.europa.eu/eurostat/web/products-datasets/-/prc_ipc_g20 [Accessed March 29, 2017].

FAPRI. 2016. “Elasticity database.” Available at: http://www.fapri.iastate.edu/tools/elasticity.aspx [Accessed March 29, 2017].

Farinelli, B., C.A. Carter, C.-Y. Cynthia Lin, and D.A. Sumner. 2009. “Import demand for Brazilian ethanol: a cross-country analysis.” *Journal of Cleaner Production* 17, Supplement 1: S9–S17.

Fischer, G., E. Teixeira, E. Tothne Hizsnyik, and H.T. van Velthuizen. 2008. “Land use dynamics and sugarcane production.” In P. Zuurbier and J. van de Vooren, eds. *Sugarcane Ethanol: Contributions to Climate Change Mitigation and the Environment*. Netherlands pp.29-62: Wageningen Academic Publishers. Available at: http://www.wageningenacademic.com/sugarcane-e [Accessed March 20, 2017].

de Freitas, L.C., and S. Kaneko. 2011. “Ethanol demand in Brazil: regional approach.” *Energy Policy* 39(5):2289–2298.

Gorter, D., Harry, D. Drabik, E. Kliauga, and G.R. Timilsina. 2013. “An economic model of Brazil’s ethanol-sugar markets and impacts of fuel policies.” No. ID 2287057, Social Science Research Network. Available at: https://papers.ssrn.com/abstract=2287057 [Accessed March 29, 2017].

Granco, G., M.M. Caldas, J.S. Bergtold, and A.C. Sant’Anna. 2015. “Exploring the policy and social factors fueling the expansion and shift of sugarcane production in the Brazilian Cerrado.” *GeoJournal* 82(1):63–80.

Greene, W.H. 2008. *Econometric analysis* 6th ed. Upper Saddle River, New Jersey: Pearson Prentice Hall.

Hausman, J.A. 1978. “Specification tests in econometrics.” *Econometrica: Journal of the Econometric Society*:1251–1271.

IBGE, Brazilian Institute of Geography and Statistics. “Sistema IBGE de Recuperação Automática - SIDRA.” Available at: http://www2.sidra.ibge.gov.br/ [Accessed March 29, 2017].

IPEA, Brazilian Institute of Applied Economics. 2015. “Ipeadata.” Available at: http://www.ipeadata.gov.br/Default.aspx [Accessed March 29, 2017].

Kendall, M.G. 1938. “A new measure of rank correlation.” *Biometrika* 30(1/2):81–93.

Lin, C.-Y.C. 2005. “Estimating annual and monthly supply and demand for world oil: a dry hole?” *Repsol YPF-Harvard Kennedy School Fellows*:213.

Maciel, M.S. 2011. “Tributos incidentes sobre os combustíveis.” Nota Tecnica Camara dos Deputados. Available at: http://bd.camara.leg.br/bd/bitstream/handle/bdcamara/8426/tributos_incidentes_maciel.pdf?sequence=1 [Accessed May 20, 2015].

Manzatto, C.V., E.D. Assad, J.F.M. Baca, M.J. Zaroni, and S.E.M. Pereira. 2009. “Zoneamento agroecológico da cana-de-açúcar: expandir a produção, preservar a vida, garantir o futuro.” *Embrapa Solos. Documentos*.

MAPA, Ministry of Agriculture, Live Stock and Supply. 2013. *Anuário estatístico da agroenergia 2012: Statistical yearbook of agrienergy.* Brasília: Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Produção e Agroenergia.

MAPA, Ministry of Agriculture, Live Stock and Supply. 2010. “Mistura carburante automotiva (etanol anidro /gasolina): cronologia.” Available at: http://www.faespsenar.com.br/arquivos/pdf/gerais/faesp/eco/Bioenergia-Legislacao/Percentual%20de%20Mistura-gasolina%20(MAPA)-2011.pdf.

Marjotta-Maistro, M.C., and G.S. de C. Barros. 2003. “Relações comerciais e de preços no mercado nacional de combustíveis.” *Revista de Economia e Sociologia Rural* 41:829–858.

McGuirk, A.M., P. Driscoll, and J. Alwang. 1993. “Misspecification testing: a comprehensive approach.” *American Journal of Agricultural Economics* 75(4):1044–1055.

MDIC, Ministry of Industry, Foreign Trade and Services. 2016. “Aliceweb2.” *Ministry of Development, Industry and Foreign Trade of Brazil*. Available at: aliceweb2.desenvolvimento.gov.br [Accessed June 2, 2015].

Moraes, M.A.F.D. de, and D. Zilberman. 2014. *Production of ethanol from sugarcane in brazil: from state intervention to a free market*. Springer Science & Business Media.

Neves, M.F., V.G. Trombin, and M. Consoli. 2011. “The sugar-energy map of Brazil.” In E. L. Leao de Sousa and I. de C. Macedo, eds. *Etanol and bioelectricity: sugarcane in the future of the energy matrix*. São Paulo: UNICA, pp. 14–43.

Nuñez, H.M., H. Önal, and M. Khanna. 2013. “Land use and economic effects of alternative biofuel policies in Brazil and the United States.” *Agricultural Economics* 44(4–5):487–499.

Oliveira, A. de, and J. Ramalho. 2006. “Plano Nacional de Agroenergia: 2006-2011. rev.” *Brasília, DF: Embrapa Informação Tecnológica*.

Oliveira, M.P., J.R. de Alencar, and G. da S. Souza. 2008. “Energia renovável: uma análise sobre oferta e demanda de etanol no Brasil.” In *46 Congresso da Sociedade Brasileira de Economia e Sociologia Rural*.

Pregibon, D. 1979. *Data analytic methods for generalized linear models*. University of Toronto Canada.

Procana. 2013. *Brazilian sugar and ethanol guide 2013*. Ribeirão Preto: ProCana Brasil.

Ramsey, J.B. 1969. “Tests for specification errors in classical linear least-squares regression analysis.” *Journal of the Royal Statistical Society. Series B (Methodological)*:350–371.

Royston, J.P. 1983. "A simple method for evaluating the Shapiro-Francia W'test of non-normality." *The Statistician*:297–300.

Royston, P. 1993. "A pocket-calculator algorithm for the Shapiro-Francia test for non-normality: An application to medicine." *Statistics in medicine* 12(2):181–184.

Sant'Anna, A.C., G. Granco, J.S. Bergtold, M.M. Caldas, T. Xia, P. Masi, T. Link, and W. Lorenzani. 2016. "The challenges of the sugarcane expansion: how do producers and land owners think and act?" In G. R. Santos, ed. *Forty years of ethanol in Brazil: hide or confront the crises?* Brasilia: IPEA, pp. 113–142.

Sant'Anna, A.C., A. Shanoyan, J.S. Bergtold, M.M. Caldas, and G. Granco. 2016. "Ethanol and sugarcane expansion in Brazil: what is fueling the ethanol industry?" *International Food and Agribusiness Management Review* 19(4):163–182.

Santos, G.F. 2013. "Fuel demand in Brazil in a dynamic panel data approach." *Energy Economics* 36:229–240.

Shikida, P.F.A. 2013. "Expansão canavieira no Centro-Oeste: limites e potencialidades." *Revista de Política Agrícola* 22(2):122–137.

Shikida, P.F.A., L.R.A. Alves, E. de SOUZA, and E.M. Carvalheiro. 2007. "Uma análise econométrica preliminar das ofertas de açúcar e álcool paranaenses." *Revista de Economia Agrícola, São Paulo* 54(1):21–32.

Silva, A.A., and F. Miziara. 2011. "Sucroalcohol sector and agricultural frontier expansion in the Goiás state, Brazil." *Pesquisa Agropecuária Tropical* 41(3):399–407.

UNICA, Brazilian Sugarcane Industry Association. 2015. "UNICAData." *UNICAData*. Available at: http://www.unicadata.com.br/ [Accessed May 20, 2015].

USDA. ERS. 2013. "Sugar and sweeteners yearbook tables." Available at: https://www.ers.usda.gov/data-products/sugar-and-sweeteners-yearbook-tables.aspx#25440 [Accessed March 29, 2017].

USDA, F.A.S. 2017. "Production, supply and distribution." Available at: https://apps.fas.usda.gov/psdonline/app/index.html#/app/home [Accessed March 29, 2017].

Wooldridge, J.M. 2009. *Introductory econometrics: a modern approach* 4th edition. Mason, OH: Cengage Learning.

Zellner, A., and H. Theil. 1962. "Three-stage least squares: simultaneous estimation of simultaneous equations." *Econometrica* 30(1):54–78.

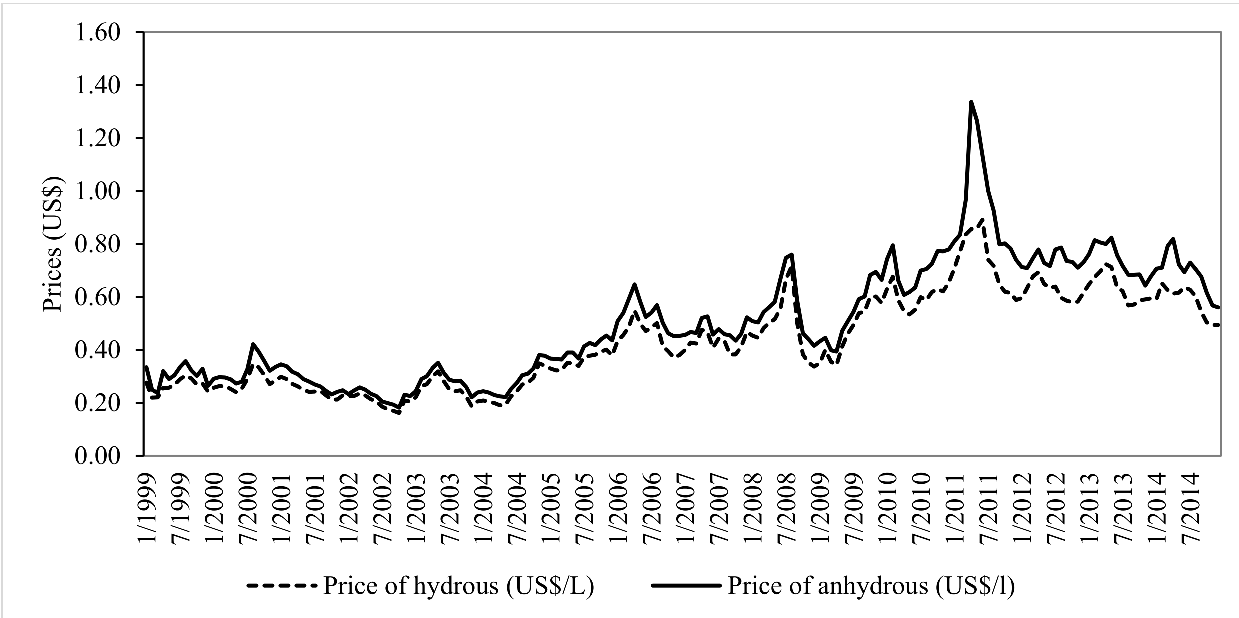


Figure 2.1: Evolution of domestic hydrous and anhydrous ethanol prices in dollars per liter (US$/L) from 1999 to 2014

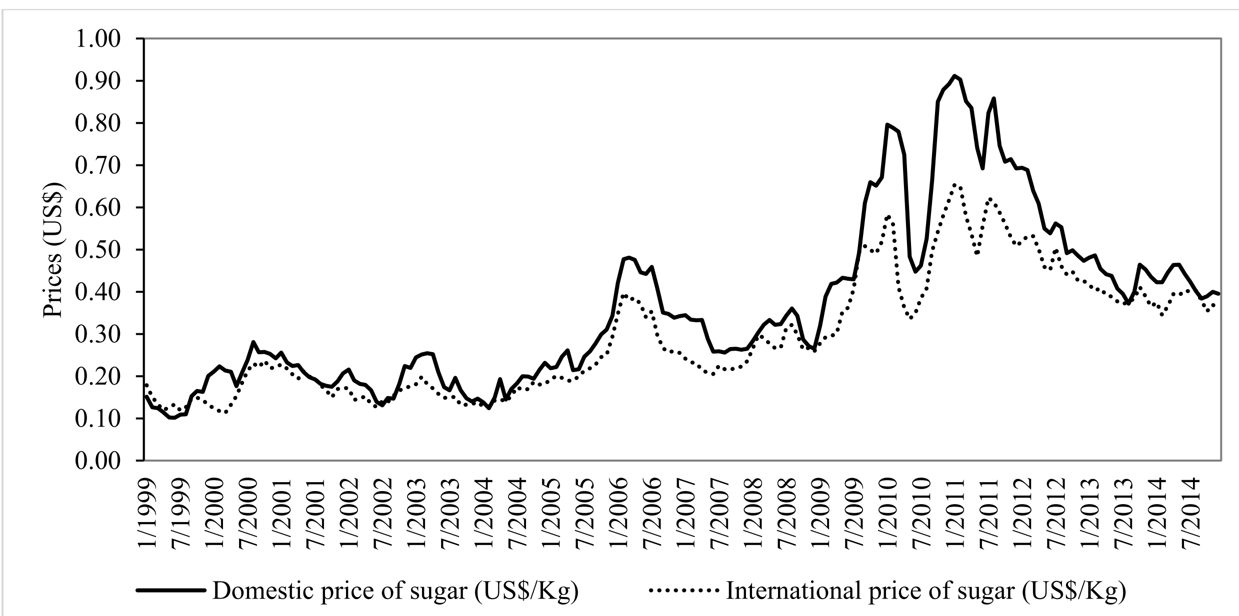


Figure 2.2: Evolution of domestic and international sugar prices in dollars per kilo (US$/Kg) from 1999 to 2014

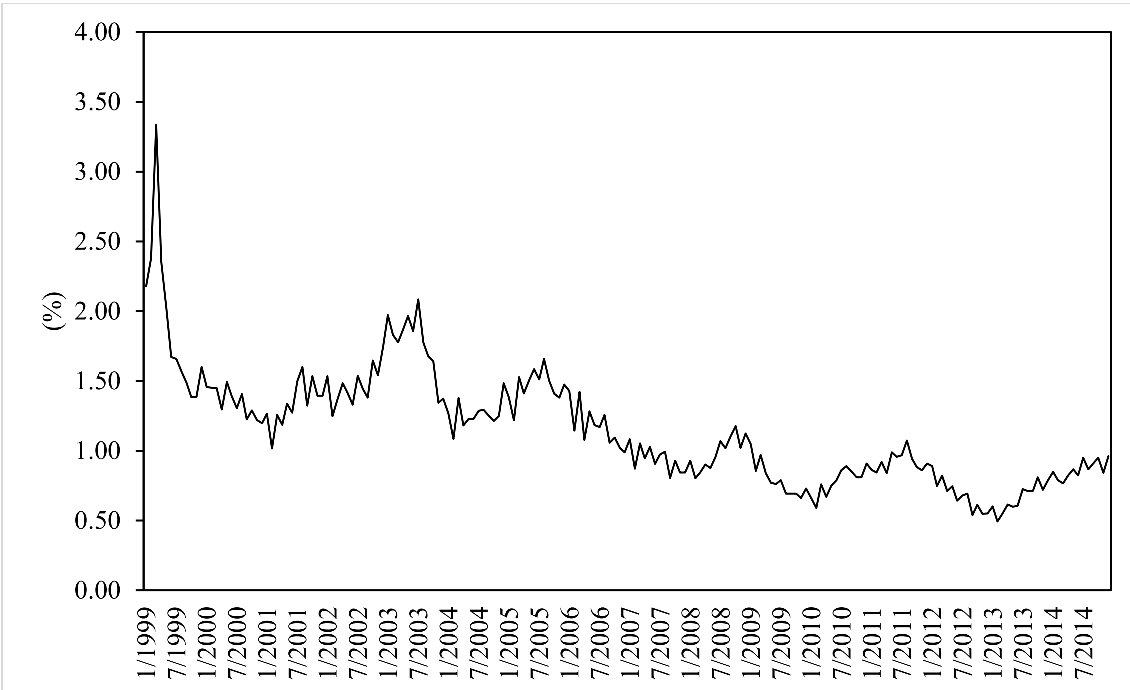


Figure 2.3: Brazilian interest rate (SELIC) between 1999 and 2014

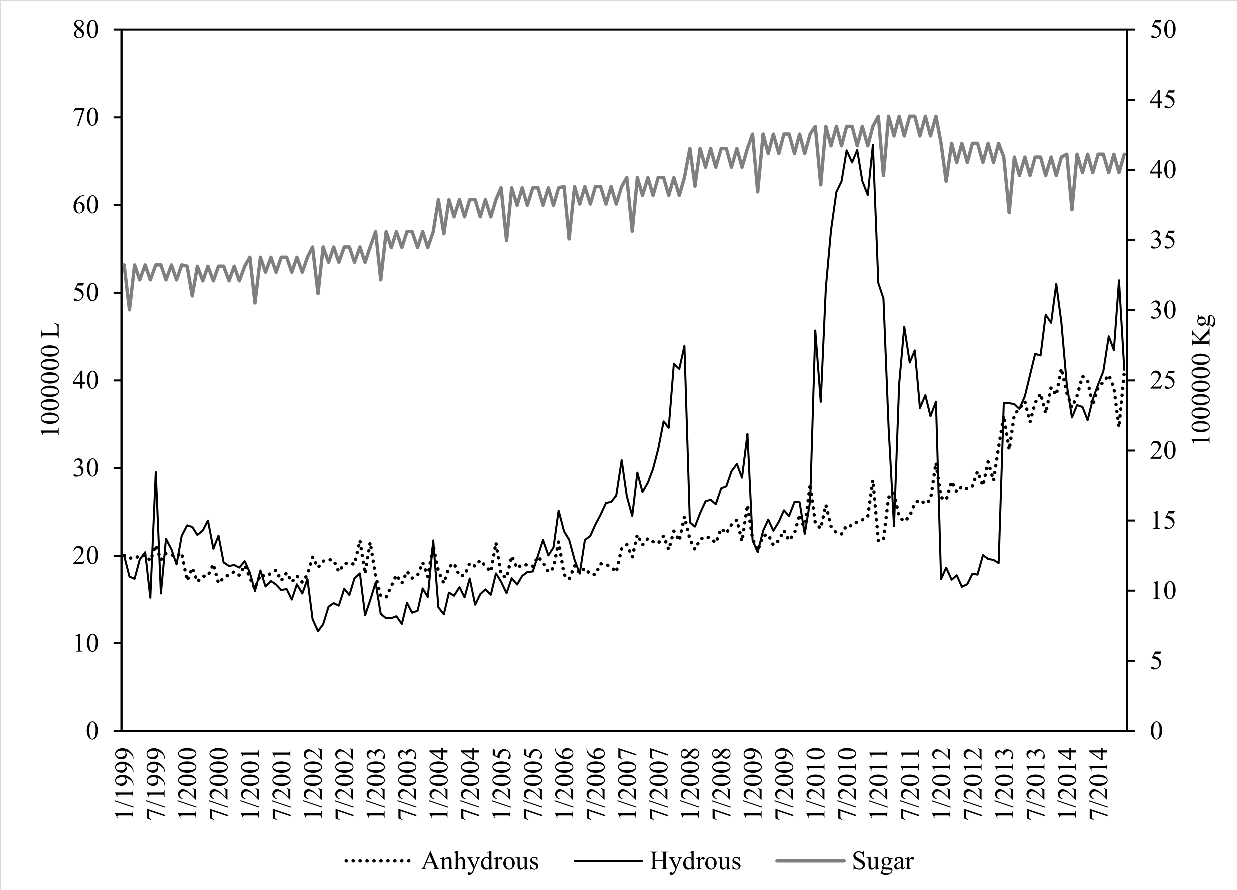


Figure 2.4: Hydrous, anhydrous and sugar consumption in Goiás and Mato Grosso do Sul between 1999 and 2014

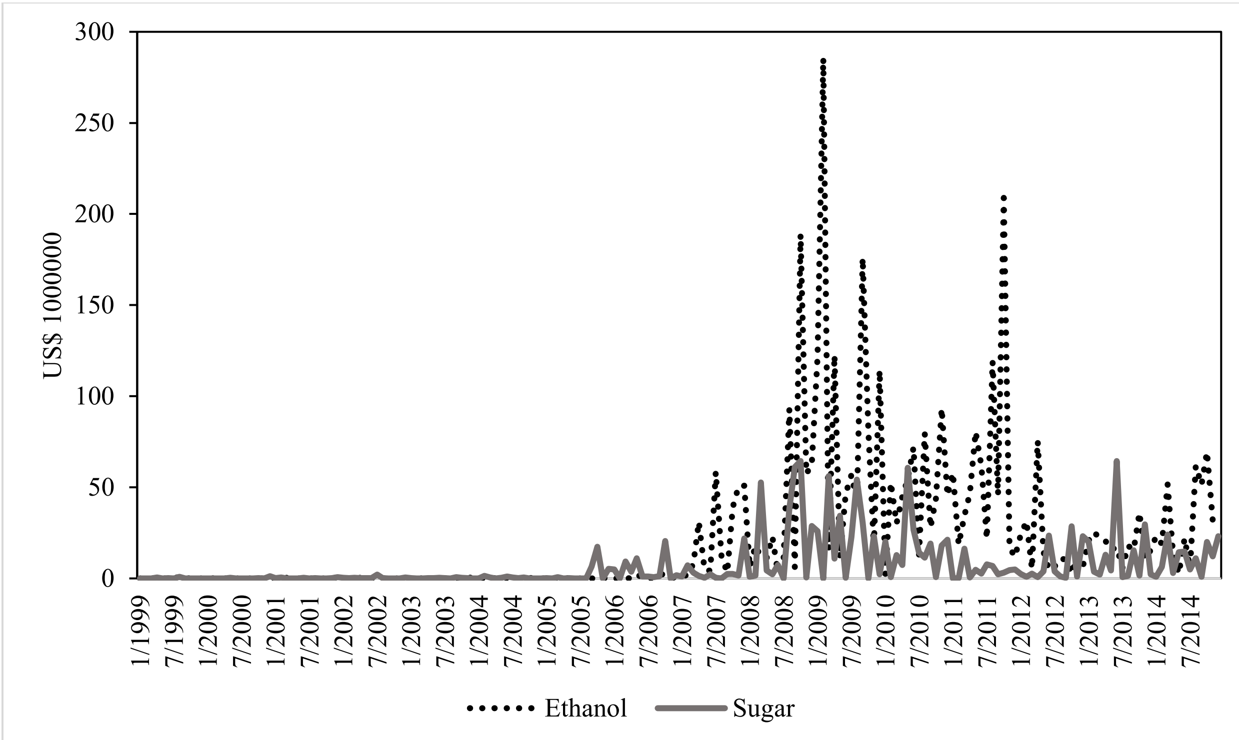


Figure 2.5: Loans granted through the BNDES program towards investments in sugar and ethanol production in millions of dollars to the states of Goiás and Mato Grosso do Sul between 1999 and 2014

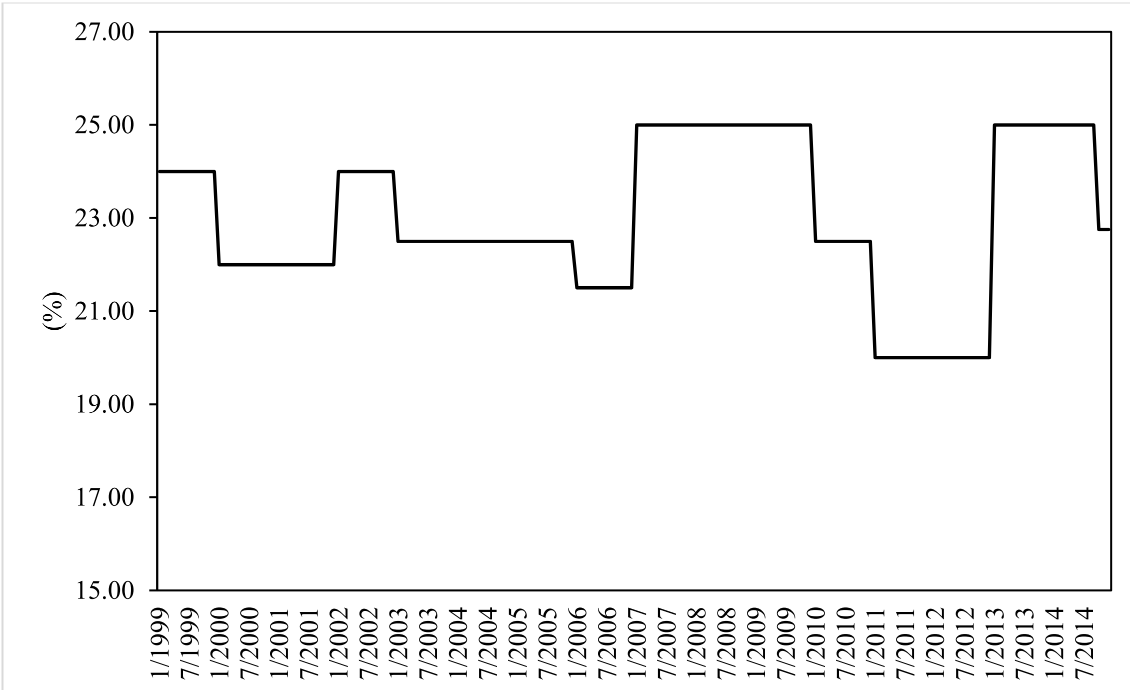


Figure 2.6: Blend ratio percentages in practice between 1999 and 2014

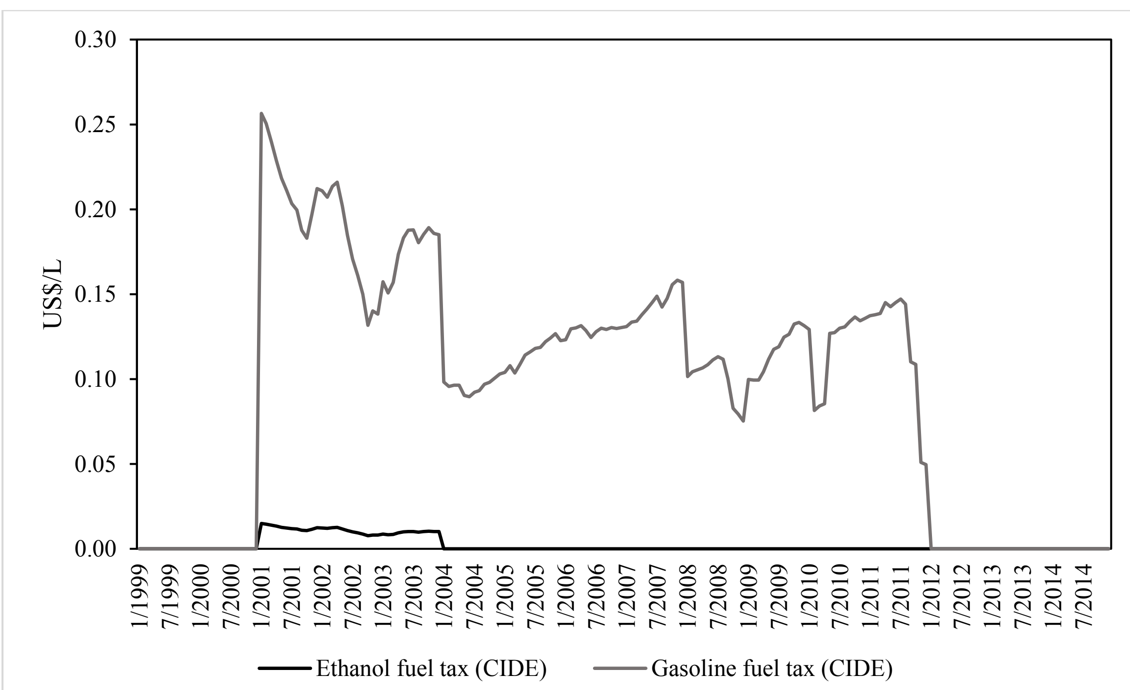


Figure 2.7: CIDE fuel tax charged per liter in US$ between 1999 and 2014

Table 2.1: Description of the variables in the econometric model

Variable	Description
Lnscons	log of the quantity of sugar demanded
lnpsugrow	log of the real international price of sugar
Lngdp	log of the real GDP per capita
dummyfeb	dummy for sugar consumption in the months of February*
Trend	trend variable
Lnssup	log of the quantity of sugar supplied
Lnphyd	log of the real price of hydrous ethanol
Dsbndes	dummy for times when credit subsidies for sugar production were low
Lnselic	log of the interest rate for loans in Brazil
Lnpcane	log of the real price of sugarcane paid to the producer
Zone	dummy for the start of the Agroecological Zone
Dsugsup	dummy to control for months when sugar supply was above 100 million Kg
dum3	dummy to control for months (Jun, Aug, Sep, Dez) in 1999 and March, 2001 when sugar consumption was much higher
Lnsexp	log of the quantity of ethanol exported
dum4	dummy to control for months when sugar exports were above 56 million Kg
dum7	dummy to control for months when the log of sugar exports was negative
Lnesup	log of the quantity of ethanol supplied
Psugrow	real international price of sugar
Pcane	real price of sugarcane
Phyd	real price of domestic hydrous ethanol
Debndes	dummy for time periods when credit subsidies for ethanol production were low
Diffcide	the difference between the tax on ethanol and the tax on gasoline
Lnblend	log of the percentage of ethanol that needs to be mixed into gasoline as determined by the Brazilian blend mandate
Lnpgas	log of the real domestic price of gasoline at the pump
Lnacons	log of the quantity of anhydrous ethanol supplied
Dumadem	dummy to control for year 1999*
Ratio	the real price of hydrous ethanol divided by the real price of gasoline
dumhydem	dummy to control for when consumption was lower than normal: Feb. 2010, Mar. and Apr. 2011*

*Please refer to the appendix for more information on the variables added.

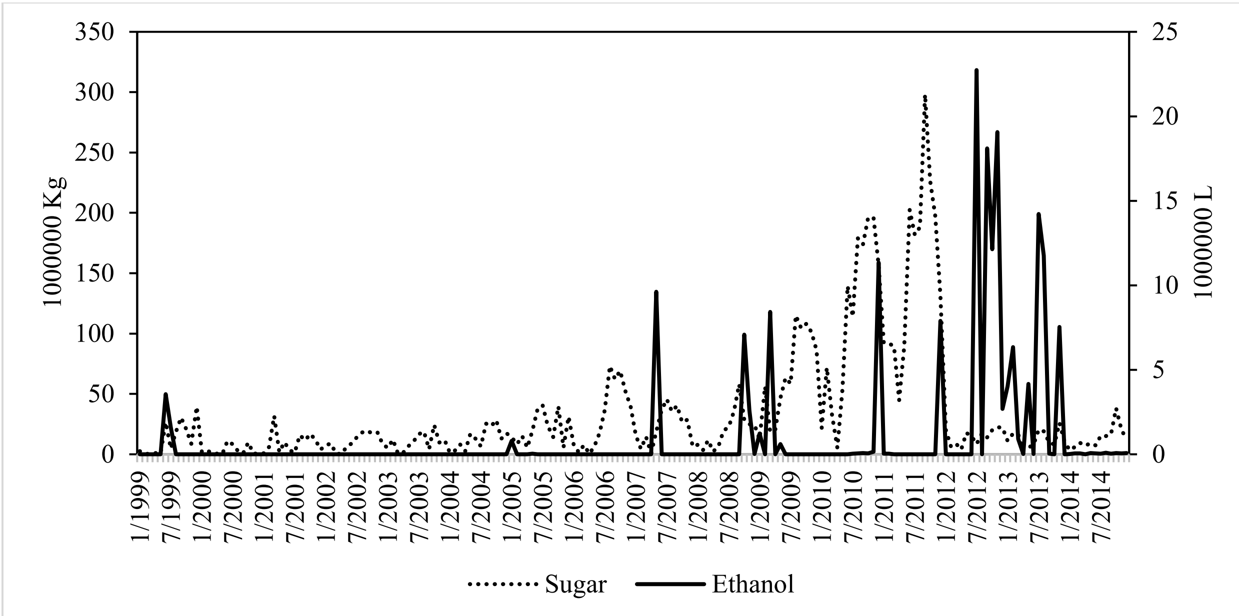


Figure 2.8: Sugar and ethanol exports from Goiás and Mato Grosso do Sul from 1999 to 2014

Table 2.2: Summary statistics of the variables of the model

Variable	Mean	Standard deviation	Unit
Price of sugar	0.71	0.16	R$/Kg
Zoning (dummy)	0.31	0.46	Zoning start =1
Selic	1.15	0.41	%
GDP per capita	2.40	0.56	R$1,000
Sugar Consumption	38.05	3.5	1,000,000Kg
Sugar Exports	32.92	49.66	1,000,000Kg
Anhydrous Consumption	23.09	6.54	1,000,000 liters
Hydrous Consumption	26.79	12.93	1,000,000 liters
Blend mandate	23.00	1.67	%
Difference between fuel taxes	-0.21	0.17	R$
Ethanol Supply	49.88	17.5	1,000,000 liters
Sugar Supply	70.97	51.55	1,000,000Kg
Price of hydrous	1.05	0.13	R$/liter
Price of gasoline	2.89	0.33	R$/liter
Price of Sugarcane	0.38	0.07	R$/Kg TRS
Ratio	0.37	0.06	hydrous price/gasoline price
Debndes (dummy)	0.52	0.5	Low subsidies = 1
Dsbndes (dummy)	0.43	0.5	Low subsidies = 1
Sales of Ethanol and Flex cars	5600	4706	1 car
Population	674	33	1000 people

All prices in Reais (R$) of 2010.

Table 2.3: Results from the 3sls model for the sugar market

	Coefficient Estimates		Std Err
Sugar Demand			
Constant	-0.87	***	0.187
log real price of sugar	-0.01		0.009
log real gdp	0.17	***	0.029
dumfeb	-0.08	***	0.005
$lnsconn_{t-2}$	0.62	***	0.032
$lnsconn_{t-3}$	0.27	***	0.034
$trend^2$	-0.000003	***	0.000
R^2	0.96		
Sugar Supply			
Constant	2.235	***	0.203
log real price of sugar	0.636	***	0.147
log real price of sugarcane	-0.873	***	0.133
Dsbndes	-0.080	*	0.043
log pride of hydrous	0.354	***	0.146
log interest rate	0.001		0.052
Zone	0.041		0.042
dsugsup	-0.642	***	0.246
$lnsugarsup_{t-1}$	0.272	***	0.044
dsugsup*$lnsugarsup_{t-1}$	0.271	***	0.055
dum3	0.418	***	0.084
R^2	0.857		
Sugar Supply to the Rest of the World			
Constant	0.479		0.446
log real price of sugarcane	-2.429	***	0.548
log real price of sugar	2.283	***	0.593
$lnsexp_{t-1}$	0.185	***	0.037
dum3	1.516	***	0.335
dum4	1.379	***	0.173
dum7	-2.068	***	0.143
Dsbndes	-0.192		0.142
zone	0.100		0.152
R^2	0.756		

*** Significant at 1% level of significance

* Significant at 10% level of significance

Endogenous variables: sugar consumption, sugar supply, sugar supply to the rest of the world, price of hydrous ethanol, price of sugar

Table 2.4: Results from the 3sls model for the ethanol market

	Coefficient Estimates	Std Err
	Ethanol Supply	
Constant	11.07 ***	2.440
real price of sugar	2.98 ***	0.392
real price of hydrous	0.41	4.213
real price of hydrous^2	-0.46	1.915
real price of sugarcane	-2.86 ***	0.635
Zone	0.57 ***	0.091
Debndes	-0.84 ***	0.094
log interest rate	-0.08	0.123
Difference in fuel taxes	1.25 ***	0.184
log of blend mandate	3.14 ***	0.406
R^2	0.895	
	Anhydrous Ethanol Demand	
Constant	8.55 ***	0.992
log real gdp per capita	-0.63 ***	0.120
log real price of gasoline	-0.75 ***	0.147
dumadem	0.12 ***	0.030
trend^2	0.00 ***	0.000
R^2	0.924	
	Hydrous Ethanol Demand	
Constant	2.20 ***	0.188
real ratio	-7.03 ***	0.910
real gdp per capita	0.0017 ***	0.000
dumhydem	-0.13	0.199
R^2	0.756	

*** Significant at 1% level of significance

Table 2.5: Public policy elasticities

		Public Policies					
		Zae Cana	Subsidized Loans (Ethanol)	Subsidized Loans (Sugar)	Interest Rate	Blend	Difference in fuel taxes
Quantity	Sugar	0.04		-0.08 *	0.001		
		(0.04)		(0.04)			
	Sugar Exports	0.1		-0.192			
		(0.15)		(0.14)			
	Ethanol	0.57 ***	-0.84 ***		-0.08	3.14 ***	1.25 ***
		(0.09)	(0.09)		(0.12)	(0.41)	(0.18)

Note: Standard errors are in parenthesis. Significant levels: *** is 1%, ** is 5%, * is 10%.

Table 2.6: Supply elasticities

		Prices		
		Sugar	Hydrous	Sugarcane
Quantity	Sugar	0.64***	0.35**	-0.87***
		(0.15)	(0.15)	(0.13)
	Sugar Exports	2.28***		-2.43***
		(0.59)		(0.55)
	Ethanol	2.11***	0.43	-1.07***
		(0.28)	(4.42)	(0.24)

Note: Standard errors are in parenthesis. Significant levels: *** is 1%, ** is 5%, * is 10%.

Table 2.7: Compensated and uncompensated demand elasticities

		Uncompensated			Compensated	
		Prices			Prices	
		Sugar	Ratio	Gasoline	Sugar	Gasoline
Quantity	Sugar	-0.01			-0.009	
		(0.01)			(0.01)	
	Anhydrous			-0.75***		-0.77***
				(0.15)		(0.15)
	Hydrous		-2.58***			
			(0.33)			

Note: Standard errors are in parenthesis. Significant levels: *** is 1%, ** is 5%, * is 10%.

Table 2.8: Expenditure elasticities

Good	Gross Domestic Product
Sugar	0.17***
	(0.03)
Anhydrous	-0.63***
	(0.12)
Hydrous	3.99***
	(0.21)

Note: Satndard errors are in parenthesis. Significant levels: *** is 1%, ** is 5%, * is 10%.

Chapter 3 - Sugarcane contracts in Brazil: How sweet is the deal?

3.1 Introduction

Brazil is one of the world's leading ethanol producers, primarily from sugarcane, and was responsible for almost half of the world's sugarcane production in 2012 (MAPA 2013). The sugar-energy sector in Brazil accounts for approximately 2% of the country's Gross Domestic Product (Neves, Trombin and Consoli 2011). Brazilian ethanol is produced from sugarcane, a crop that since its introduction in the country, has expanded from the North-Northeast Region to the Center-Southeast, particularly into the *Cerrado* area, the country's second largest biome. In the *Cerrado*, this expansion has been most significant in the states of Goiás (GO) and Mato Grosso do Sul (MS) (Shikida 2013). From 2000 to 2012 over 40 mills have been constructed in these states (Procana 2013). Although over 50% of Brazil's sugarcane production is located in the state of São Paulo, in 2014, these two states (GO and MS) had 1.5 million hectares planted with sugarcane and contributed to 15% of the total amount of sugarcane produced in the country (IBGE 2014). In addition, the Sugarcane Agroecological Zoning, launched in 2010, mapped 12.6 million hectares in GO and 10.8 million hectares in MS as suitable areas for sugarcane production and expansion (Manzatto et al. 2009).

Access to sugarcane is a vital factor in the location and operation of an ethanol plant (Queiroz 2008). Sugarcane in GO and MS is obtained by (i) mills contracting directly with farmers or (ii) mills renting farm land and producing sugarcane themselves. These procurement methods help mills guarantee a supply of sugarcane (Picanço Filho and Marin 2012a). Thus, sugarcane is produced on land managed by autonomous farmers (40%) and, by ethanol companies (mills)

(60%) (Brazil, 2013). Due to time limitations between sugarcane harvesting and processing, as well as, transportation costs, mills acquire their sugarcane supply from lands within a certain distance from the mill (e.g. 50km) (Neves, Waack and Marino 1998).

Transition to sugarcane production in the states of MS and GO has not been smooth. In fact, in Jatai, a County in Goiás, grain farmers lobbied to pass a law restricting the amount of land planted to sugarcane (O Popular 2011). This attempt to restrict production of sugarcane was a way to prevent increases in land and labor prices. The installation of the mill increased demand for both inputs, increasing the price of land and labor (Sant'Anna, Shanoyan, et al. 2016). Hence, it is important for the mill to design contracts that are attractive to farmers and landowners, making them willing to grow sugarcane. Knowing the attributes and contract types farmers and landowners prefer, is pertinent for sugarcane expansion in the *Cerrado* region.

Although sugarcane expansion in the *Cerrado* region has been the focus of many studies (Silva and Miziara 2011; CONAB 2013; Shikida 2013) few have considered contracting and the relationship between sugarcane producers and mills (Sant'Anna, Granco, et al. 2016; Picanço Filho and Marin 2012a; Picanço Filho and Marin 2012b). In fact, most of the Brazilian data on contracts comes from case studies (de Almeida and Buainain 2016). No study has investigated farmers' willingness to produce sugarcane under different contractual conditions. In broad terms this study contributes to the understanding of farmer preferences towards different contracts (i.e. land lease, supply and cropshare contrats). It provides researchers with methodology to consider cases where each choice has an unbalanced number of attributes and there are multiple opt-out options. In terms of Brazil, this study provides guidance to mills and farmers about contract design and to the Brazilian government on contracting policy. In particular, the government could design policies aimed at strengthening contract enforcement, protecting the rights and well-being of both parties.

The government has a special interest in motivating sugarcane expansion, as the installation of a mill brings benefits to the local community: economic development, infrastructure improvement, and increase in job opportunities for the local population, among others (Roberto 2012). Sugarcane expansion has potential environmental benefits and is part of the Brazilian National Policy on Climate Change, aimed at reducing greenhouse gas emissions from 36.1% to 38.9% by 2020 (Brazil 2009).

The purpose of this study is to examine landowners' and farmers' willingness to produce sugarcane under different contractual arrangements using a hypothetical stated choice experiment. In order to capture farmers' preferences for each contract we propose a new model that has two opt-out options allowing for a better understanding of remaining with the status quo in comparison with traditional stated choice models with only a status quo or an "opt-out" option. The objective is to capture respondents' choice preferences with regards to marginal changes in contract choices. Respondent's willingness to pay for certain contract attributes is estimated from stated choice model results. The study uses data collected by a survey conducted in 22 Counties throughout the states of Goiás and Mato Grosso do Sul – Brazil, in June/July of 2014.

The paper is divided into seven parts. In the first section, we introduce the topic and explain the purpose of the paper. Section two examines sugarcane contracting in Brazil and the advantages and disadvantages of different contracts is highlighted. The third section presents the data gathered and compares it with that of the Brazilian Census in order to illustrate the representativeness of the sample. The fourth section, goes over the conceptual model for this study, while the fifth section presents the empirical estimation of the models. The sixth section presents the results, comparing it to the expectations presented in the conceptual model section, while the last section wraps up the article by highlighting the conclusions and possible implications of the study.

3.2 Sugarcane contracting

A contract is a legal document constraining signing parties. It is a means for an exchange to occur in the presence of transaction costs, asymmetric information and irreversible investments (Vavra 2009). Contracts vary by crop, available technology, market development, and other socio and demographic characteristics (Eswaran and Kotwal 1985). An increase in the use of contracts in agriculture arises due to forces such as market consolidation, variations in trade patterns, technological developments, and logistic issues (Vavra 2009). These forces, present in the sugarcane market in the *Cerrado*, make it difficult for a farmer to market and produce sugarcane without a contract (Picanço Filho and Marin 2012a).

A mill may seek to sign various types of contracts with farmers and landowners in order to balance the risks for both parties (Feltre and de Oriani e Paulillo 2015). Three types of contracts are currently used in Brazil: (1) land rental contracts – which give the local mill use of the land for sugarcane production for a fixed rental rate; (2) agricultural partnership contracts – which give the local mill use of the land for sugarcane production for a percentage of the harvested crop; and (3) supply contracts – by which farmers agree to supply sugarcane to the local mill for an agreed price and quantity (Brazil 1966). Numbers from the last Agricultural Census in 2006 relate that from 135,683 farms in GO and 64,862 farms in MS, 4.6% of producers in MS and 3.2% in GO have a land rental contract (IBGE 2006). The percentage of producers with an agricultural partnership is smaller: 0.31% in GO and 0.43% in MS for all types of agricultural commodities (IBGE 2006; Almeida and Buainain 2016). Though the 2006 Agricultural Census has no information on supply contracts we can have an idea of how many could be on a supply contract by looking at producers working on their own property. The percentage of producers using their own property is 87% in

GO and 75% in MS (IBGE 2006). Keep in mind that these facts are for all agricultural commodities and livestock and reflects information from 2006.

3.2.1 Advantages and disadvantages of each contract type

Land rental contracts allow mills to select the optimal amount of inputs for sugarcane production. The mill controls all stages of production, minimizing the risk of losing sugarcane suppliers to a competing plant (Feltre and de Oriani e Paulillo 2015). The landowner transfers all risks associated with the production process to the mill. However, the landowner incurs the risk of the mill potentially over-utilizing the land or natural resources associated with it (Almeida and Buainain 2016). Landowners and farmers may prefer a land rental contract because (Picanço Filho 2010): (1) they are undercapitalized due to previous crises in the rural sector; (2) the costs to form and maintain a sugarcane plantation are high; (3) they are resistant to entering a new sector; (4) current labor regulations are too restrictive; (5) they are averse to climate and fire risks; or (6) they prefer a guaranteed periodic fixed payment under contract (Almeida and Buainain 2016).

In the agricultural partnership contract the mill and the farmer share production risks. There is an incentive for the producer to use less factors of production than under the land rental contract and over-utilize the landowners' factors of production (e.g. land and soil nutrients). This situation arises because the producer only receives a share of the harvest (Almeida and Buainain 2016). Preference for an agricultural partnership may be due to the fact that higher revenue may be achieved depending on the quality or yield the of sugarcane, providing, potentially, greater return than the land rental contract at a lower risk than entering into a supply contract.

The supply contract transfers the production costs and risks from the mill to the producer, enabling the mill to concentrate solely on ethanol and sugar production. The payment of the supply contract depends on the yield and the quantity supplied. The choice of the supply contract over other options may be due to producers wanting more autonomy over sugarcane production and use of their land. In the case of the supply contract, the producer and the landlord are usually the same person. The over-utilization of land may not be in the producer and landowner's best interest. While the mill reduces their risk, they become reliant on the quality of the sugarcane supplied from the producer (Feltre and de Oriani e Paulillo 2015).

3.2.2 Factors associated with sugarcane contracting in the *Cerrado* region

The *Cerrado* region has a long tradition in grain and livestock production. A factor that motived farmers to produce sugarcane in the past was soybean rust (2004) and low cattle prices (Picanço Filho and Marin 2012a; Sant'Anna, Granco, et al. 2016). Farmers are willing to enter into sugarcane production due to the lower risks and high returns it has in comparison to other agricultural or livestock activities (Picanço Filho and Marin 2012a). In addition, mills have provided free seedlings, technical assistance, and product delivery subsidies to attract sugarcane suppliers (Sant'Anna, Granco, et al. 2016).

Mills seek farmers and/or landowners whose land lies within 50km from the mill to sign contracts (Neves, Waack and Marino 1998). Harvested sugarcane must be delivered and processed within 72 hours (Neves, Waack and Marino 1998). The distance limitation helps to avoid high transportation costs and to prevent saccharose losses from the harvested sugarcane.

Common clauses in contracts signed between mills and farmers are: (1) compensation for the sugarcane not bought by the mill called "cana bisada"; (2) payment methods (i.e. 80% upon delivery and 20% at the end of the harvest year); (3) and fidelity[2] in sugarcane sales (Picanço Filho and Marin 2012a).

On average, contracts last for one or two sugarcane cycles (i.e. 6 or 12 years) (Picanço Filho and Marin 2012a). At the end of the sugarcane cycle the land must be remediated (e.g. by rotating with soybeans or peanuts) for its productivity to be restored (Feltre and de Oriani e Paulillo 2015). Farmers have historically been willing to sign longer contracts with financially stable mills (Feltre and de Oriani e Paulillo 2015).

Farmers willingness to sign longer contracts can also be motivated by a strong presence of the State. By enforcing contracts, the State prevents opportunistic behaviors from either party (i.e. the agent or the principal) (Watanabe and Zylbersztajn 2014). When contract enforcement is weak, firms may opt to vertically integrate, internalizing all activities (Watanabe and Zylberstein 2014). In the agribusiness system, state intervention is focused on the farmer, the economically weaker party. This protects the farmer from rules imposed by the agro-industry, who generally holds more power (Watanabe and Zylberstein 2014).

In terms of bargaining power, farms closer to the mill and/or larger in size may hold more bargaining power than other farms when signing a contract (Picanço Filho and Marin 2012a; Sant'Anna, Granco, et al. 2016). Closer farms to the mill provide less saccharose losses during transportation. Larger farms can guarantee a larger amount of sugarcane supply in one contract (Picanço Filho and Marin 2012a). Mills, though, also hold bargaining power due to the presence of asymmetric information (Picanço Filho and Marin 2012a). Since this area has only recently started to produce sugarcane, mills generally have a broader understanding of sugarcane production and quality, as well as, of ethanol and sugar markets. Knowledge of these factors

[2] By fidelity we mean that the farmer can only supply sugarcane to a particular mill, though a mill may buy from many suppliers (Neves, Waack and Marino 1998).

influences expected sugarcane yields and the expected prices of sugar and ethanol, giving them an advantage over the producers who may not have the same information.

3.2.3 Previous studies on contracting

Studies on contracts with varying autonomy and risk (Lusk and Hudson 2004), and on biofuel contracts have been conducted in the United States (Bergtold, Fewell and Williams 2014) and in Australia (Windle and Rolfe 2005). Bergtold, Fewell and Williams (2014) examined farmers' willingness to produce biofuel under different contract options using a stated choice experiment. Farmers were presented with different scenarios and asked to choose a contract from a set of alternatives with varying attributes and a do not adopt option. The authors found that farmers prefer contracts with shorter lengths, higher net returns and with the option of the bio-refinery harvesting needed biomass and replacing lost soil nutrients. Although only supply contracts are considered, we expect our results to be similar to theirs, as both studies consider large commercial farming operations.

Hudson and Lusk (2004) determined how certain contract attributes make farmers, in Texas and Mississippi, more likely to choose a particular contract. Farmers had the option of contracts with different levels of autonomy and price risk. Results showed farmers derive utility from input provision (i.e. provision of seeds), shorter contract lengths, autonomy in decision-making, and from shifting price risk to the contractor. The authors concluded that risk avoidance plays an important role in contract choice. Producers were willing to forgo 4% of their annual income ($5,950.78) in order to pass on the full risk to the contractor (Hudson and Lusk 2004). Although producers want more autonomy, they would need to be compensated $9800 per year to give up that autonomy (Hudson and Lusk 2004). When the marginal utility of transaction cost attributes outweighs that of risk avoidance, transaction costs will guide contracting decisions. In contrast to Hudson and Lusk's (2004) research, we capture the preference for attributes that are specific to a type of contract. Our contract options differ from that in Hudson and Lusk (2004): (1) each contract has its own particular set of attributes; (2) the level of autonomy is determined by the contract type; (3) the risk is assessed in terms of a probability of receiving a late payment, and (4) the respondent must indicate the reason for choosing the status quo option by indicating whether they wish to keep their current contract or to not grow sugarcane.

Windle and Rolfe (2005) used a stated choice experiment to estimate Australian sugarcane grower's willingness to diversify farm income. The authors argue that understanding farmers' willingness to diversify is vital when predicting the speed at which an industry can restructure (e.g. farm agglomeration). Farmers' attitudes to risk, tactical opportunities and institutional impediments[3] may result in less diversification than expected (Windle and Rolfe 2005). The authors concluded that in order to avoid risk, producers may not be willing to diversify production, even though gross margins play an important role in decision making.

3.3 Data

Data was collected using face-to-face enumerated surveys with landowners and farmers in 22 counties in the states of Goiás (GO) and Mato Grosso do Sul (MS) in Brazil. Survey design was based on studies conducted in Quirinopolis, in GO (Picanço Filho and Marin 2012a; Picanço Filho 2010). The survey and stated choice experiment were tested by experts and farmers within

[3] E.g. the sugar quota production system stopped producers from leaving the sugar industry for there was no guarantee of regaining the quota afterwards.

the study region prior to its application in the field. The counties surveyed in each state were chosen based on: (i) geographic location of sugarcane production in 2012 using the National Institute for Space Research (INPE) Canasat Project (Rudorff et al. 2010); and, (ii) sugarcane production growth obtained from the Brazilian survey of county-level agricultural production – PAM (IBGE 2014).

Landowners and farmers from sugarcane growers' associations, rural syndicates, the Goiás and the Mato Grosso do Sul Federation of Agriculture and Livestock (FAEG and FAMASUL) were contacted to participate in the survey. Information was collected on participants' demographics, farm characteristics, landownership, sugarcane production and contracts, perceptions of mills' interaction with the local community, and land use. The stated choice experiment was the last portion of the survey.

Surveys were conducted in 2014 from June to July. The team that applied the survey was composed of 10 enumerators (graduate and undergraduate students), a Professor from the State University of Sao Paulo and a Professor (the Co-Principal Investigator) from Kansas State University. The team was split in three cars which ran over 1864 miles. Each survey lasted about an hour to complete. A total of 148 landowners and farmers were interviewed, a considerable size given the limitations and difficulties faced: (1) landowners residing in another state; (2) dirt roads; (3) isolated and extensive farms; (3) respondents cancelling or not showing up for the survey. Of those, 104 either produced sugarcane or rented land for sugarcane production. From the survey, there were 110 landowners and farmers that responded to the hypothetical experiment, 69 of which were either sugarcane producers or rented land for sugarcane production.

Though our survey may not represent the entire farmer population in Brazil, respondents fall into the group of commercial farmers that would likely be approached by mills to supply sugarcane or to rent out their land. This is explained by the sample consisting largely of farmers belonging to associations, rural syndicates, and/or cooperatives involved in sugarcane production. Farmers belonging to one of these organizations tended to manage mostly commercial farms, which tend to be larger in size. The average size of the farm in our sample is 913 hectares while that of the 2006 Agricultural Census[4] is 415 hectares (IBGE 2006). This difference is due to the census comprising a much larger number of smaller farms than the survey. The percentage of male farmers in the census is similar to that of the survey. The census reports 92% of farmers are male, while 96% of our survey respondents were male. In terms of education, our survey has a higher percentage of farmers with high school and college degrees than the census. In our survey, 37% of the respondents had completed high school and 28% college. In the census 4% had completed high school and 3% college. The average sugarcane production value and yield is also higher in the survey compared to CONAB (2013). CONAB (2013) reports an average yield of 70.30 tons/ha in this region, while our respondents have a yield of 87.71 tons per hectare (Table 3.1).

3.3.1 Stated choice experiment

Stated choice methods were chosen to investigate farmers' preferences for a certain contract type (land rent, agricultural partnership, supply). Stated choice methods were chosen over revealed preference methods. It provided more variation than revealed data, given the presence of only a single mill in proximity to a respondent farm most of the time. In addition, contract information is usually classified. For example, farmers and landowners could not provide information on contract payment amounts. Another reason for choosing stated choice data over

[4] The 2006 Agricultural Census is the most current census.

revealed preference is that there could be a tendency for mills to provide mainly one type of contract (e.g. land rental contract). The stated choice data allows us to assess a potential change in behavior when farmers and landowners would hypothetically have more contract options.

In order to capture choice differences specific to each type of contract we conducted a labelled stated choice experiment. This planned process generated stated choice data, in which choices and attribute levels of three contract types (land rent, agricultural partnership, supply) were pre-determined and then varied to create choice alternatives. Table 3.2 shows all the contract attributes for the three different contract options examined in the stated choice experiment.

The full factorial design, which considers all possible combinations of all attribute levels and contract options (Table 3.2), amounted to 884,736 $(= (4 * 3 * 2) * (4 * 4 * 2 * 3) * (4 * 2 * 3 * 2 * 2 * 2 * 2))$ combinations. Due to the many combinations in the full factorial design and concerns about respondent burden, a fractional factorial design was created from the full factorial using PROC OPTEX in SAS 9.3. The fractional factorial considered only main effects. From the fractional factorial design, 48 profiles were chosen by PROC OPTEX, yielding a D-efficiency score of 92%[5].

The generated profiles were grouped into blocks of 8, such that the survey consisted of 8 versions, each with 6 different contract scenarios. Each scenario provided the respondent the option of choosing between a: land rental contract, agricultural partnership contract, supplier contract, or the status quo option. Respondents who chose status quo then had to determine if they wanted to keep their current contract or if they wanted to not grow sugarcane (Figure 3.1). From

[5] The D-efficiency score ranges between 0% and 100% and provides information about the efficiency of the experimental design. The aim is to determine a design that provides balance and orthogonality, therefore a higher D-efficiency score is desired (Kuhfeld 2005).

the 148 farmers and landowners surveyed only 110 answers were complete and usable for this study.

Generally stated choice studies use one of two kinds of opt-out options: a "do not adopt" (or "do not purchase") and "keep my current brand" (or "status quo") (Banzhaf, Johnson and Mathews 2001). In this study, we expand the stated choice model to include two opt-out options resembling these. They are "keep my current contract" and "not to grow sugarcane". This unique design has the benefit of eliminating uncertainty about why a respondent chooses the status quo option, making it possible to distinguish between the preferences to not grow sugarcane and to keep their current contract (Figure 3.1). For example, in our case, out of a total of 660 responses, 18% of respondents chose the land rental contract, 20% the agricultural partnership, 10% the supply contract and 51% the status quo option. At a first glance once could ironically interpret these preliminary results as the farmer preferring not to grow sugarcane. When considering the two opt-out model, the status quo option is split into 40% preferring their current contract and 11% opting not to grow sugarcane. The two opt-out model is a novelty that has not been explored in previous studies to the author's knowledge. Previous studies (Adamowicz et al. 1997; Carson et al. 1994) have focused on how different opt-out options (e.g. status quo or keep my current brand) can impact the results from the study but no study to the author's knowledge has been designed to include both opt-out options.

In general, all contract options had information on payment, contract length, and risk of late payment. The probability of late payment was added to reflect the current situation in which financially unstable mills are paying landowners/farmers late, representing a risk attribute of entering into a contract. In 2008/2009 Picanço Filho and Marin (2012a) note that mills paid producers late, which resulted in financial burden to them as these farmers were not able to make the payments to their input suppliers and for third party services (e.g. fertilization services). In addition, results from this survey indicate that late payments occur at least once a year and 20% of respondents complained that the mills did not fulfill their role in the contract (Sant'Anna, Granco, et al. 2016).

Payment type varied by contract. The land rental contract payment is a percentage of the value of the land. The agricultural partnership contract payment is a percentage of the sugarcane production. The percentage levels of the land rental and agricultural partnership contracts were chosen following Brazilian legislation and the National Agricultural Council contract manual (CNA 2007; Brazil 1966).

The agricultural partnership and the supply contract payments both depend on sugarcane yield and TRS (total recoverable sugar) levels. TRS pricing is set by the Council of Sugarcane, Sugar and Ethanol producers of the state of São Paulo – CONSECANA (Valdes 2011). TRS levels determine the value of the sugarcane. In this experiment TRS levels are the minimum, average and maximum observed in the two states (CONAB 2013; Picanço Filho 2010). Apart from the TRS levels, the supply contract has other attributes that affect payment such as: the mill only buying part of the sugarcane produced, the provision of seedlings and that of harvesting, hauling and delivery services. These attributes are part of the common clauses found in current supply contracts. Mills that only buy part of the sugarcane produced must compensate at *cana bisada* the remaining sugarcane in the field. Mills, in GO and MS, usually offer services, such as harvesting, hauling and delivery and the provision of seedlings or a loan, to motivate farmers into producing sugarcane (Picanço Filho 2010). The services were included in the experiment as binary attributes (i.e. they are offered or not) (Table 3.2).

3.4 Conceptual model

In our study, we focus on the farmer and landowner's utility. The conceptual framework is based upon research conducted by Hudson and Lusk (2004) and Bergtold, Fewell and Williams (2014). Farmer *i* derives utility from each of the attributes in contract *j* (Hudson and Lusk 2004). That is:

$$U_{ij} = u_{ij}(R_j, Late, L, CS_j, More1) \tag{3.1}$$

where *R* refers to the returns from contract *j*, *Late* refers to the probability of receiving payments late, and *L* refers to the length of the contract. Each contract has contract specific attributes denoted as CS_j (see Table 3.2). Lastly, *More1* is a dummy that takes on the value 1 if there is more than one mill in the area that the farmer can sell to.

A farmer will choose the contract which maximizes their utility given by equation (3.1). We hypothesize that farmers prefer higher returns$\left(\frac{\partial U}{\partial R_j} > 0\right)$ and lower probability of late payment $\left(\frac{\partial U}{\partial Late} < 0\right)$. The preference for the length of the contract is ambiguous. Given the irreversible nature of start-up costs for growing sugarcane and sugarcane being a perennial crop, it can be expected that farmers may prefer longer contracts $\left(\frac{\partial U}{\partial L} > 0\right)$. Profits from sugarcane production can be achieved by spreading out the initial investment over time (Picanço Filho and Marin 2012a). Longer contracts can help to avoid renegotiation costs and quasi-rental appropriation, as well (Lusk and Hudson 2004; Joskow 1987; Crocker and Masten 1988). Farmers, though, may also prefer shorter contracts in order to have more management flexibility or due to weak contract enforcement $\left(\frac{\partial U}{\partial L} < 0\right)$ (Bergtold, Fewell and Williams 2014).

Contract specific (CS) attributes include the TRS values in the supply and agricultural partnership contracts. In the supply contract, CS attributes also include planting, harvesting, hauling and delivery and "mill buys all" (see Table 3.2). A higher TRS value for the sugarcane implies a higher return for the farmer, since the sugarcane sold is of higher quality. Due to the high costs associated with entering into sugarcane production (Silva and Miziara 2011), a contract with the mill providing financial aid for planting is preferred to one that does not. Due to the machinery and infrastructure needed for harvesting, hauling and delivery, it is likely that farmers will prefer a contract that offers these services over a contract that does not. Finally, the farmer would prefer that the mill buys all of the sugarcane they produce and not just a part of it. Thus, the CS attributes are expected to be seen as beneficial to the farmer $\left(\frac{\partial U}{\partial CS_j} > 0\right)$. Lastly, the number of mills located close to a farmer to which he/she can supply sugarcane to, may impact his/her choice between different contracts or the status quo option. In counties with more than one sugarcane buyer, farmers may have more bargaining power allowing them to demand better contract conditions and higher payments. Hence, it is expected that *More1* brings disutility in the stop growing sugarcane option $\left(\frac{\partial U}{\partial More1} < 0\right)$ for the farmer could bargain for a higher payment, making the option to not to grow sugarcane a bad one. Using the same rational, we would expect *More1* to bring utility to the other contract options $\left(\frac{\partial U}{\partial More1} > 0\right)$since it would increase farmers' bargaining power.

3.5 Empirical model and estimation

The empirical model follows the random utility modelling (RUM) framework, given the researcher can only observe the actual contract choice by a respondent. RUM defines the utility function given by equation (3.1) as having both an observed (V) and a random component (e), such that the utility of farmer *i* choosing contract *j* is (Hudson and Luck 2004; Bergtold, Fewell and Williams 2014):

$$U_{ij} = V_{ij}\left(R_j, Late, L, CS_j\right) + e_{ij} \tag{3.2}$$

where V_{ij} is the nonrandom component of utility, which is a function of the observed attributes of contract *j,* and e_{ij} is a random component of utility and is assumed to be independent and identically distributed extreme value Type 1 (Train 2009; Bergtold, Fewell and Williams 2014).

The functional form of the observed component of utility, V_{ik}, will vary according to the contract chosen. Each contract has contract-specific attributes (e.g. planting and harvest assistance) and general attributes, that are common to all of them (e.g. length of contract and probability of late payment). In the case of the model with the two opt-out options there are five random utility functions that are compared, one for each option and the opt-out choices. Following Bergtold, Fewell and Williams (2014), the observed component of utility for each option (land rental (LR), agricultural partnership (AP), supply (S), not to grow sugarcane (NS) and keep current contract (KC) is given by:

$$V_{iLR} = a_{0i} + a_1 R_{LR} + a_2 Late + a_3 L + a_4 More1, \tag{3.3}$$

$$V_{iAP} = b_{0i} + b_1 R_{AP} + b_2 Late + b_3 L + b_4 TRS + b_5 More1, \tag{3.4}$$

$$V_{iS} = c_{0i} + c_1 Late + c_2 L + c_3 TRS + c_4 P + c_5 H + c_6 D + c_7 B + c_8 More1, \tag{3.5}$$

$$V_{iNS} = d_{0i} + d_1 More1, \text{ and} \tag{3.6}$$

$$V_{iKC} = e_{0i} + e_1 More1 \tag{3.7}$$

where $\boldsymbol{V_{ij}}$ are linear additive functions in the attributes pertaining to each option, where j=LR, AP, S, NS, KS (Louviere, Hensher and Swait 2000). The intercepts or alternative specific constants (ASC) (a_{0i}, b_{0i}, $c_{0i,}d_{0i}, e_{0i}$) in equations (3.3) to (3.7) are contract and individual specific, allowing the ASC to capture individual specific preferences for each option in relation to a "base" case. This approach allows for the average marginal utility to vary among each individual and allows for each contract type to be viewed on average differently due to its nature. We assume that each ASC varies across the sample following a normal distribution and is modeled as (Louviere, Hensher and Swait 2000):

$$a_{0i} = \alpha + \sigma_a \mu_{ai}, \tag{3.8}$$

$$b_{0i} = \beta + \sigma_b \mu_{bi}, \tag{3.9}$$

$$c_{0i} = \tau + \sigma_c \mu_{ci}, \tag{3.10}$$

$$d_{0i} = \delta + \sigma_d \mu_{di}, \text{ and} \tag{3.11}$$

$$e_{0i} = \varepsilon + \sigma_e \mu_{ei}. \tag{3.12}$$

Equations (3.8) to (3.12) indicate that the ASC is a function of the unconditional mean $(\alpha, \beta, \tau, \delta, \varepsilon)$ and a random term (i.e. $\boldsymbol{\mu_{ai}, \mu_{bi}, \mu_{ci}, \mu_{di}, \mu_{ei}}$**),** which is assumed to have a normal distribution N(0,1). $\boldsymbol{\sigma_a, \sigma_b, \sigma_c, \sigma_d, \sigma_e}$ represent the standard deviation of the distribution of each ASC (Louviere, Hensher and Swait 2000). To estimate the proposed model, the utility V_{iKC} is set as the base and, as such, it is normalized to be zero (i.e. $V_{iKC} = 0$). This is possible given that utility functions are ordinal and, as such, the preference relation is not distorted by affine linear transformations of the utility function. In a separate analysis, as an extra step, we introduced heterogeneity in the means by modelling the random parameters using trust and welfare indices to see how these could affect the contract choices (see Appendix B)[6].

In this study, we run both the single opt-out model, resembling stated choice models commonly found in the literature, and a stated choice model with two opt-out options. The objective is to account for omitted choices, such as the case of the choice to keep the current contract. If only the one opt-out model is run, then the coefficients may be biased due to omitted variables (choices). In the results section, we compare both models to show how controlling for the choice not to grow sugarcane is important to explain the estimates.

In the case of the single opt-out model, there are four observed utilities, one for each contract and a fourth for the status quo option. The status quo option is the combined observed utility of not to grow sugarcane and of keep my current contract. Hence equations (3.11) and (3.12) are combined to form the status quo option (i.e. $f_{0i} = (\varepsilon + \delta) + (\sigma_e \mu_{ei} + \sigma_d \mu_{di})$). The status quo option is set as the base case of the single opt-out model (i.e. $V_{istatusquo} = 0$). The coefficients of the variable *More1* captures the marginal utility of a farmer or landowner in an area with more than one mill to sell to, signing a contract[7]. A description of the variables used in the empirical model is presented in Table 3.3.

The observed data indicates the choice made by a respondent. The probability that farmer i chooses option k instead of j is given by the probability that the utility derived from k is greater than or equal to that derived from j, from a set of alternatives C (Hudson and Lusk 2004):

---

[6] Details on the method, related studies and results are described in Appendix B.

[7] A dummy for the state was also considered as there have been studies (e.g. Bergtold, Fewell, Williams 2014) that have noted a difference between willingness to grow biofuels between respondents in different regions. In our case, over 60% of respondents in Goiás and 13% of the respondents in Mato Grosso do Sul had more than 1 mill to sell their sugarcane to. We believe this effect is also being captured by the *More1* dummy, so to avoid collinearity we have decided to keep only the More1 dummy. Also in previous modeling the dummy state was not statistically significant.

$$Pr\{k\ is\ chosen\} = Pr\{\ V_{ik} + e_{ik} \geq \ V_{ij} + e_{ij};\ \forall\ j \neq k;\ j, k \in C\} \tag{3.13}$$

The unconditional probability of choosing k can be obtained from the integral of the conditional multinomial choice probability over all possible values of θ_0 (Train 2009; Bhat 1998):

$$\Pr(k_i) = \int \left[\frac{\exp(\theta_{0k} + \theta_k{}'x_{ik})}{\sum_j \exp(\theta_{0j} + \theta_j{}'x_{ij})}\right] f(\theta_0)d\theta_0 \tag{3.14}$$

where θ_0 is a vector containing all random ASC's and θ_k is a matrix containing the other parameters in each utility function, k = land rental, agricultural partnership, supply, keep current contract and not grow sugarcane. The distribution of $f(\theta_0)$ is assumed to be iid multivariate normal ($N(\mathbf{0}, \mathbf{\Omega})$), where $\mathbf{\Omega}$ is the covariance matrix of θ_0 (Train 2009). Equation (3.14) is a form of mixed logit probability (Train 2009). The advantage of using the mixed logit is that it is not sensitive to the independence of irrelevant alternatives (Swait 2006). The mixed logit also has the benefit of allowing θ_0 to vary among individuals accounting for their individual specific "tastes" or heterogeneous contract preferences (Broch and Vedel 2011; Train 2009). Estimation of the model was done using NLOGIT 4.0 and a simulated maximum likelihood with 1000 Halton draws and the BFGS Quasi-Newton Algorithm.

In order to capture how changes in common attributes across the contracts (i.e. probability of late payment) affect the probability of choosing a competing contract we calculated cross elasticity measures. Cross elasticity measures provide information on how percentage changes in one attribute in a type of contract can impact the probability of the respondent choosing a competing contract. Cross elasticity and direct elasticity measures are calculated using the following formulae (Louviere, Hensher and Swait 2000):

$$E_{Xjsi}^{Pki} = \frac{\partial P_{ki}}{\partial X_{jsi}} \cdot \frac{X_{jsq}}{P_{ki}} \tag{3.15}$$

$$E_{Xjsi}^{Pji} = \frac{\partial P_{ji}}{\partial X_{jsi}} \cdot \frac{X_{jsq}}{P_{ji}} \tag{3.16}$$

The cross elasticity measure (E_{Xjsi}^{Pki}) is the elasticity of the probability of individual i choosing option k with respect to a marginal change in the sth attribute describing the utility from contract j, where $j \neq k$, by the individual i. The direct elasticity measure (E_{Xjsi}^{Pji}) is the elasticity of the probability of the individual i choosing option j with respect to a marginal change in the sth attribute describing the utility from contract j, by the individual i (Louviere, Hensher and Swait 2000).

In order to calculate the value of the contract attributes to the individual, results from the estimation were used to calculate the willingness to pay for certain attributes. Willingness to pay (WTP) for a particular contract attribute follows the calculations proposed by Hensher, Rose and Greene (2015). Normally, the coefficient associated with net return or price is used. In this study, the coefficients used to represent these returns differs from one contract to the other. In the land rental contract, WTP is found by dividing the coefficient of the attribute (β_i) by that of the payment rate (β_{Rate}):

$$\frac{\beta_i}{\beta_{Rate}} \tag{3.17}$$

Similarly, willingness to pay for a particular contract attribute in both the agricultural partnership and the supply contracts is found by dividing the coefficient of the attribute (β_i) by that of the TRS (β_{TRS}):

$$\frac{\beta_i}{\beta_{TRS}} \tag{3.18}$$

Hence, when referring to the land rental contract, willingness to pay is expressed in terms of percentage of the land value the farmer or landowner is willing to forgo per year for that attribute. In the supply and agricultural partnership contracts, willingness to pay is expressed in units of TRS the farmer or landowner is willing to give up for more or less of a particular attribute. Asymptotic standard errors were estimated using the delta method (Greene 2008).

3.6 Results

The results for the single opt-out model (i.e. the model with the three contract options and a status quo) and those for the two opt-out model are presented in tables 3.4 and 3.5, respectively. They are similar to those from previous studies (Bergtold, Fewell and Williams 2014; Hudson and Luck 2004) and also confirm the assumptions made in the conceptual model section 3.4. The McFadden Pseudo R^2 of 0.36 and 0.41, respectively, indicate a decent fit to the data. The random alternative specific constants (ASC) are all statistically significant at a 1 percent level of significance. The statistical significance of the random components of the ASC's (standard deviation) indicate the presence of preference heterogeneity across farmers for different contract types.

3.6.1 Single versus two opt-out

The single opt-out model and the two opt-out model present similar parameter values, though the two opt-out model provides more explanatory power. The two opt-out model explains the status quo option by distinguishing between the individual's choice not to grow sugarcane or to keep their current contract. Results from the single opt-out (Table 3.4) might lead us to conclude that farmers in Goiás and Mato Grosso do Sul may prefer not to sign contract nor produce sugarcane. Yet, the marginal disutility of choosing not growing sugarcane is the highest among all other choices. This result is in line with Picanço Filho and Marin's (2012a) findings that farmers in this area are willing to grow sugarcane due to lower risks and higher returns. If there is more than 1 mill buying sugarcane, then disutility is even higher. The coefficient for the variable indicating if the farmer has the option to sell sugarcane to more than one mill (i.e. *More1*) was only statistically significant for the option not to grow sugarcane. This is expected since when there are multiple sugarcane buyers, landowners and farmers are more likely to grow sugarcane as they have more bargaining power and the mill has no monopsony power. More bargaining power means more flexibility in contract negotiations and, possibly higher returns. Over 90% of sugarcane in these states is procured through contracts. Sugarcane spot markets in this region are nonexistent. Around 2% of what mills acquire in sugarcane comes from spot markets.

Differently from Hudson and Lusk (2004) the random alternative specific constant for each contract type (intercepts) are statistically significant and negative. This indicates farmers' and landowners', in general, receive higher utility from their current contract to the ones in the experiment. This may be a result of individually specific contract peculiarities that could not be accounted for in this study. Another reason for the negative intercepts could be the respondent's systematic preference for a contract, a result that Hudson and Lusk (2004) did not find in their study.

Differences in terms of the coefficients between the two models are: (1) the marginal utility of hauling and delivery in the supply contract is statistically significant in the single opt-out model but not in the two opt-out model; and (2) the parameters of *More1* differ in signs between the two models, though they are not statistically significant.

3.6.2 Contract preferences

Given the better fit and explanatory power the discussion will concentrate on the results from the two opt-out model (Table 3.5). In terms of preference for autonomy, our study finds a different result than that of Hudson and Lusk (2004). These authors found that farmers are more willing to sign contracts with more autonomy than that with less, while our results point to a preference for land rental contracts over the other contracts, where the landowner has no say in sugarcane production. The land rental contract, where the agent has less autonomy, brings less disutility to the farmer than the supply or the agricultural partnership contracts, where the farmer has more control over sugarcane production. This stronger preference for the land rental contract, may be due to a preference to minimize production risks. Hudson and Lusk's (2004) find that farmers and landowners prefer options with less risk. The land rental contract, in comparison with the other two contract options, has the lowest production risk and a fixed payment. In their study, Picanço Filho and Marin (2012a) also find that sugarcane producers are tempted to switch to land rental contracts once their contracts expire due to late payments made by mills.

When the mills pay late, farmers cannot meet payment deadlines of input suppliers causing them financial hardship. The preference to avoid risk is also present in the preference for a lower probability of late payment. As mentioned this is a common event in the sugarcane industry in this area that can bring financial hardship to the producer. The attribute, probability of receiving a late payment, was negative for all three contracts, though only statistically significant in the land rental and supply contracts. To see how landowners and farmers value this attribute the willingness to pay (accept) for a reduction in the probability of a late payment was calculated. Landowners are willing to accept a contract with a 1% higher probability of late payment as long as the land rental rate received increases by 0.37% per year. Willingness to pay for a lower probability of late payment was not significant in the cases of the agricultural partnership and supply contracts. The reason for the statistical insignificance of the willingness to pay may be because agents signing these contracts usually are paid at the end of the growing season, which is dependent on harvest timing.

Although sugarcane has high start-up costs and is a perennial crop with a life cycle of 6 years, longer contracts reduce the marginal utility from farmers and landowners signing a contract. The coefficients of the contract length attribute were negative and statistically significant for all three types of contracts. In the land rental contract, farmers and landowners were willing to accept a payment reduction of 6.25% per year, to sign a six-year contract instead of a twelve year one. In the agricultural partnership, farmers and landowners were willing to sign a longer contract if they received an extra 27.8 units of TRS per kilo yearly. Reasons for the preference for a shorter contract may vary. According to Bergtold, Fewell and William's (2004) the preference for shorter contracts stems from the farmer's preference for more flexibility in their farming activities. Watanabe and Zylberstein (2014) argue that weak contract enforcement by the State may prompt agents to prefer shorter contracts. Another reason may be due to concerns about the financial stability of the mill. In fact, Sant'Anna, Granco, et al. (2016) find that 72% of sugarcane producers and landowners in Goiás and Mato Grosso do Sul state as their main concern about sugarcane production is the mill's financial situation.

The coefficients related to attributes that affect the contract payment (i.e rate of LR, share payment, TRS and mill buys all) were all positive and statistically significant, indicating that farmers and landowners, as rational agents, receive utility from higher net returns. In the land rental contract, returns are represented by the percentage of the value of the land. At a 1% level of statistical significance, an increase in the percentage of the value of the land increases the landowner's marginal utility from signing a land rental contract. In the agricultural partnership and supply contracts, returns are represented by the level of TRS used in the calculation of sugarcane prices and revenues. Increases in TRS levels increases the marginal utility of a farmer or landowner signing an agricultural partnership or supply contract. Further attributes that impact returns from the contract are also positive and statistically significant. If the mill is willing to buy all production instead of only buying what it requires, then the farmer's utility increases. The same occurs with increases in the share of the production received by farmers in agricultural partnership contracts. In fact, with a statistical significance level of 5%, farmers and landowners are willing to accept 1.26 units less of TRS per kilo for a one percentage increase in the percentage of the sugarcane production received. These results are like those found in Bergtold, Fewell and Williams' (2014), who point out the importance of the level of net returns as a contract attribute.

Although there have been reports (Picanço Filho and Marin 2012a) of the mills in Goiás and Mato Grosso do Sul attracting sugarcane suppliers by offering certain services (e.g. planting, harvesting, hauling and delivery), results show that farmers are not willing to pay for these services. In fact, results show that although the coefficients associated with these attributes are positive, as previously expected, only planting is statistically significant. Hence, as Hudson and

Lusk (2004) find, the provision of inputs does increase the farmer's marginal utility from signing a contract, but differently from Bergtold, Fewell and Williams (2004), services do not appear to be a deciding factor in the farmer's willing to sign a supply contract.

3.6.3 Substitutability between contracts

Cross and direct elasticity measures from the two opt-out model were calculated for attributes with continuous variables and arc elasticities for dummy attributes. Direct elasticities capture how changes in an attribute in a given contract affects the probability of an individual choosing that contract over a competing option (Tables 3.6 to 3.9). Cross-elasticities allows for the analysis of the substitutability between contract options.

Cross-elasticity measures for the option not to grow sugarcane show that changes in attributes in the agricultural partnership and supply contract have a greater impact in the probability of not choosing to grow sugarcane than in choosing to grow (Table 3.9). For example, an increase of one percent in the TRS per kilo of sugarcane decreases the probability of choosing not to grow sugarcane by 0.05%. Increases in length and risk in the contracts, in turn, induce an increase of less than 0.001% in an individual choosing not to grow sugarcane. When there is more than one mill in the area, the likelihood of choosing not to grow sugarcane decreases by 0.11% while the likelihood of choosing any of the other options is around 0.03% (Table 3.9).

When considering the substitutability between contract options in the experiment (e.g. land rental, agricultural partnership and supply contracts), a one percent increase in the rate of land rental payment increases the probability of the land rental contract being chosen by 0.66%. This change decreases the probability of agricultural partnership and supply being chosen by 0.15% and 0.16%, respectively (Table 3.6). A one percent increase in the TRS value increases the probability of the agricultural partnership agreement and the supply contracts being chosen by 1.57% and 1.20%, respectively (Tables 3.7 and 3.8). This increase in TRS decreases the chance of the land rental and the supply contracts by 0.30% and in 0.20%, respectively, being chosen over the agricultural partnership agreement (Table 3.7). For the supply contract, an increase in one percent of the value of the TRS reduces the chance of the land rental agreement or the agricultural partnership agreement of being chosen by 0.10% and 0.13%, respectively (Table 3.8).

We may want to understand what changes in attributes would make the farmer willing to switch from his current contract. Among the attributes analyzed, changes in TRS appear to be the deciding factor for respondents to switch from their current contract to one in the experiment. A one percent increase in TRS per kilo decreases the probability of an individual to prefer his current contract instead of an agricultural partnership by 0.58% (Table 3.7). A one percent increase in TRS per kilo decreases the probability of a farmer preferring his current contract instead of a supply by 0.23% (Table 3.8). In the land rental contract, rate is the attribute where changes have a larger impact on the probability of keeping the current contract (Table 3.6). A one percent increase in the rate paid decreases the likelihood of an individual preferring to keep their own contract by 0.23%. Out of the services offered by the mill (e.g. planting, hauling and delivery, and the mill buys all), the mill buying all the production has the highest direct elasticity. Thus, when the mill buys all the sugarcane production from the producer, their probability of choosing their current contract instead of a supply contract decreases by 0.03% (Table 3.8).

Interestingly increases in risk (i.e. the probability of late payment) do not increase the probability of a farmer choosing not to grow sugarcane. In general, increases in the probability of late payment causes the farmer to resort to his current contract. For example, an increase in 1% in the probability of late payment in the supply contract increases the probability of the farmer choosing his current contract by 0.05%. The same effect occurs when the length of the contracts from the hypothetical experiment changes from 6 to 12 years. In the end, farmers are willing to switch from their current contracts if attributes associated with returns increase (i.e. changes in rate, sharepay and TRS). Hence, if mills want farmers to switch from their current contracts they should offer higher returns.

3.7 Conclusions

This paper examines farmer's and landowner's willingness to sign a contract with a local ethanol mill in the Brazilian *Cerrado*. It contributes to the understanding of the extensive expansion in sugarcane production that has occurred in this region, and to the literature on stated choice modeling by providing a novel manner to deal with omitted choices masked by the status quo option.

A hypothetical stated choice experiment was conducted with farmers and landowners in Goiás and Mato Grosso do Sul. The experiment involved farmers and landowners choosing between three contract options (land rental contract, an agricultural partnership contract, a supply contract) and a status quo option. If the status quo option was chosen, individuals had to indicate the reason for this choice ("keep current contract" or "not grow sugarcane"). We ran a single opt-out model and a two opt-out model. The two opt-out model, not used in past stated choice studies, allows for a better interpretation of the single opt-out model, commonly found in the literature. Data from the stated choice experiment was analyzed using a random parameter model and the respondent's willingness to pay for contract attributes was calculated. Direct and cross-elasticity measures were also calculated to interpret the substitutability between contract options. Results made it possible to identify which attributes gave farmers and landowners' utility and which disutility. Farmers and landowners are more likely to sign contracts that offer higher returns, are shorter in length and have a lower probability of late payments.

Results from the study provide information for the industry. To reduce the transaction costs and facilitate the implementation of an ethanol plant, in a particular location, mills should focus on designing more attractive contracts. Attractive contracts have higher returns, lower probabilities of late payment, are shorter in length. Other services previously used by mills to entice farmers into growing sugarcane were not found to be as important to producers as may have been thought. Hence, mills could stop offering these services and increase payments to farmers for their production. Farmers can negotiate the removal of these services for payment increases when signing a contract with the mill. For supply contracts to be enticing mills should offer to buy all the farmers production. This means that farmers and mills should work closely to ensure that the total sugarcane production will fulfill the mill's requirements. Mills should also consider allowing farmers to sell the sugarcane they do not require to other mills instead of imposing a fidelity clause in contracts.

Farmers and landowners seem to prefer land rental contracts over other contract options (except the option to keep their current contract). This has implications for the sugarcane industry, potentially motivating mills to vertically integrate. A mill's decision to vertically integrate may have environmental and development implications. The adoption of conservation practices will have environmental consequences. As discussed in section 3.2.1, a tenant may have an incentive to overuse the land. This, in turn, may result in environmental degradation. It is possible that farmers, working on their own land, are more willing to adopt conservation practices to ensure the quality of the land for years to come. Therefore, findings warn farmers about the potential hazards of giving up their autonomy on sugarcane production by signing a land rental contract.

The decision of the mill to vertically integrate may have implications for rural development in this region. If by vertically integrating mills bring workers from other states, then the implementation of a new mill may not imply in a decrease in local unemployment. In turn, it is likely that local farmers prefer to hire local workers, since these have local references or are known to them. In this case, the economic activities of the local farmer may have a greater impact on rural development than those of the mill. In addition, the mills decision to vertically integrate can make the sustainability of the sugarcane expansion in the *Cerrado* more susceptible to the financial stability of the mill. If one mill controls the sugarcane production in a County, then its closure will imply in the end of ethanol and sugarcane production in that County. Hence, it may be in the interest of the Brazilian government to promote agricultural production by farmers, as well as the installation of more than one mill in a location.

As results have shown, when there are more mills in a location (i.e. more buyers), farmers and landowners will prefer to grow sugarcane. This is probably linked to their increase in bargaining power when negotiating with the mill. Farmers are just as likely to sign any of the contracts (i.e. land rental, agricultural partnership or supply). When there are less mills, or sugarcane buyers, it is likely that farmers prefer the land rental contract to diversify their revenue and protect themselves from low grain or cattle prices. This fact allied with farmers' preference for shorter contracts may point to the ethanol expansion in the *Cerrado* being sensitive to commodity prices. In other words, as grain and livestock become more profitable farmers will want their lands back for grain and cattle production. With shorter contracts (i.e. 6-year contracts), this switch could be done after the first sugarcane cycle.

The fact that farmers and landowners are willing to receive less to sign shorter contracts could be indicative of a lack of trust concerning contract enforcement, the financial situation of the mills, or the desire for more flexibility in their farming operations. Given that sugarcane production requires high initial investments costs that are diluted throughout its production cycle (i.e. six to twelve years), the first two reasons appear to be a better explanation for the preference for shorter contracts. The Brazilian government should be interested in promoting longer contracts as a form to guarantee sugarcane production in the *Cerrado* after public policies subside. Therefore it should focus on policies that promote contract enforcement as well as the establishment of producer associations. Associations have the advantage of providing farmers and landowners with more information allowing for better transparency when negotiating a contract with the mill. In order to understand the impact of contract enforcement and asymmetric information on the sustainability of the sugarcane expansion in the *Cerrado* further studies will need to be conducted. Perhaps studies should focus on farmers and landowners willingness to sign contracts at different levels of asymmetric information or trust.

Findings from this study can not only guide Brazilian farmers, landowners, mills and policy makers but also stakeholders in other countries seeking to expand biofuel production. It highlights the complexity of expanding the production of a biofuel feedstock into a region with previously established crop and livestock production. Farmers may only be willing to sign a sugarcane contract with the aim of diversifying their revenues. This in turn, motivates vertical integration bringing consequences to rural development, the environment and the sustainability of the expansion of the production of the biofuel crop.

3.8 References

Adamowicz, W., J. Swait, P. Boxall, J. Louviere, and M. Williams. 1997. “Perceptions versus objective measures of environmental quality in combined revealed and stated preference models of environmental valuation.” *Journal of Environmental Economics and Management* 32(1):65–84.

de Almeida, P.J., and A.M. Buainain. 2016. “Land leasing and sharecropping in Brazil: determinants, modus operandi and future perspectives.” *Land Use Policy* 52:206–220.

Banzhaf, M.R., F.R. Johnson, and K.E. Mathews. 2001. “Opt-out alternatives and anglers’ stated preferences.” *The choice modelling approach to environmental valuation. Edward Elgar, London*:157–177.

Bergtold, J.S., J. Fewell, and J. Williams. 2014. “Farmers’ willingness to produce alternative cellulosic biofuel feedstocks under contract in Kansas using stated choice experiments.” *BioEnergy Research* 7(3):876–884.

Bhat, C.R. 1998. “Accommodating flexible substitution patterns in multi-dimensional choice modeling: formulation and application to travel mode and departure time choice.” *Transportation Research Part B: Methodological* 32(7):455–466.

Brazil. 1966. Decree No. 59,566. Regulamenta as Seções I, II e III do Capítulo IV do Título III da Lei nº 4.504, de 30 de Novembro de 1964, Estatuto da Terra, o Capítulo III da Lei nº 4.947, de 6 de abril de 1966, e dá outras providências. Brasilia: Presidência da República.

Brazil. 2009. Law No. 12,187. Institui a Política Nacional sobre Mudança do Clima – PNMC e dá outras providências. Brasilia: Presidência da República. Available at: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm.

Broch, S.W., and S.E. Vedel. 2011. “Using choice experiments to investigate the policy relevance of heterogeneity in farmer agri-environmental contract preferences.” *Environmental and Resource Economics* 51(4):561–581.

Carson, R.T., J.J. Louviere, D.A. Anderson, D.S. Bunch, D.A. Hensher, R.M. Johnson, W.F. Kuhfeld, D. Steinberg, J. Swait, H. Timmermans, and J.B. Wiley. 1994. “Experimental analysis of choice.” *Marketing Letters* 5(4):351–367.

CNA, Confederação da Agricultura e Pecuária do Brasil. 2007. *Cana-de-açúcar: orientações para o setor canavieiro. ambiental, fundiáaria e contratos.* Brasilia: Embrapa. Available at: http://www.agencia.cnptia.embrapa.br/Repositorio/Cana-de-acucar_orientacoes_para_o_setor_canavieiro_000fipw96tk02wyiv80z4s4733kvhu6q.pdf.

CONAB, Companhia Nacional de Abastecimento. 2013. *Perfil do setor do acucar e do etanol no Brasil* Yearly. Brasília: CONAB. Available at: http://www.conab.gov.br/OlalaCMS/uploads/arquivos/13_10_02_11_28_41_perfil_sucro_2012.pdf [Accessed November 14, 2014].

Crocker, K.J., and S.E. Masten. 1988. "Mitigating contractual hazards: unilateral options and contract length." *The RAND journal of economics*:327–343.

Eswaran, M., and A. Kotwal. 1985. "A theory of contractual structure in agriculture." *The American Economic Review* 75(3):352–367.

Feltre, C., and L.F. de Oriani e Paulillo. 2015. "Plurality in different groupings: sugarcane supply in Brazil." *British Food Journal* 117(9):2265–2281.

Fischer, C. 2013. "Trust and communication in European agri-food chains." *Supply Chain Management: An International Journal* 18(2):208–218.

Goforth, C. 2015. "Using and interpreting Cronbach's Alpha." *University of Virginia Library, Available at:< http://data. library. virginia. edu/using-and-interpreting-cronbachs-alpha*.

Greene, W.H. 2008. *Econometric analysis* 6th ed. Upper Saddle River, New Jersey: Pearson Prentice Hall.

Hensher, D.A., J.M. Rose, and W.H. Greene. 2015. *Applied choice analysis*. Cambridge University Press.

IBGE, Brazilian Institute of Geography and Statistics. 2006. *Censo Agropecuario 2006*. IBGE. Available at: http://biblioteca.ibge.gov.br/visualizacao/periodicos/51/agro_2006.pdf.

IBGE, Brazilian Institute of Geography and Statistics. "Produção Agrícola Municipal – PAM." Available at: www.ibge.gov.br [Accessed May 20, 2015].

Joskow, P.L. 1987. "Contract duration and relationship-specific investments: empirical evidence from coal markets." *The American Economic Review*:168–185.

Kim, J.O., and C.W. Mueller. 1978. *Introduction to factor analysis: what it is and how to do it*. SAGE.

Kuhfeld, W.F. 2005. "Experimental design, efficiency, coding and choice design." *SAS Technical Support T's-722C*.

Louviere, J.J., D.A. Hensher, and J.D. Swait. 2000. *Stated choice methods: analysis and applications*. Cambridge University Press.

Lusk, J.L., and D. Hudson. 2004. "Willingness-to-pay estimates and their relevance to agribusiness decision making." *Review of Agricultural Economics* 26(2):152–169.

Manzatto, C.V., E.D. Assad, J.F.M. Baca, M.J. Zaroni, and S.E.M. Pereira. 2009. "Zoneamento agroecológico da cana-de-açúcar: expandir a produção, preservar a vida, garantir o futuro." *Embrapa Solos. Documentos*.

MAPA, Ministry of Agriculture, Live Stock and Supply. 2013. *Anuário estatístico da agroenergia 2012: Statistical yearbook of agrienergy.* Brasília: Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Produção e Agroenergia.

Neves, M.F., V.G. Trombin, and M. Consoli. 2011. "The sugar-energy map of Brazil." In E. L. Leao de Sousa and I. de C. Macedo, eds. *Ethanol and bioelectricity: sugarcane in the future of the energy matrix*. São Paulo: UNICA, pp. 14–43.

Neves, M.F., R.S. Waack, and M.K. Marino. 1998. "Sistema agroindustrial da cana-de-açúcar: caracterização das transações entre empresas de insumos, produtores de cana e usinas." In Anais. XXXVI Congresso da Sociedade Brasileira de Economia e Sociologia Rural - SOBER. Poços de Caldas, M.G.: SOBER, pp. 559–572. Available at: http://pensa.org.br/wp-content/uploads/2011/10/O_sistema_agroindustrial_da_cana_de_acucar_1998.pdf [Accessed November 30, 2014].

O Popular. 2011. "Jataí aprova legislação restritiva ao cultivo da cana-de-açúcar." *O Popular*. Available at: http://www.opopular.com.br/editorias/economia/jata%C3%AD-aprova-legisla%C3%A7%C3%A3o-restritiva-ao-cultivo-da-cana-de-a%C3%A7%C3%BAcar-1.81340 [Accessed December 20, 2014].

Picanço Filho, F.A. 2010. "Contratos agrários na agroindústria canavieira em Goiás: legalidades e conflitos." Available at: http://ppagro.agro.ufg.br/up/170/o/DISSERTA%C3%87%C3%83O_FINAL_ART%C3%8AMIO_2008.pdf?1354556732 [Accessed December 9, 2014].

Picanço Filho, F.A., and J.O.B. Marin. 2012a. "Sugar-cane supply agreement: the power asymmetry between agents." *Interações (Campo Grande)* 13(2):191–202.

Picanço Filho, F.A., and J.O.B. Marin. 2012b. "The sugar cane political network and its power resources in the Goiás state, Brazil." *Pesquisa Agropecuária Tropical* 42(2):189–197.

Procana. 2013. *Brazilian sugar and ethanol guide 2013*. Ribeirão Preto: ProCana Brasil.

Queiroz, S. de T.P. 2008. *Usinas de álcool: fatores influentes no processo de escolha da localização de novas unidades*. Master Thesis. Brasilia: Universidade de Brasília. Available at: http://repositorio.unb.br/handle/10482/4927 [Accessed October 10, 2014].

Roberto, C. 2012. "Cana leva progresso e esperança ao Centro-Oeste." *CANAMIX* 5(45):38–55.

Rudorff, B.F.T., D.A. Aguiar, W.F. Silva, L.M. Sugawara, M. Adami, and M.A. Moreira. 2010. "Studies on the rapid expansion of sugarcane for ethanol production in São Paulo State (Brazil) using Landsat data." *Remote sensing* 2(4):1057–1076.

Sant'Anna, A.C., G. Granco, J.S. Bergtold, M.M. Caldas, T. Xia, P. Masi, T. Link, and W. Lorenzani. 2016. "The challenges of the sugarcane expansion: how do producers and land owners think and act?" In G. R. Santos, ed. *Forty years of ethanol in Brazil: hide or confront the crises?* Brasilia: IPEA, pp. 113–142.

Sant'Anna, A.C., A. Shanoyan, J.S. Bergtold, M.M. Caldas, and G. Granco. 2016. "Ethanol and sugarcane expansion in Brazil: what is fueling the ethanol industry?" *International Food and Agribusiness Management Review* 19(4):163–182.

Sartorius, K., and J. Kirsten. 2007. "A framework to facilitate institutional arrangements for smallholder supply in developing countries: an agribusiness perspective." *Food Policy* 32(5–6):640–655.

Shikida, P.F.A. 2013. "Expansão canavieira no Centro-Oeste: limites e potencialidades." *Revista de Política Agrícola* 22(2):122–137.

Silva, A.A., and F. Miziara. 2011. "Sucroalcohol sector and agricultural frontier expansion in the Goiás state, Brazil." *Pesquisa Agropecuária Tropical* 41(3):399–407.

StataCorp, L. 2015. *Multivariate statistics reference manual*. Stata Press. Available at: http://www.stata.com/bookstore/multivariate-statistics-reference-manual/.

Swait, J. 2006. "Advanced choice models." In *Valuing environmental amenities using stated choice studies*. Springer, pp. 229–293.

Train, K.E. 2009. *Discrete choice methods with simulation*. New York: Cambridge University Press.

Valdes, C. 2011. "Brazil's ethanol industry: looking forward." Outlook No. BIO-02, Available at: http://www.ers.usda.gov/publications/bio-bioenergy/bio-02.aspx [Accessed May 20, 2015].

Vavra, P. 2009. "Role, usage and motivation for contracting in agriculture." No. 16, Available at: http://www.oecd-ilibrary.org/agriculture-and-food/role-usage-and-motivation-for-contracting-in-agriculture_225036745705 [Accessed March 30, 2017].

Watanabe, K., and D. Zylbersztajn. 2014. "Contract farming in the Brazilian agri-business system: private institutions and State intervention." *Uniform Law Review - Revue de droit uniforme* 19(3):459–478.

Weesie, J. 1997. "Enhancements to the alpha command." *Stata Technical Bulletin* 6(35). Available at: https://ideas.repec.org/a/tsj/stbull/y1997v6i35sg66.html.

Windle, J., and J. Rolfe. 2005. "Diversification choices in agriculture: a choice modelling case study of sugarcane growers." *Australian Journal of Agricultural and Resource Economics* 49(1):63–74.

Table 3.1: Statistics from the 2006 Agricultural Census versus statistics from our survey

Characteristics	Census (2006)*	Our survey
Average area of the farm (hectares)	415	913
Percentage who own land	87	78
Participation in Association or Cooperative		
Percentage participating in cooperatives	11	49
Percentage participating in an association	11	49
Gender:		
Percentage of males	92	96
Education – Percentage who completed:		
5th - 8th Grade	4	7
High School	4	37
Have a college degree	3	28
Farms with sugarcane production:		
Average sugarcane yield (ton/ha)*	70.30	87.71
Average Value of Sugarcane Production (R$1000)	330.18	1035.24

Source: IBGE 2006.
*The average yield of sugarcane comes from CONAB 2013.

Scenario 1

Option 1: Land Rental Agreement	**Option 2: Partnership Agreement**
Land is rented to the mill to produce sugarcane for a annual payment. Rate: **<u>15%</u>** of the value of the land. Possibility of a late payment: **<u>0%</u>**. Contract length: 12 **<u>years</u>**. **1**	Land is rented to the mill to produce sugarcane for a share of the production paid annually. Rate: **<u>50%</u>** of the value of the production based on **<u>155kg of TRS/ton</u>**. Possibility of a late payment: **<u>10%</u>**. Contract length: 6 **<u>years</u>**. **2**

Option 3: Supply Agreement	**Option 4: Status Quo**
You produce sugarcane to the mill. The mill is responsible for: Planting: **<u>NO.</u>** Harvesting: **<u>NO</u>** Delivery: **<u>NO.</u>** Price is based on TRS of: **<u>155kg of TRS/ton</u>** Possibility of a late payment: **<u>10%</u>**. Mill buys all the production: **<u>NO</u>** Contract length: 12 **<u>years</u>** **3**	I prefer to remain in my current situation **4**

(Please write down the number corresponding to the option you prefer)

Which option do you choose? ☐

If you ***<u>choose "Status Quo"</u>*** *please answer the following:*

Would you rather: (*Please mark one*)

Answer *(Enter 1 for selected option, leave blank if not used)*

☐ Stay with your current contract

☐ Stop growing sugarcane

Figure 3.1: Example choice scenario for the stated choice experiment

Table 3.2: A description of contract attributes and levels for the stated choice experiment

Attribute	Contract Type(s)*	Description	Levels
Late payment	LR, AP, S	Probability of the mill paying late the amount in the contract	0%, 10%, 20%
Length of contract	LR, AP, S	Time commitment in consecutive years of the contractual agreement	6 or 12 years
TRS	AP, S	Total Recovered Sugar (TRS) value used to calculate the monetary value received for the payment in sugarcane	110 kg of TRS 125 kg of TRS 140 kg of TRS 155 kg of TRS
Rate of LR	LR	Amount received by the landowner in return for giving up his rural property to the mill.	5%; 10%; 15% and 20% of the land value.
Share payment (rate of AP)	AP	Percent of the total production paid by the mill for the use of the land for sugarcane production.	20%, 30%, 40%, 50% of the total sugarcane production
Planting	S	"Yes": mill provides the farmer with seedlings or a loan for the formation of the sugarcane plantation. "No": planting costs fall upon the supplier.	Yes or No
Harvesting	S	"Yes": mill is responsible for harvesting "No": supplier is responsible for harvesting.	Yes or No
Hauling and delivery	S	"Yes": mill is responsible for hauling and delivery "No": supplier is responsible for hauling and delivery.	Yes or No
Mill buys all	S	"Yes": mill buys all harvested sugarcane. "No": mill buys only the amount of sugarcane it needs. It pays the rest of the production as "cana bisada" (i.e. at 50% the value of the harvested sugarcane).	Yes or No

*LR: land rental contract. AP: agricultural partnership contract. S: supply contract.

Table 3.3: Description of the variables in the econometric model

Variable	Description
R_{LR}	The payment for the land rental (LR) contract that is based on the value of land
R_{AP}	The payment for the agricultural partnership (AP) that is a share of the yield
$Late$	The probability of the mill making a late payment.
L	The length of the contract in years.
TRS_k	The Total Recovered Sugar (TRS) value used to calculate the price received for the harvested sugarcane in the agricultural and supply contracts.
P	A *dummy* indicating whether the mill provides the farmer with seeds or a loan for planting
H	A *dummy* indicating whether the mill is responsible for harvesting the sugarcane
D	A *dummy* indicating whether the mill is responsible for hauling and delivery of the sugarcane
B	A *dummy* indicating whether the mill is responsible for buying all the sugarcane produced by the supplier or not
$More1$	A *dummy* indicating whether there is more than one mill in the vicinity to which the producer can sell sugarcane to.

Table 3.4: Results from the random parameter model with single opt-out and willingness to pay estimates

Attribute	Choices					
	Land Rental (LR)		Agricultural Partnership (AP)		Supply (S)	
	Coefficient Estimate	Willingness to Pay	Coefficient Estimate	Willingness to Pay	Coefficient Estimate	Willingness to Pay
Intercept	-3.97 ***		-6.75 ***		-6.50 ***	
	(0.84)		(1.43)		(1.73)	
Rate of LR	0.16 ***					
	(0.03)					
TRS			0.03 ***		0.02 *	
			(0.01)		(0.01)	
Late Payment	-0.06 ***	-0.37 **	-0.04	-1.18	-0.06 **	-3.20
	(0.02)	(0.15)	(0.03)	(0.95)	(0.02)	(2.26)
Length	-1.01 ***	-6.37 **	-0.87 ***	-27.59 **	-1.17 ***	-62.06
	(0.33)	(2.58)	(0.29)	(12.56)	(0.40)	(41.19)
Share payment			0.04 ***	1.27 **		
			(0.01)	(0.55)		
Planting					0.71 *	37.55
					(0.38)	(28.06)
Harvesting					0.41	22.05
					(0.37)	(22.44)
Hauling and delivery					0.68 *	36.42
					(0.42)	(32.57)
Mill buys all					1.32 ***	70.52
					(0.4)	(46.76)
More than 1 buyer	0.62		0.04		0.50	
	(0.84)		(3.13)		(0.75)	
	Distances of Random Parameters Standard Deviations					
Contract LR	3.30 ***					
	(0.50)					
Contract AP	3.01 ***					
	(0.45)					
Contract S	2.84 ***					
	(0.53)					
Log-likelihood	-588.59					
McFadden Pseud R^2	0.36					
AIC	1223					
Observations	660					

Note: Standard error are in parenthesis. Significance Levels: *** is 1%, ** is 5%, * is 10%

Table 3.5: Results from the random parameter model with two opt-outs and willingness to pay estimates

Attribute	Choices						
	Land Rental (LR)		Agricultural Partnership (AP)		Supply (S)		Not grow sugarcane
	Coefficient Estimate	Willingness to Pay	Coefficient Estimate	Willingness to Pay	Coefficient Estimate	Willingness to Pay	Coefficient Estimate
Intercept	-3.75 ***		-6.20 ***		-5.55 ***		-23.62 ***
	(0.98)		(1.42)		(1.67)		(7.56)
Rate of LR	0.17 ***						
	(0.03)						
TRS			0.03 ***		0.02 *		
			(0.01)		(0.01)		
Late Payment	-0.06 ***	-0.37 **	-0.04	-1.14	-0.06 ***	-3.28	
	(0.02)	(0.15)	(0.03)	(0.92)	(0.02)	(2.29)	
Length	-1.04 ***	-6.25 **	-0.87 ***	-27.75 **	-1.16 ***	-62.60	
	(0.33)	(2.53)	(0.29)	(12.33)	(0.39)	(42.92)	
Share payment			0.04 ***	1.26 **			
			(0.013)	(0.53)			
Planting					0.68 *	36.70	
					(0.38)	(27.61)	
Harvesting					0.41	21.92	
					(0.37)	(22.13)	
Hauling and delivery					0.64	34.28	
					(0.41)	(31.97)	
Mill buys all					1.30 ***	70.16	
					(0.39)	(46.57)	
More than 1 Mill	0.86		-0.30		-0.03		-9.74 ***
	(0.93)		(0.68)		(0.67)		(3.43)
	Distances of Random Parameters Standard Deviations						
Contract LR	3.71 ***						
	(0.64)						
Contract AP	2.74 ***						
	(0.39)						
Contract S	2.47 ***						
	(0.4)						
Opt Out	30.37 ***						
	(8.99)						
Log-likelihood	-623.93						
McFadden Pseud R^2	0.41						
AIC	1300						
Observations	660						

Note: Standard error are in parenthesis. Significance Levels: *** is 1%, ** is 5%, * is 10%

Table 3.6: Direct and cross-elasticities in the land rental contract

	Land Rental	Agricultural Partnership	Supply	Current Contract	Not grow Sugarcane
Rate	0.66	-0.16	-0.16	-0.23	-0.02
Risk	-0.17	0.04	0.04	0.06	0.01
Length	-0.07	0.02	0.02	0.03	0.00
More1	0.09	-0.02	-0.02	-0.03	0.00

Note: Length and More1 are arc elasticities since these are dummy variables.

Table 3.7: Direct and cross-elasticities in the agricultural partnership contract

	Land Rental	Agricultural Partnership	Supply	Current Contract	Not grow Sugarcane
Risk	0.01	-0.07	0.02	0.02	0.00
Length	0.02	-0.10	0.03	0.05	0.00
Sharepay	-0.10	0.53	-0.14	-0.20	-0.02
TRS	-0.30	1.57	-0.40	-0.58	-0.05
More1	0.01	-0.03	0.01	0.01	0.00

Note: Length and More1 are arc elasticities since these are dummy variables.

Table 3.8: Direct and cross-elasticities in the supply contract

	Land Rental	Agricultural Partnership	Supply	Current Contract	Not grow Sugarcane
Risk	0.02	0.03	-0.27	0.05	0.00
Length	0.01	0.02	-0.09	0.03	0.00
TRS	-0.10	-0.13	1.20	-0.23	-0.02
Planting	-0.01	-0.01	0.10	-0.02	0.00
Harvesting	0.00	-0.01	0.05	-0.01	0.00
Hauling and delivery	-0.01	-0.01	0.09	-0.02	0.00
Mill buys all	-0.01	-0.02	0.20	-0.03	0.00
More1	0.00	0.00	0.00	0.00	0.00

Note: Length, Planting, Harvesting, Hauling and delivery, Mill buys all and More1 are arc elasticities since these are dummy variables.

Table 3.9: Direct and cross-arc elasticities for the presence of more than 1 mill in the option not to grow sugarcane

	Land Rental	Agricultural Partnership	Supply	Current Contract	Not grow Sugarcane
More1	0.03	0.03	0.03	0.03	-0.11

Chapter 4 - Assessing the relationship between vertical coordination strategy and technical efficiency: Evidence from the Brazilian ethanol industry

4.1 Introduction

The sugar-energy sector in Brazil accounts for almost 2% of the country's Gross Domestic Product (Neves, Trombin and Consoli 2011). It employs 1.2 million workers, encompassing 70,000 sugarcane producers and over 400 mills (Chaddad 2015). As one of the leading producers of ethanol and sugar, Brazil was responsible for half of the world's sugarcane production in 2012 (MAPA 2013). The production-processing interface of the Brazilian sugarcane supply chain is predominantly governed through two vertical coordination strategies: i) contracting – where farmers are contracted by the mills, and ii) vertical integration – where the mills either acquire or rent the land and backward vertically integrate into sugarcane production (Moraes and Zilberman 2014; Sant'Anna, Shanoyan, et al. 2016). With the expansion of the sugarcane industry, the choice of vertical coordination strategy at the production-processing interface can have important implications not only for operational efficiency and competitive strategy of sugarcane processors, but also, for agricultural production and policy.

From the operations perspective, due to technical aspects of the refining process, a number of factors at the sugarcane production stage (e.g. distance and harvest timeline limitations) can affect the efficiency at the processing stage (Chaddad 2015; Neves, Waack and Marino 1998). Thus, vertical integration can potentially reduce transaction costs associated with coordinating, monitoring, and enforcing transactions with farmers and can, potentially, result in efficiency gains. From the strategy perspective, with the increased control over the production stage mills can gain a potential competitive advantage by ensuring a procurement base while reducing/eliminating the bargaining power of suppliers. Additionally, in geographic areas with limited production resources, such vertical coordination strategies can limit access to a procurement base for competitors and create barriers to entry. However, there are costs and risks associated with backwards vertical integration by mills into sugarcane production. Strategically and operationally sugarcane production and processing are very different and require distinct sets of resources and capabilities. Vertical integration into sugarcane production will a) expose mills to additional risks that are inherent in production agriculture, and b) will require/lock additional capital for acquiring production resources and capabilities (e.g. land, infrastructure and machinery). Taking on these additional costs and risk can have important implications for strategic decisions and the operational efficiency of the mills.

From the policy perspective, the effect of vertical coordination strategies at the production-processing interface of the sugarcane supply chain can be magnified through the ongoing expansion of the sugarcane industry from the North-Northeast region to the Center-South region of Brazil (Granco et al. 2015). Since the 2000's, evidence of this expansion has been predominant in the *Cerrado*, Brazil's second largest biome, with over 40 mills being constructed in the states of Goiás and Mato Grosso do Sul (Procana 2013). This expansion has provoked a change in land use in a region historically known for livestock and soybean production (Granco et al. 2015). Policy makers have long recognized the importance of potential long-term impacts of the expansion on production agriculture. In 1941, the Brazilian government issued the Statute of Sugarcane (Brazil 1941). It sets that 40% of the sugarcane processed by mills should come from independent sugarcane producers. The only exception being when sugarcane supply by independent producers cannot fulfill this allocation. In this case, mills may produce their own sugarcane. This placed a regulatory barrier to vertical integration with an aim to ensure a competitive market for sugarcane and to support agricultural producers. In fact, in 2013, 40% of sugarcane supplied to mills came from independent producers and 60% was produced under the management of mills (Chaddad 2015).

Research into the relationship between vertical integration and efficiency is not uncommon in the literature, with no definite conclusion on the impact of vertical integration on efficiency[8]. Pieri and Zaninotto (2013) investigated the relationship between vertical integration and technical efficiency in the Italian machine tool industry, while Federico (2010) looked at the links between productivity and vertical integration. Tomiura (2007) examined vertical integration practices among productive and unproductive firms in the Japanese manufacturing industry. Bakhtiari (2011) looked at cost efficiency and vertical integration in the Australian manufacturing industry. Pieri and Zaninotto (2013) conclude that technically efficient firms decide to vertically integrate, but they cannot show evidence of an impact of vertical integration on technical efficiency. Federico (2010) finds a positive relationship between productivity and the decision to vertically integrate (Pieri and Zaninotto 2013). Tomiura (2007) finds that productive firms tend to be vertically integrated, while Bakhtiari (2011) finds that cost efficient firms prefer to vertically integrate (Pieri and Zaninotto 2013). Looking at different types of businesses, D'Aveni and Ravenscraft (1994) found that vertical integration was not always beneficial. Although, the authors found a low positive relation of vertical integration and performance, they had no conclusive evidence that the vertical integration of production stages provided technical benefits. Stuckey and White (1993)

[8] Studies look at technical and cost efficiencies.

warn about the high setup costs and coordination risks of vertical integration, suggesting that vertical coordination may at times be more beneficial. D'Aveni and Ravenscraft (1994) also mention a study conducted by Pyrdol (1978) where vertically integrated captive coal mines had a lower productive performance than noncaptive mines.

The importance of both vertical coordination and efficiency in the context of the Brazilian ethanol industry has been recognized by researchers. However, the previous studies in the literature have looked at these two issues separately. Analyzing data from 2009 to 2012, Bastos (2013) finds higher levels of vertical integration in areas where sugarcane has had recent expansion, such as the states in the Center-West region, and lower levels in areas with a tradition in sugarcane production. Junior, Carlucci and Grespan (2014), when analyzing the technical efficiency of Brazilian mills, find a higher concentration of efficient mills in the state of São Paulo, the largest sugarcane producing state. Torquato, Martins and Ramos (2009) conclude that mills in counties, in the state of São Paulo, with a tradition of growing sugarcane are more homogeneous and closer to the cost efficiency frontier than those in counties where sugarcane production is more recent.

To the author's knowledge no study has looked at the impact of vertical coordination on the technical efficiency of ethanol and sugarcane mills in Brazil. Technical efficiency measures the mill's ability to minimize input usage at a given level of output. Likewise, inefficiency is measured by feasible reductions in the quantities of inputs used (Färe, Grosskopf and Lovell 1994). Our study contributes to the literature by providing the analysis of the relationship between the vertical coordination strategy at the production-processing interface of the Brazilian ethanol supply chain and the technical efficiency of the mills. The main purpose of the study is to estimate the impact from vertical coordination on technical efficiency. The study provides insight on whether the strategic decision to vertically integrate leads to gains in technical efficiency. These insights are beneficial to: (1) Brazilian stakeholders and policy makers in the sugarcane and ethanol industry; (2) Stakeholders and policy makers in countries looking at developing the sugarcane, ethanol industry (e.g. Mozambique), and; (3) Stakeholders in industries with similar characteristics (e.g. temporal and geographic market specificities). Examples of similar markets are second generation ethanol production (e.g. ethanol production from wood chip or corn stover feedstock). Even though this study focuses on ethanol production in Brazil, findings can aid in the analysis of similar industries in other parts of the world.

This paper is divided into six sections. The first introduces the topic, discusses its importance and presents the main research purpose. The following section elaborates on the particularities of sugarcane production in Brazil and the role of vertical integration. The third section presents the data, followed by the fourth section which lays down the methods and empirical strategies employed in this study. In the fifth section results are presented along with a discussion. Conclusions are provided in the last section.

4.2 Vertical integration in the Brazilian ethanol industry

Sugarcane production in Brazil involves high location, temporal and physical asset specificities (de Moraes and Zilberman 2014). To minimize transportation costs and avoid sugarcane quality losses, sugarcane production is limited to a certain radius of the mill, restricting its market geographically (de Moraes and Zilberman 2014, Chaddad 2016). Sugarcane's perishable nature imposes a temporal limit between harvesting and processing (de Moraes and Zilberman 2014, Neves, Waack and Marino 1998). Although inputs and machinery for sugarcane production can be reverted to the production of other crops, its perennial nature implies a minimal 5-year production commitment (de Moraes and Zilberman 2014). Given these specificities, suppliers and processors depend on each other.

During the 21st century, Brazil increased its ethanol production capacity by expanding into the *Cerrado*, a region with little tradition in planting sugarcane until the late 1990s (Silva and Miziara 2011). The mills' dependence on sugarcane suppliers increases according to: (1) the supplier's participation in the sugarcane crushing capacity of the mill; (2) the number of neighboring mills suppliers can sell their sugarcane to (de Moraes and Zilberman 2014).

Uncertainties in sugarcane commercialization, its oligopsony structure[9] and the high level of specialization and investments involved in the production of sugarcane makes it difficult for a strong and stable network of sugarcane suppliers to develop (Bastos 2013; Sant'Anna, Granco et al 2016). Bastos (2013) argues that more vertically integrated mills are generally in areas that did not have prior sugarcane production before the Statute of Sugarcane. In areas that produced sugarcane production before 1941 (e.g. São Paulo), the Statute had the benefit of promoting the establishment of a strong supply chain (Bastos 2013).

Years after the implementation of the Statute of Sugarcane in 1941 up until 1984/85, farmers and mills shared the percentages in sugarcane production used in ethanol and sugar production (Figure 4.1). From 1985 until 2000, mills began to take over sugarcane production, supplying up to 70% of the sugarcane they required for production (Chaddad 2015). Recently the relationship of farmers to mills in the sugarcane production has declined to a 40:60 ratio (MAPA 2013). In fact, data points to a trend towards shares in production observed before 1984 (Figure 4.1)

[9] Sant'Anna, Granco, et al. (2016) find that due to distance limitations, farmers in Goiás and Mato Grosso do Sul only have one mill or two that it is feasible to supply sugarcane to.

The degree of vertical integration by state in 2012 is shown in table 4.1. Vertical integration at the processing and input supply stage is given by the percentage of the sugarcane production produced by mills, as well as, by the comparison of the areas produced by mills and farmers. Total vertical integration (100%) occurs in areas with a smaller number of mills (e.g. Rio Grande do Sul and states in the North region). Higher percentages of vertical integration are present in states with no previous tradition of growing sugarcane (e.g. Mato Grosso do Sul, Goiás and Mato Grosso). These states also contain a larger number of new plants, which adopt the strategy to vertically integrate due to uncertainties with sugarcane supply (Bastos 2013). States with a tradition in sugarcane production, such as Pernambuco and São Paulo, have less vertical integration. In the case of São Paulo, the share of sugarcane produced by the mills is about 50%. In states bordering São Paulo, such as Minas Gerais, there is less vertical integration as well. Although Minas Gerais does not have a tradition of growing sugarcane, it is likely that mills in this state, on the border, utilize spot markets available in São Paulo to acquire sugarcane (Figure 4.2).

In a survey applied to mills in the state of Parana, Augusto, Souza and Cario (2013) find that mills decided to vertically integrate to gain control of sugarcane production, allowing for better planning and management. Chaddad (2015) believes that mills chose to vertically integrate not only to guarantee sugarcane supply, but also to decrease transaction costs with suppliers. Vertical integration also eases the implementation of technologies and agricultural practices that increased sugarcane productivity (Chaddad 2015). Increasing productivity in sugarcane production can be beneficial to a mill since sugarcane accounts for 70% of total production costs (Chaddad 2015). In fact, Crago et al. (2010) reports that Brazilian mills have higher sugarcane yields than independent farmers, 81 tons per hectare versus 75 tons per hectare, respectively. Technical efficiency in sugarcane production is also a function of the quality of the sugarcane. Higher levels of sugar content in the sugarcane implies higher ethanol or sugar output (Chaddad 2015). The benefits from controlling the coordination of harvesting, hauling and transportation are: (1) to minimize transportation costs of a low-value and high-volume crop; and (2) to reduce quality losses (harvested sugarcane must be processed within 72 hours to avoid sugar content losses) (Chaddad 2015; Neves, Waack and Marino 1998). While vertical integration has the benefit of providing the mill with full control over the supply and coordination of sugarcane production, it requires significant capital investments and exposes the business to risks inherent in agricultural production (Neves, Waack and Marino 1998). Relying on farmers for the supply of sugarcane does not require large capital investments in production, but could increase transactions costs associated with harvest coordination and contract enforcement.

Apart from securing the supply of sugarcane, mills may decide to vertically integrate to create barriers to entry for competing mills. By integrating backwards, a processor can control the supply of an input making it difficult for another mill to locate in the same region (Besanko et al. 2009). In the case of Brazil, given that sugarcane supply is restricted to a 30 mile radius from the mill, vertical integration could impede a new mill from locating nearby and from competing for inputs, causing increases in sugarcane prices in the area. If the mill controls sugarcane production in the area around its location, it reduces the risk of its suppliers being poached by a competing mill that is new to the region.

There are also cases when vertical integration can reduce efficiency. In fact, D'Aveni and Ravenscraft (1994) believe that the advantages of combining stages of production may be beneficial only in certain industries, such as paper/pulp production. Stuckey and White (1993) stress that the coordination effectiveness of vertical integration is uncertain. Cost inefficiencies from vertical integration may arise when the firm is less skilled than the outsourcing producer

(Kerkvliet 1991). The lack of competitors (i.e. market pressure) may also cause a mill to be less efficient (D'Aveni and Ravenscraft 1994). Cost inefficiency may occur if the mill needs to forgo buying inputs cheaper at the spot market to use that from its own production (D'Aveni and Ravenscraft 1994). For instance, Bastos (2013) finds that demand for sugarcane from independent producers is higher in states such as São Paulo, where market prices are lower than sugarcane production costs. Cost and technical inefficiencies may also take place due to managerial inefficiencies such as underutilized capacity (D'Aveni and Ravenscraft 1994). Vertical integration increases the size of the firm which may bring about communication distortions, as well as the involvement in tasks where proper skills and knowledge may be lacking (D'Aveni and Ravenscraft 1994). These aspects may result in both cost and technical inefficiency.

It is important to realize that vertical coordination decisions and operational efficiency are two separate things, the first refers to a strategic decision, while the second refers to the operations of the mill. There are, in fact, times when a company is willing to sacrifice operational efficiency to vertically integrate regardless of its impact on efficiency. Among the reasons to vertically integrate, Stuckley and White (1993) list market failure, gains in market power, creation of barriers to entry and the development of markets. In referring to mills in Brazil reasons to vertically integrate may be to: (1) ensure a procurement base, or; (2) moderate competition for sugarcane (i.e. create barriers to entry) by controlling sugarcane production in the mill's surroundings, or; (3) increase the mill's bargaining power when negotiating with sugarcane suppliers.

4.3 Methods

A two-stage analysis is used to examine how vertical coordination impacts technical efficiency. In the first stage, data envelopment analysis (DEA) is used to obtain efficiency scores for each of the mills. In the second stage, a Tobit model is estimated using the estimated efficiency scores, from the first stage, as the dependent variable.

DEA is a nonparametric approach used to construct efficiency frontiers allowing for the evaluation of relative efficiency of decision making units (DMU). The benefit of using DEA is that no a priori assumptions about the production relationships between inputs and outputs are needed (Zhou, Ang and Poh 2008). The DEA assumes that all mills have access to the same technology. This study uses an input-oriented DEA with variable returns to scale. The decision to allow variable returns to scale was made after testing for whether the underlying technology exhibited constant, variable returns to scale or non-increasing returns to scale using code developed by Simm and Besstremyannaya (2016). This program tests the null hypothesis of constant returns to scale against the alternative hypothesis of variable returns to scale, or the null hypothesis of non-increasing returns to scale against the hypothesis of variable returns to scale. It uses test statistics developed by Simar and Wilson (2002; 2011a). Results from both tests rejected the null hypothesis confirming with a statistical significance level of 5% the presence of variable returns to scale[10].

The DEA input-oriented model measures efficiency by the firm's ability to minimize the quantity of inputs given a fixed quantity of outputs (Fare, Grosskopf and Lovell 1994). In this study there are N DMUs and M inputs. The M inputs are used in the production of S outputs. The

[10] The test of constant returns to scale against variable returns to scale had a p-value of 0.02, while the test of non-increasing returns to scale against constant returns to scale had a p-value of 0.01.

model determines the minimum level of input ($x_{m,k}, \theta_n$) each DMU requires to produce a certain level of output and be technically efficient. This is done using the following minimization problem for the *nth* DMU (Färe, Grosskopf and Lovell 1994) [11]:

$$\min_{\theta_n, \lambda_k} \theta_n \tag{4.1}$$

$$s.t. \sum_{k=1}^{N} \lambda_k x_{m,k} \leq x_{m,n}\theta_n \; for \; m = 1, \dots, M$$

$$\sum_{k=1}^{N} \lambda_k y_{s,k} \geq y_{s,n} \; for \; s = 1, \dots, S$$

$$\sum_{k=1}^{N} \lambda_k = 1$$

$$(\lambda_1, \dots, \lambda_N) \geq 0$$

where $\lambda_1, \dots, \lambda_N$ are weights estimated by the model, $x_{m,k}$ are the $m = 1, \dots, M$ inputs and $y_{s,k}$ are the $s = 1, \dots, S$ outputs. θ_n is the input-oriented technical efficiency of mill *n* ranging from 0 to 1. The closer θ_n is to one the more efficient the mill is (Färe, Grosskopf and Lovell 1994). Mills with θ_n =1 are fully efficient. When $\theta_n$is less than one it provides information on reductions in input use that could be made to produce the same level of output.

Once the technical efficiency for each DMU has been calculated, the effect of vertical integration on the efficiency of the mill was estimated. Vertical integration can be measured as the

[11] We acknowledge that there are studies that argue for bootstrapping DEA scores Simar and Wilson (2011b) but after comparing the results of the bootstrapped DEA with the non-bootstrapped DEA we found grave inconsistencies. Although the bootstrapped DEA provides a symmetric distribution we believe resulting efficiencies are not representative of the original data. For instance, mills under the non-bootstrapped DEA that are highly efficient (e.g. have a score of 0.98), under the bootstrapped DEA become highly inefficient (e.g. have a score of 0.15).

quantity of a good transferred from one stage of production to another inside a firm (Perry 1989). In this study, vertical integration is measured as the percentage of the total crushed sugarcane used for production that came from land controlled by the mill. Thus, mills with a higher percentages of own sugarcane production are assumed to be more vertically integrated.

Prior to estimating the impact of vertical integration on technical efficiency, we checked that the assumption of separability held. Technical efficiency scores (θ_n) are only interpretable in a second-stage regression analysis when a separability condition applies (Simar and Wilson 2011b; Daraio, Simar and Wilson 2015). The separability condition assumes that environmental variables do not impact the efficiency frontier. That is, the possible set of combinations of inputs and outputs is the same regardless of the presence of environmental variables. Daraio and Simar (2005) describe environmental variables as factors that the producer has no control over but that may influence production. We tested for this condition by comparing the conditional to the unconditional DEA technical efficiency scores and found that the separability condition holds (see Appendix C). The DEA was calculated in R-Studio using the rDEA (Simm and Besstremyannaya 2016) and Benchmarking packages (Bogetoft and Otto 2015).

Given that the separability assumption holds, we measured the impact of vertical coordination on technical efficiency score using a two-sided Tobit regression with an upper limit censuring of 1 and a lower limit of 0. The efficiency score, the dependent variable, ranges from 0 to 1, such that mills with an efficiency score closer to one are more efficient and closer to the efficiency frontier. In the literature, there are different views on the use of the Tobit model in the second stage regression. Simar and Wilson (2011b) argue strongly against the use of the Tobit model. We decide, though, to follow Hoff (2007) who argues that the Tobit model is sufficient for regressing DEA scores against exogenous variables. Nevertheless, we provide estimates for two more commonly suggested models: Simar and Wilson's algorithm #1 (see Simar and Wilson 2007; Tauchmann 2016) and the fractional regression model with a logistic distribution (see Williams 2016; Ramalho, Ramalho and Henriques 2010). The Tobit model estimated in this study was:

$$\theta_n = \alpha_n + \beta_1 perown_n + \beta_2 mixed_n + \beta_3 SP_n + \beta_4 CW_n + \beta_5 ALPE_n + \beta_6 SP * perown_n + \beta_7 CW * perown_n + \beta_8 ALPE * perown_n + \beta_6 age_n + e_n \quad (4.2)$$

where *perown* is the percentage of crushed sugarcane that was produced by mills; *mixed* is a dummy that is 1 if the mill produces both ethanol and sugar and 0 otherwise; *sp* is a dummy variable that is 1 if mill is in the state of São Paulo and 0 otherwise; *cw* is a dummy variable that is 1 if the mill is in the Center-West region and 0 otherwise; *alpe* is a dummy variable that is 1 if the mill is in the states of Alagoas or Pernambuco and 0 otherwise; and *age* is how old the mill is in years (see Table 4.2 for summary statistics of the variables). Second stage regressions were estimated using Stata 14. Standard errors are obtained through a bootstrap procedure with replacement using 5000 repetitions to correct for the serial correlation of the DEA efficiency estimates as mentioned by Simar and Wilson (2007). We checked for misspecification in the Tobit model by running the link test (Pregibon 1979). The link test involves refitting the estimated model with the values of the predicted dependent value and its squared term. If the coefficient of the predicted y squared is statistically significant than the model is misspecified[12]. We also used inefficiencies (1-θ_n) as the dependent variable to run the bctobit test for misspecification written by Vincent (2010)[13].

[12] The coefficient of the predicted dependent variable squared had a p-value of 0.313 and was not found to be statistically significant at a 5% level of significance.
[13] Bctobit tests the tobit specification, using the LM-Statistics, against a model that is non-linear in the regressors with heteroskedastic and non-normally distributed errors (Vincent 2010). Our test statistic of was 0.212 was compared with the critical value of 4.59, such that the null hypothesis cannot be rejected with a 5% level of statistical significance.

The choice of exogenous variables was guided by previous studies. The region of the Center-West along with the states of São Paulo, Alagoas and Pernambuco are where most of the mills in the sample are concentrated (Figure 4.2). São Paulo is the largest sugar, ethanol and sugarcane producer in Brazil, where Bastos (2013) finds mills to be less vertically integrated and Junior, Carlucci and Grespan (2014) find the presence of more efficient mills than in other Brazilian states. In terms of the Center-West, this region has experienced a recent sugarcane expansion with over 40 new mills installed since 2000 (Sant'Anna, Granco, et al. 2016). Alagoas and Pernambuco are in the Northeast region, where sugarcane production began in Brazil. Given past studies (Junior, Carlucci and Grespan 2014; Bastos 2013) we would expect there to be more technical efficient mills in São Paulo and in the Center-West and older and, perhaps, less technical efficient mills in Alagoas and Pernambuco. We interact the location dummies with the proxy for vertical integration to understand how vertical integration in these areas impacts technical efficiency.

Other variables were *age* and *mixed*. The type of mill (i.e. mixed or not) was controlled for to account for differences in the mills due to the diversity of their output production set. We expect *mixed* to have a positive effect (i.e. mills that produce two products instead of one are more efficient), since *mixed* mills may likely have newer technology in place in comparison to mills that produce only one good. We expect *age* to have a negative impact on efficiency. The older the mill, the older the technology they may utilize. The impact of *perown* is ambiguous. *Perown* should have a positive effect if through vertical integration mills become more efficient. That is, by having more control over the coordination of planting, harvesting and hauling of sugarcane, mills can increase efficiency in ethanol and/or sugar production. On the other hand, if mills are integrating for reasons other than increasing efficiency and coordination in sugarcane production (e.g. to gain independency from trading partners), the effect of *perown* on the efficiency of the mill is not known and could be negative.

Marginal effects were estimated after the estimation of the Tobit regression given the nonlinear nature of the model. Marginal effects allow us to evaluate the effect of a one unit change of an exogenous variable on technical efficiency (Onukwugha, Bergtold and Jain 2015). Marginal effects for the exogenous variables, with the exception of the interaction terms, are estimated as average partial effects. The average partial effect was estimated by obtaining separate marginal effects for each observation and then taking the average over individual marginal effects (Onukwugha, Bergtold and Jain 2015). For instance, the marginal effect (ME) of different levels of vertical integration (*perown*) on technical efficiency (θ) is:

$$ME_{perown} = \frac{\partial\theta}{\partial perown} \tag{4.3}$$

Marginal effects of interaction terms are interpreted as changes in the marginal effects due to changes in another variable of interest (Onukwugha, Bergtold and Jain 2015). Generally, the marginal effect of the interaction term is the partial derivative of the marginal effect of one of the variables in the interaction (Onukwugha, Bergtold and Jain 2015). In the equation (4.2) the interaction terms consist of a dummy and a continuous variable. Thus, the marginal effect of the interaction term is estimated as the difference in the marginal effects of *perown* at each of the dummy values (Onukwugha, Bergtold and Jain 2015). For example, the marginal effect (ME) of *perown*cw* on technical efficiency (θ) is the marginal effect of *perown* at cw=0 minus the marginal effect of *perown* at cw=1:

$$ME_{perown*cw} = \left.\frac{\partial\theta}{\partial perown}\right|_{cw=1} - \left.\frac{\partial\theta}{\partial perown}\right|_{cw=0} \tag{4.4}$$

Asymptotic standard errors for the marginal effects were estimated using the delta method (Onukwugha, Bergtold and Jain 2015).

4.4 Data

Information on mills in Brazil were collected from the 2013 Brazilian Sugar and Ethanol Guide (Procana 2013). From the 422 mills in the guide, only 204 had all the information needed for the study[14]. In 2013, Brazil produced 38.4 million tons of sugar and 23.2 billion liters of ethanol. The 204 firms considered produced 48% of the ethanol and 54% of the sugar produced (Procana 2013). Two inputs[15] (capacity and crushed sugarcane), and two outputs[16] (sugar and ethanol) were modeled in the input-oriented DEA model (Table 4.2). Of the inputs, capacity is a proxy for the capital of the mill, representing a long-term variable, while sugarcane would represent a short-term input variable of the production process. Of the 204 mills, 60 produced only ethanol and 6 only sugar, while the rest produced both ethanol and sugar. Information on capacity was gathered for the year before (i.e. Procana 2012) for 12 mills that did not report this information in the 2013 Brazilian Sugar and Ethanol Guide[17]. Most of the mills in the sample are in São Paulo

[14] Some of the issues encountered were: firms with more than a mill declaring consolidated information; mills not producing in 2013; and, mills only declaring partial information.
[15] Information on sugarcane yield and labor were not added. Labor was only rarely reported by the mills and would significantly reduce the sample size. Yield information is not reported and would require dividing the amount of crushed sugarcane over the total area reported which might introduce measurement errors, as well as, endogeneity issues in second stage regressions estimated.
[16] The amount of energy sold by the mills was not considered as an output due to the limited information available. For the same reason, the amount of labor was not considered as an input.
[17] We assumed that the capacity of the mill will remain unchanged from one year to the next.

(69 mills), a state responsible for over 50% of the sugarcane produced in the country. The North region was the region with the least number of mills (4 mills). From the Center-West, an area that has recently experienced sugarcane expansion, there were 37 mills in the sample.

Considering the sample for this study, in 2013 the amount of sugarcane used by a single mill in the production of ethanol and sugar varied from 33 thousand tons to 7 million tons. Sugarcane crushing capacity of the mills ranged from 800 to 42,000 tons of sugarcane per day. The average mill produced 62 thousand metric liters of ethanol and produced 91.5 thousand tons of sugar (Table 4.2).

The second stage of the analysis used the calculated input-oriented technical efficiency scores along with other data from the 2013 Brazilian Sugar and Ethanol Guide which included the percentage of crushed sugarcane produced by mills out of the total amount of sugarcane used (*Perown*), and information on the location of the mill. The age of the mill was calculated by adding the years from when the mill started operating up to 2013. The year that the mill began operations was obtained from the websites of the individual mills, as well as, search engines for company profiles (Graphiq Inc 2017; Bloomberg 2017). In the cases where the mill was sold to another company, the start of production is that of when the buying company started production.

In the sample, there are mills that are totally vertically integrated (i.e. *Perown* is 100%) and those that have all their sugarcane supplied by a third party (i.e. *Perown* is 0%). On average mills produce 64% of the sugarcane they crush. Hence, mills that produce a portion of the sugarcane they require (e.g. 64%) need to combine more than one vertical coordination strategy to acquire their sugarcane (e.g. vertical integration and contracts). Mills in areas where sugarcane production ranges from 2,808 to 10 million tons, produced themselves 99% of the sugarcane they crushed (Figure 4.1). Mills in the expansion region (i.e. Center -West) are on average 80%

vertically integrated. Areas with a longer history in sugarcane production (i.e. Alagoas, Pernambuco and São Paulo) were 62% vertically integrated.

The sample was comprised of mills that had just started in that year (i.e. 1 year old) and mills that had over a century of existence (Table 4.2). The oldest mills were in Alagoas and Pernambuco with an average age of 65 years. The oldest mill in these two states had 152 years. Younger mills were in the Center-West, where on average mills were 11 years of age.

4.5 Results

Results from the input-oriented DEA show that out of 204 plants analyzed, 20 were found to be fully efficient (i.e. $\theta = 1$) (Table 4.3). Every region (i.e. North, Northeast, Southeast, South and Center West) had at least one efficient mill. Like Junior, Carlucci and Grespan (2014), we found that most of the efficient mills (i.e. 6 of them) were in São Paulo. Mills in the Center-West appear to be more homogeneous in terms of efficiency, as the standard deviation is the lowest among all the regions (Table 4.3). This may arise due to most of the mills operating in this region starting after 2000. In ten of the states, there were no fully efficient mills. These states do not have a large number of mills, hence the low efficiency scores could be a result of the lack of market pressure, as described by D'Aveni and Ravenscraft (1994). The least efficient mill, with an efficiency score of 0.53, is in the state of Minas Gerais. Mills in this state appear to be more heterogeneous in comparison to other states, due to their higher standard deviation. The standard deviation of the efficiency scores is 0.10. On average, the least efficient mills are in the North region while the most efficient mills are in the Center-West region (Table 4.3).

Considering the total sample, mills on average have an input-oriented technical efficiency score of 0.88 and a standard deviation of 0.08. There are 21 firms in the top 10^{th} percentile (Figure 4.3). Mills on the efficiency frontier have a score of one and those away from the frontier, the inefficient mills, have a score below one. Close to 10% of the mills were fully efficient, and less than 12% had an efficiency score below 0.8 (Figure 4.3).

The second stage regressed 204 observations using a two sided Tobit model. Following UCLA Statistical Consulting Group (2017) we calculate a rough estimate of the Pseudo R^2 by squaring the correlation of the predicted efficiency scores ($\hat{\theta}_n$) with the actual efficiency scores (θ_n). The model accounts for 12% of the variation in the dependent variable. The Wald test shows that the hypothesis that the sum of all the coefficients is zero is rejected (Table 4.4). Corresponding coefficients of the three estimated models (Tobit, Simar Wilson Algorithm #1 and fractional) have the same signs though they are of different magnitudes (Table 4.4). This indicates that the results are relatively robust to different functional forms and that all three models can equally describe the data generated process (Table 4.4). Marginal effects have the same sign and relative magnitudes between the models (e.g. *cw* has a higher effect followed by *alpe* then *sp*) (Table 4.5). Average partial effects of the interaction terms were not found to be statistically significant at a 5% level in any of the models, though their signs and relative magnitudes are the same. The major concern could be the fact that the marginal effect of *perown* is not statistically significant in the Simar Wilson Algorithm #1 model but it is in the other two models (Table 4.5). We argue, though, that the size of the marginal effect of vertical integration is small enough for it not to change the conclusions of this paper. Average marginal effects and the marginal effects of the interaction terms are not calculated in the same manner. Our discussion concentrates on the marginal effects of the Tobit regression, given the nonlinear nature of the model and the greater difficulty in interpreting the coefficient estimates.

The average marginal effects for the location dummies and vertical integration by itself had a statistically significant impact on technical efficiency (Table 4.5). The marginal effect related to the age of the mill and the fact that the mill produced two goods instead of one were statistically insignificant, but had the expected sign. Older mills may have older technology, reducing technical efficiency. The mill's age may not have an effect on technical efficiency since older mills may be updating their facilities. By assigning sugarcane between ethanol and sugar production mixed mills may be able to more efficiently allocate inputs.

The remainder of the results discussion will focus on the marginal effects of impacts from increases in vertical integration on technical efficiency (Table 4.5). An increase in vertical integration by 1% implies a decrease of 0.0004 in technical efficiency. This negative effect may be capturing management inefficiencies. It is a small impact. Consider, for instance, an average mill with 64% of vertical integration, a 10% increase in vertical integration would mean a change in technical efficiency from 0.8834 to 0.8790, which when rounded to two decimal places remains at 0.88. This result is similar to Pieri and Zaninotto (2013) who do not find evidence of vertical integration significantly impacting technical efficiency. It appears that the decision to vertically integrate is not linked to the desire to increase technical efficiency. Even if mills have higher sugarcane productivity (Chaddad's 2015) or produce higher yields (Crago et al. 2010), vertical integration of the production process does not lead to gains in technical efficiency. This result does not rule out gains in efficiency from other forms of vertical coordination. Quasi-vertical integration, such as mills signing supply or crop share contracts with farmers or overseeing harvesting, hauling and delivery services could possibly bring gains in technical efficiency[18].

Marginal effects from location dummies are all positive (Table 4.5). Mills located in the Center-West have a higher technical efficiency score relative to mills in other nonmodeled states of Brazil, by 0.05. The marginal effect from the Center-West location is also the largest relative to the other locations controlled (i.e. SP and ALPE). This difference could come from the fact that mills in the Center-West are newer and may have newer technology. When analyzing mills in the Center-South, Pereira et al. (2016) find that mills only adopt technologies with proven efficiency. Also, there is evidence of quasi-vertical integration in this region. Sant'Anna, Granco, et al (2016) finds that mills in Mato Grosso do Sul and Goiás attract local farmers to sugarcane production by providing them with sugarcane seedlings, payment advances and consulting.

The marginal effect of a mill being in Alagoas or Pernambuco from that of not being in one of the unmodeled regions is 0.05. Given the regression of the sugarcane sector in these states (Andrade 2001) it is likely that the mills that have survived are the efficient ones. Similar to our study, Junior, Carlucci and Grespan (2014) does find efficient firms in the state of Alagoas. Mills located in São Paulo also have a larger efficiency score than in other areas not controlled for in the second stage. The difference in technical efficiency score is of 0.04. Due to the larger number of mills in São Paulo, it is likely that pressure from competing mills has forced mills in this state to be more efficient.

In order to understand the impact from vertical integration in the different locations we plotted the predicted technical efficiency scores against 1% changes in vertical integration (Figures 4.3 to 4.5). The plots demonstrate the predicted technical efficiency scores at each level of vertical

[18] We were unable to account for this scenario. There was no data available on quasi-vertical integration.

integration for mixed mills, while remaining factors are held constant. We chose mixed mills since these were the majority of mills in the sample and they represent the state-of-the-art in mill technology. Plots show that differences in technical efficiency, between mills in the Center-West or in São Paulo and those unmodelled, occur when mills are about 60% vertically integrated. For mills in the Center-West and São Paulo, technical efficiency does not seem to change with vertical integration, considering a confidence interval of 95% (Figures 4.4 and 4.5). It appears that it is the location rather than the level of vertical integration that is impacting the technical efficiency of the mill.

Vertical coordination could explain why we do not see changes to technical efficiency at higher levels of vertical integration in the Center-West (Figure 4.4). In this region, contract negotiations are part of the sugarcane industry. In general, in Goiás and Mato Grosso do Sul and other states of the Center-West, farmers find it hard to grow sugarcane without a contract (Sant'Anna, Granco, et al. 2016). Hence, it is likely that the results are showing how vertical coordination through contracting may be just as beneficial, in terms of technical efficiency, as vertical integration. The occurrence of vertical integration in the Center-West may be a management strategy to create barriers to entry to other mills. Given that sugarcane has recently expanded into this region, mills settling in the Center-West may want to control sugarcane production in surrounding lands to limit new mills from settling in. New mills would bring more competition for sugarcane.

In the state of São Paulo, the presence of a sugarcane spot market may explain why technical efficiency does not change with higher levels of vertical integration. As suggested by D'Aveni and Ravenscraft (1994), competitive markets may be pressuring farmers to be more efficient. If so, it may be difficult for mills to be more productive than their suppliers. This may explain why mills in São Paulo are less likely to vertically integrate than in other states (Bastos 2013). The occurrence of vertical integration in São Paulo may be a management strategy for mills to depend less on suppliers such that mills increase their bargaining power with suppliers and reduce the rivalry for procurement.

The technical efficiency of mills in Alagoas and Pernambuco changes as the percentage of vertical integration increases (Figure 4.6). The statistically significant difference between mills in these states and those in other unmodeled states occurs from the level of 40% to 70% of vertical integration. As vertical integration increases, mills in these states start to have the same technical efficiency as those in unmodeled states, at a lower level of technical efficiency, Bastos (2013) reports a constant high level of vertical integration in the Northeastern states in past years. As Andrade (2001) reports, the sugarcane sector in Pernambuco is regressing. A declining sugarcane market may be a reason why we still see mills vertically integrating (Stuckey and White 1993). Another reason may be the costs associated with dis-integration. Stuckey and White (1993) argue that vertical integration may be difficult and costly to reverse. The state of Pernambuco, for instance, has a history of consolidated economic groups being responsible for their own sugarcane production (Andrade 2001). This suggests that mills may have decided, in the past, to vertically integrate and now find it too costly to dis-integrate. In addition, current policies in place in Brazil seem to favor sugarcane production in the Center-South (e.g. the Sugarcane Agroecological Zoning identifies larger areas for sugarcane production in the Center-South states (Sant'Anna, Granco, et al. 2016; Manzatto 2009)). This discourages new farmers from entering sugarcane production or current producers from investing in sugarcane production.

4.6 Conclusion

The purpose of this study was to assess the relationship between vertical coordination and input-oriented technical efficiency using data envelopment analysis and a Tobit censored model. Inputs considered in the DEA model were the amount of crushed sugarcane and the mills' crushing capacity. Outputs were the quantities of ethanol and sugar produced. The sample consisted of 204 Brazilian mills responsible, in 2013, for half of the country's total production of sugar and ethanol. The Tobit censored model controlled for the percentage of crushed sugarcane produced on lands owned or rented by mills, if the mill produced two goods (i.e. ethanol and sugar), the age of the mill, location dummies and interaction terms. The interaction terms consisted of the percentage of crushed sugarcane produced by the mill interacted with different locational dummy variables (São Paulo, Center-West region and Alagoas and Pernambuco).

Results indicate that vertical integration and the location of the mill have a statistically significant impact on efficiency. The age of the mill, as well as, its level of specialization (i.e. if it can produce two products instead of one) does not impact technical efficiency. Differences in technical efficiency between mills in different locations are more significant at higher levels of vertical integration.

Vertical integration, by itself, has a minimal negative marginal effect on efficiency. Hence technical efficiency is not the main driver of vertical integration. In fact, losses in technical efficiency are a cost from the decision to vertically integrate. Although vertical integration may not be motivated by gains in operational efficiency there are other benefits from vertical integration. According to agribusiness theory (Peterson, Wysocki and Harsh 2001; Williamson 1985; Milgrom and Roberts 1990; Macaulay 1963; Vukina and Leegomonchai 2006) motivators for vertical integration could be: (1) to establish a procurement base; (2) to moderate competition by creating barriers to entry; (3) to reduce rivalry for inputs whereby increasing bargaining power with suppliers. When deciding on vertical coordination strategies mills will balance the costs and benefits from each strategy. Our study has found that technical efficiency is located on the cost side. Thus, if a mill still decides to vertically integrate it implies that the benefits overcome the losses in technical inefficiencies. If, though, the benefits disappear overtime then the balance between cost and benefits might point against vertical integration.

Mills in states with little sugarcane production (i.e. North region) may be vertically integrating to ensure a procurement base (reason 1). If the strategic purpose is to guarantee sugarcane supply, then vertical integration will persist until a supply market is established. Once a strong supply chain is in place it would be expected for mills to rely more on suppliers for their input needs. Mills in the Center-West, where sugarcane has recently expanded into, may be deciding to vertically integrate to create barriers to entry (reason 2). The aim of reducing rivalry for sugarcane and to increase the bargaining power with suppliers, may be what motivates vertical integration in the regions with the highest sugarcane production (e.g. São Paulo) (reason 3). In the cases of reasons (2) and (3), the strategic benefits from vertical integration are not expected to dissipate over time since the decrease in rivalry and the barriers to entry will remain. Mills appear, thus, to be willing to sacrifice in technical efficiency for the strategic benefits gained from vertical integration. Hence, the minimal negative impact from vertical integration and the different vertical coordination strategies that can be witnessed throughout the country.

It is important to understand the factors motivating vertical integration in Brazil. As discussed, vertical integration is not a recent phenomenon and public policies have been in place since 1941 to contain it. Allowing firms to vertically integrate in the Center-West (*Cerrado* region), where sugarcane production has recently expanded into, can have serious implications to the sustainability of sugarcane, ethanol and sugar production in Brazil. If all of the mill's sugarcane supply comes from its own production, then sugarcane production becomes more sensitive to the financial stability of the mill. For example, by controlling the production around the mill, a firm can create barriers to entry to new mills. This means that if the mill goes into bankruptcy then it is likely that sugarcane, ethanol and sugar production will cease in that location. In turn, when there is more than one mill in a location with independent farmers supplying sugarcane to mills, sugarcane production is likely to continue after the closure of one of the mills. Therefore, if the government wishes to not only guarantee the benefits from the sugarcane expansion to farmers but also ensure the sustainability of the industry it needs to understand the mill's motives to vertically integrate.

Findings from this study imply that drivers of vertical integration vary according to the characteristics of the states and regions where mills are located. In the Center-West region mills may decide to vertically integrate to create barriers to entry to new mills. The first mills to location may decide to control all sugarcane production within a 30-mile radius of itself, limiting new mills from locating next to it. New mills would mean increased competition for inputs, by preventing new mills from locating nearby and avoiding increases in input prices. In this case, the government can put antitrust laws in place or even motivate farmers to negotiate with firms before the mill is built in a certain location. Long term contracts instead of vertical integration can also be an option in this situation. As seen in the chapter 3, though, farmers want to receive higher returns to sign longer contracts, and the government may need to provide further measures to guarantee contract enforcement.

Findings from this study also provide guidance to industries highly dependent on one input and with high location specificity. It points to the fact that vertical integration requires sacrificing technical efficiency. Also, it suggests that there may are other vertical coordination strategies that may be more beneficial for technical efficiency. For instance, to establish a supply market, the industry can seek partnerships with farmers, offering them technical support and financial help to start producing sugarcane. Policy makers deciding to entice mills to a new location need to put in place policies to limit vertical integration or allow for negotiations between suppliers and producers before the installation of the mill. In this way, the strategy to vertically integrate to create barriers to entry, such as may be the case in the Center-West, could possibly be avoided. Nevertheless, further studies on the strategic benefits from vertical integration in ethanol production are required to fully understand the benefits and costs from vertical integration. There are other outside factors, such as the environmental laws (e.g. burn ban) that may be impacting the decision to vertically integrate. This article has shown that gains in technical efficiency are not a major driver for vertical integration. There may are other vertical coordination strategies that may be more beneficial to increases in technical efficiency.

4.7 References

Andrade, M.C. de. 2001. "Espaço e tempo na agroindústria canavieira de Pernambuco." *Estudos Avançados* 15(43):267–280.

Augusto, C.A., J.P. de Souza, and S.A.F. Cario. 2013. "Governance structures and strategic resources in distilleries located in the state of Paraná: an analysis based on TCE and RBV complementarity." *Revista de Administração (São Paulo)* 48(1):179–195.

Bădin, L., C. Daraio, and L. Simar. 2012. "How to measure the impact of environmental factors in a nonparametric production model." *European Journal of Operational Research* 223(3):818–833.

Bakhtiari, S. 2011. "Size evolution and outsourcing: theory and evidence from australian manufacturing." No. 2012-08, School of Economics, The University of New South Wales. Available at: https://ideas.repec.org/p/swe/wpaper/2012-08.html [Accessed March 24, 2017].

Bastos, A. da C. 2013. "Fornecimento de cana-de-açúcar e integração vertical no setor sucroenergético do Brasil." *Universidade de São Paulo (USP). Escola Superior de Agricultura "Luiz de Queiroz"–Dissertação de Mestrado* 130.

Besanko, D., D. Dranove, M. Shanley, and S. Schaefer. 2009. *Economics of strategy*. John Wiley & Sons.

Bloomberg. 2017. "Snapshot." Available at: http://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=33172765 [Accessed March 1, 2017].

Bogetoft, P., and L. Otto. 2015. *Benchmarking*. Available at: https://cran.r-project.org/web/packages/Benchmarking/Benchmarking.pdf [Accessed March 1, 2017].

Brazil. 1941. Decree No. 3,855 of November 21st 1941. Estatuto da lavoura canavieira. Rio de Janeiro: Diario oficial da uniao. Available at: http://www.planalto.gov.br/ccivil_03/decreto-lei/Del3855.htm [Accessed June 1, 2016].

Chaddad, F. 2015. *The economics and organization of Brazilian agriculture: recent evolution and productivity gains*. Academic Press.

Crago, C.L., M. Khanna, J. Barton, E. Giuliani, and W. Amaral. 2010. "Competitiveness of Brazilian sugarcane ethanol compared to US corn ethanol." *Energy Policy* 38(11):7404–7415.

Daraio, C., and L. Simar. 2005. "Introducing environmental variables in nonparametric frontier models: a probabilistic approach." *Journal of Productivity Analysis* 24(1):93–121.

Daraio, C., L. Simar, and P.W. Wilson. 2015. "Testing the 'separability' condition in two-stage nonparametric models of production." No. 2015/21, LEM Working Paper Series. Available at: https://www.econstor.eu/handle/10419/119865 [Accessed March 11, 2017].

D'Aveni, R.A., and D.J. Ravenscraft. 1994. "Economies of integration versus bureaucracy costs: does vertical integration improve performance?" *The Academy of Management Journal* 37(5):1167–1206.

Fare, R., S. Grosskopf, and C.K. Lovell. 1994. *Production frontiers*. Cambridge University Press.

Federico, S. 2010. "Outsourcing versus integration at home or abroad and firm heterogeneity." *Empirica* 37(1):47–63.

Granco, G., M.M. Caldas, J.S. Bergtold, and A.C. Sant'Anna. 2015. "Exploring the policy and social factors fueling the expansion and shift of sugarcane production in the Brazilian Cerrado." *GeoJournal* 82(1):63–80.

Graphiq Inc. 2017. "FindTheCompany." Available at: http://www.findthecompany.com.br/ [Accessed January 1, 2017].

Hoff, A. 2007. "Second stage DEA: Comparison of approaches for modelling the DEA score." *European Journal of Operational Research* 181(1):425–435.

IBGE, Brazilian Institute of Geography and Statistics. 2014. "Produção Agrícola Municipal – PAM." Available at: www.ibge.gov.br [Accessed May 20, 2015].

Junior, A.P.S., F.V. Carlucci, and C.A. Grespan. 2014. "Investment potential for new sugarcane plants in Brazil based on assessment of operational efficiency." *International Food and Agribusiness Management Review* 17(2):41.

Kerkvliet, J. 1991. "Efficiency and vertical integration: the case of mine-mouth electric generating plants." *The Journal of Industrial Economics* 39(5):467–482.

Macaulay, S. 1963. "Non-contractual relations in business: A preliminary study." *American sociological review*:55–67.

MAPA, Ministry of Agriculture, Live Stock and Supply. 2013. *Anuário estatístico da agroenergia 2012: statistical yearbook of agrienergy.* Brasília: Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Produção e Agroenergia.

Milgrom, P., and J. Roberts. 1990. "Bargaining costs, influence costs, and the organization of economic activity." *Perspectives on positive political economy* 57:60.

Moraes, M.A.F.D. de, and D. Zilberman. 2014. *Production of ethanol from sugarcane in brazil: from state intervention to a free market*. Springer Science & Business Media.

Neves, M.F., V.G. Trombin, and M. Consoli. 2011. "The sugar-energy map of Brazil." In E. L. Leao de Sousa and I. de C. Macedo, eds. *Ethanol and bioelectricity: sugarcane in the future of the energy matrix*. São Paulo: UNICA, pp. 14–43.

Neves, M.F., R.S. Waack, and M.K. Marino. 1998. "Sistema agroindustrial da cana-de-açúcar: caracterização das transações entre empresas de insumos, produtores de cana e usinas." In Anais. XXXVI Congresso da Sociedade Brasileira de Economia e Sociologia Rural - SOBER. Poços de Caldas, M.G.: SOBER, pp. 559–572. Available at: http://pensa.org.br/wp-content/uploads/2011/10/O_sistema_agroindustrial_da_cana_ de_acucar_1998.pdf [Accessed November 30, 2014].

Onukwugha, E., J. Bergtold, and R. Jain. 2015. "A Primer on Marginal Effects—Part I: Theory and Formulae." *PharmacoEconomics* 33(1):25–30.

Pereira, C.N., J.M.F.J. Silveira, C.N. Pereira, and J.M.F.J. Silveira. 2016. "Análise exploratória da eficiência produtiva das usinas de cana-de-açúcar na região Centro-Sul do Brasil." *Revista de Economia e Sociologia Rural* 54(1):147–166.

Perry, M.K. 1989. "Vertical integration: determinants and effects." In R. Schmalensee and R. D. Willig, eds. *Handbook of industrial organization*. Holland: Elsevier, pp. 183–255.

Peterson, H.C., A. Wysocki, and S.B. Harsh. 2001. "Strategic choice along the vertical coordination continuum." *The International Food and Agribusiness Management Review* 4(2):149–166.

Pieri, F., and E. Zaninotto. 2013. "Vertical integration and efficiency: an application to the Italian machine tool industry." *Small Business Economics* 40(2):397–416.

Pregibon, D. 1979. *Data analytic methods for generalized linear models*. University of Toronto Canada.

Procana. 2012. *Brazilian sugar and ethanol guide 2012*. Ribeirão Preto: ProCana Brasil.

Procana. 2013. *Brazilian sugar and ethanol guide 2013*. Ribeirão Preto: ProCana Brasil.

Pyrdol, J. 1978. "The effects of electric utilities' captive coal operations." *Washington, DC: Federal Energy Regulatory Commission*.

Ramalho, E.A., J.J.S. Ramalho, and P.D. Henriques. 2010. "Fractional regression models for second stage DEA efficiency analyses." *Journal of Productivity Analysis* 34(3):239–255.

Sant'Anna, A.C., G. Granco, J.S. Bergtold, M.M. Caldas, T. Xia, P. Masi, T. Link, and W. Lorenzani. 2016. "The challenges of the sugarcane expansion: how do producers and land owners think and act?" In G. R. Santos, ed. *Forty years of ethanol in Brazil: hide or confront the crises?* Brasilia: IPEA, pp. 113–142.

Sant'Anna, A.C., A. Shanoyan, J.S. Bergtold, M.M. Caldas, and G. Granco. 2016. "Ethanol and sugarcane expansion in Brazil: what is fueling the ethanol industry?" *International Food and Agribusiness Management Review* 19(4):163–182.

Silva, A.A., and F. Miziara. 2011. "Sucroalcohol sector and agricultural frontier expansion in the Goiás state, Brazil." *Pesquisa Agropecuária Tropical* 41(3):399–407.

Simar, L., and P.W. Wilson. 2007. "Estimation and inference in two-stage, semi-parametric models of production processes." *Journal of econometrics* 136(1):31–64.

Simar, L., and P.W. Wilson. 2011a. "Inference by the m out of n bootstrap in nonparametric frontier models." *Journal of Productivity Analysis* 36(1):33–53.

Simar, L., and P.W. Wilson. 2002. "Non-parametric tests of returns to scale." *European Journal of Operational Research* 139(1):115–132.

Simar, L., and P.W. Wilson. 2011b. "Two-stage DEA: caveat emptor." *Journal of Productivity Analysis* 36(2):205.

Simm, J., and G. Besstremyannaya. 2016. *rDEA*. Available at: https://cran.r-project.org/web/packages/rDEA/rDEA.pdf [Accessed March 1, 2017].

Stuckey, J., and D. White. 1993. "When and when 'not' to vertically integrate." *Sloan Management Review* 34(3):71.

Tauchmann, H. 2016. *SIMARWILSON: Stata module to perform Simar & Wilson efficiency analysis*. Boston College Department of Economics. Available at: https://ideas.repec.org/c/boc/bocode/s458156.html [Accessed March 15, 2017].

Tomiura, E. 2007. "Foreign outsourcing, exporting, and FDI: A productivity comparison at the firm level." *Journal of International Economics* 72(1):113–127.

Torquato, S.A., R. Martins, and F.S. Ramos. 2009. "Cana-de-açucar no estado de São Paulo. Eficiência econômica das regionais. Novas e tradicionais de produção." *Informações Econômicas, Instituto Economia Agrícola*.

UCLA: Statistical Consulting Group. 2017. "Tobit analysis | Stata data analysis examples." *IDRE Stats*. Available at: http://stats.idre.ucla.edu/stata/dae/tobit-analysis/ [Accessed March 15, 2017].

Vincent, D. 2010. *BCTOBIT: Stata module to produce a test of the tobit specification*. Boston College Department of Economics. Available at: https://ideas.repec.org/c/boc/bocode/s457163.html [Accessed March 15, 2017].

Vukina, T., and P. Leegomonchai. 2006. "Oligopsony power, asset specificity, and hold-up: Evidence from the broiler industry." *American Journal of Agricultural Economics* 88(3):589–605.

Williams, R. 2016. "Analyzing proportions: fractional response and zero one inflated beta models." Available at: https://www3.nd.edu/~rwilliam/stats3/FractionalResponseModels.pdf [Accessed March 1, 2017].

Williamson, O.E. 1985. *The economic institutions of capitalism: Firms, markets, relational contracting*. Free Press New York.

Zhou, P., B.W. Ang, and K.-L. Poh. 2008. “A survey of data envelopment analysis in energy and environmental studies.” *European Journal of Operational Research* 189(1):1–18.

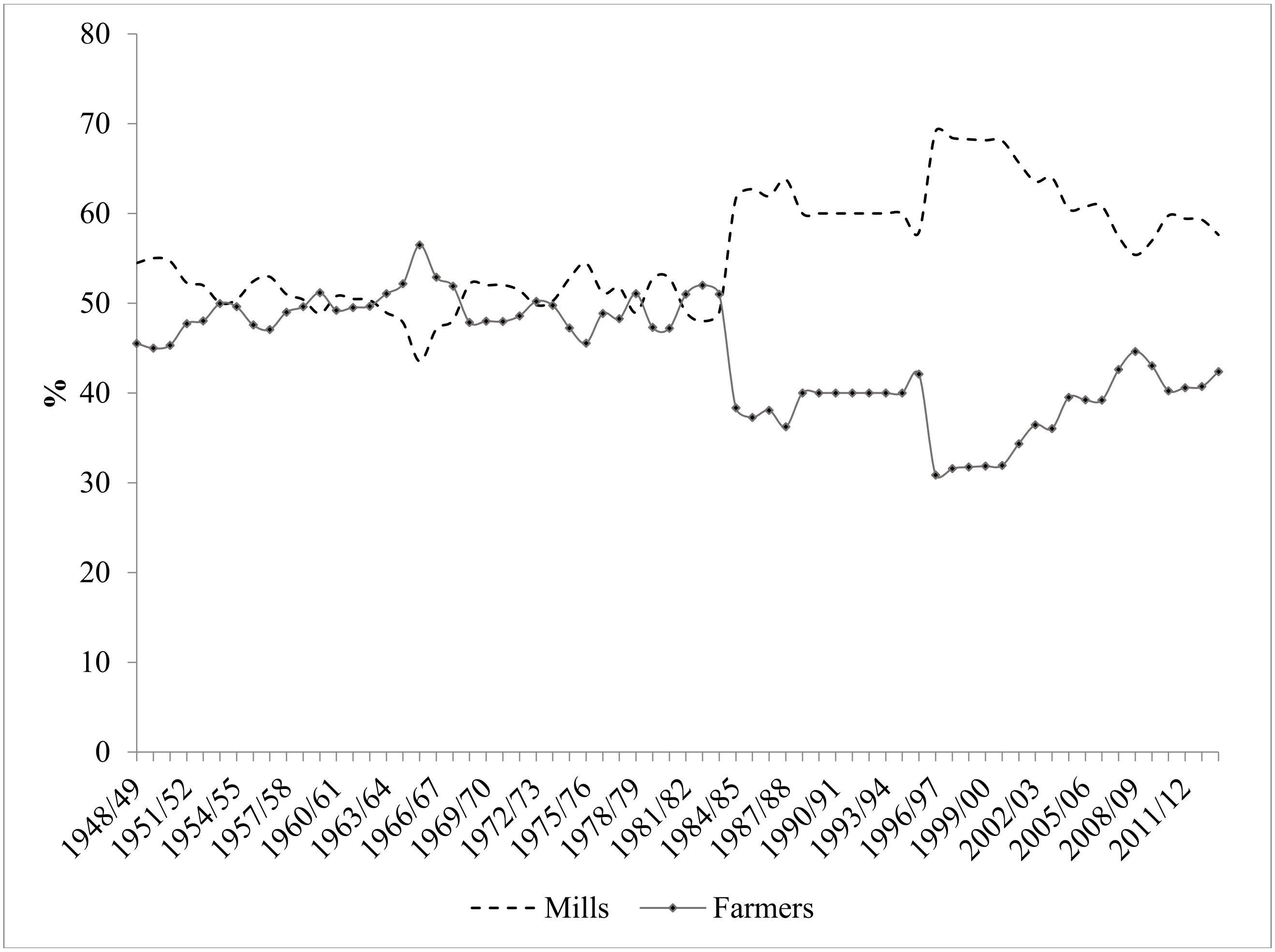
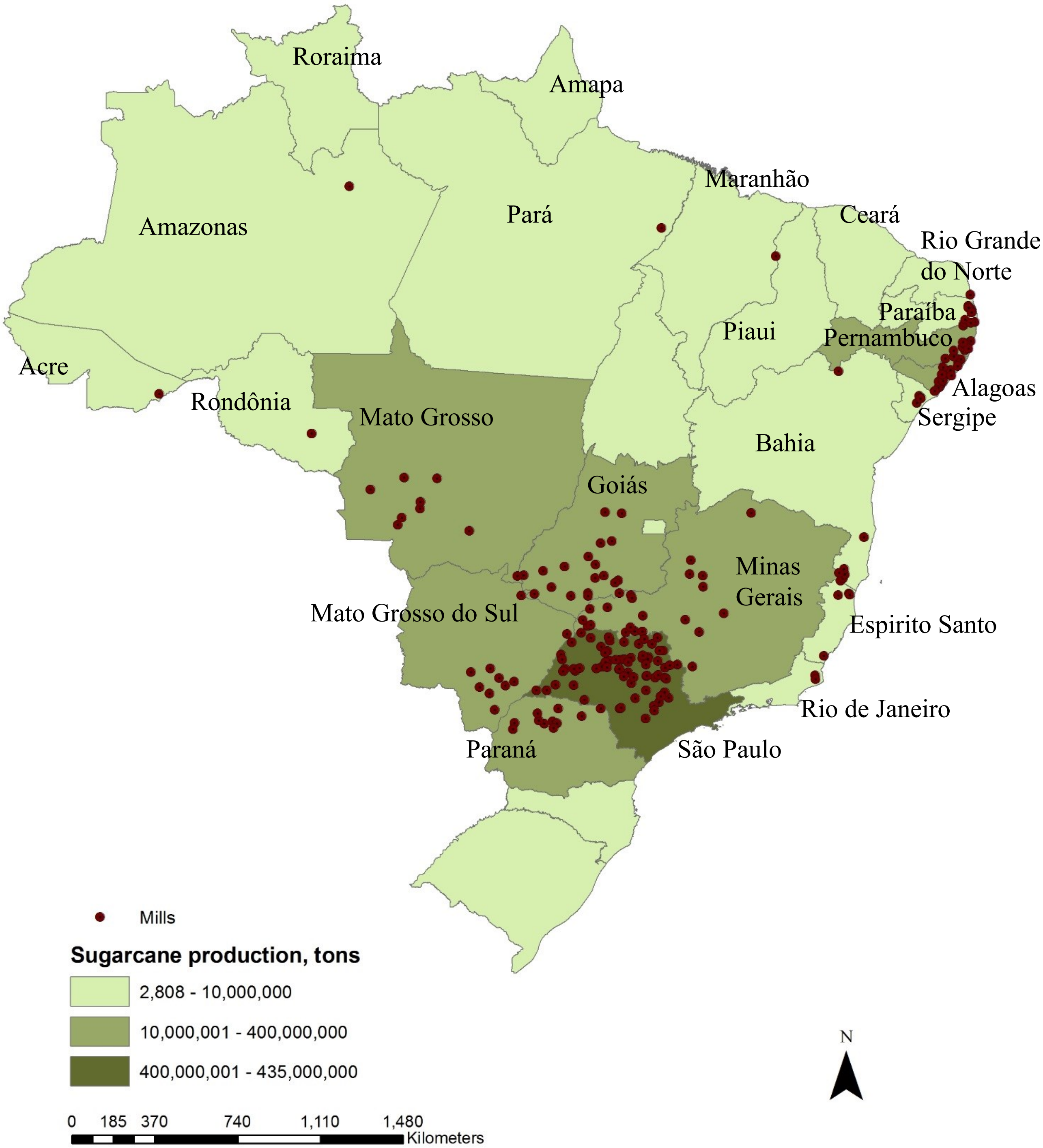


Figure 4.1: The evolution in the percentages of crushed sugarcane supplied by the mills and by farmers between 1948/49 and 2012/13 in Brazil



Source: IBGE (2014) and CONAB (2013)

Figure 4.2: Sugarcane production in the Center-South of Brazil in the crop year 2011/12

Table 4.1: Sugarcane supply share and average area cultivated by farmers and mills in the crop year 2011/12

States and Regions	Cane production share		Land cultivated by	
	Mill(%)	Farmer(%)	Mills (ha)	Farmers (ha)
North				
Acre	100%	0%	526.22	0.00
Amazonas	100%	0%	3,870.64	0.00
Para	100%	0%	12,115.82	0.00
Rondonia	84%	16%	2,328.74	437.97
Northeast				
Alagoas	66%	34%	11,732.95	6,098.28
Bahia	69%	31%	4,332.74	1,908.60
Paraiba	55%	45%	7,710.81	6,365.15
Pernambuco	60%	40%	8,559.10	5,611.60
Piaui	83%	17%	11,619.26	2,417.05
Rio Grande do Norte	79%	21%	11,385.73	3,039.37
Sergipe	74%	26%		
Southeast				
São Paulo	57%	43%	14,680.91	10,971.56
Minas Gerais	58%	42%	9,470.81	6,960.16
Espirito Santo	57%	43%	6,037.94	4,618.50
Rio de Janeiro	11%	89%	1,338.32	10,985.42
South				
Parana	90%	10%	18,272.56	2,127.75
Rio Grande do Sul	100%	0%	1,876.97	0.00
Center West				
Mato Grosso do Sul	73%	27%	16,806.98	5,671.26
Goiás	77%	23%	15,126.91	4,184.86
Mato Grosso	87%	13%	21,705.23	3,024.44
Brazil	64%	36%	13,110.12	7,348.45

Source: CONAB 2013.

Table 4.2: Summary statistics of inputs, outputs and exogenous variables used

Variables	Description		N	Minimum	Mean	Maximum	Standard Deviation
Inputs							
sugarcane	Amount in 1,000 tons of sugarcane crushed by the DMU		204	33.11	1,484.69	7,601.58	1,155.33
capacity	Amout of sugarcane daily crushing capacity		204	800.00	10,130.19	42,000.00	6,707.17
Outputs							
ethanol	Amount of ethanol produced in 1,000,000 liters by each DMU		204	0.00	62.00	295.85	52.37
sugar	Amount of sugar produced in 1,000 tons by each DMU		204	0.00	91.51	638.70	99.99
Exogenous							
perown	Percentage (%) of sugarcane crushed that was produced by the mill		204	0.00	64.27	100.00	29.29
mixed	Dummy that is 1 when the mill produces two goods and 0 otherweise		204	0.00	0.68	1.00	0.47
cw	Dummy that is 1 when the mill is in the Center-West and 0 otherweise		204	0.00	0.18	1.00	0.39
cw*perown	Interaction of a dummy indicating if the mill is in the Center West region with perown	cw=0	167	0.00	0.61	1.00	0.29
		cw=1	37	0.00	0.80	1.00	0.27
sp	Dummy that is 1 when the mill is in São Paulo and 0 otherweise		204	0.00	0.34	1.00	0.47
sp*perown	Interaction of a dummy indicating if the mill is in the state of Sao Paulo with perown	sp=0	135	0.00	0.66	1.00	0.30
		sp=1	69	0.00	0.62	1.00	0.27
alpe	Dummy that is 1 when the mill is either in Alagoas or Pernambuco and 0		204	0.00	0.16	1.00	0.36
alpe*perown	Interaction of a dummy indicating if the mill is in the states of Alagoas or Pernambuco with perown	alpe=0	172	0.00	0.65	1.00	0.31
		alpe=1	32	0.00	0.62	0.90	0.19
age	Age of the mill in years		204	1.00	28.33	152.00	27.84

Table 4.3: Input-oriented efficiency scores by region and state with variable returns to scale

States and Regions	N	Minimum	Mean	Maximum	Standard Deviation
North	4	0.70	0.82	1.00	0.13
Acre	1	1.00	1.00	1.00	.
Amazonas	1	0.75	0.75	0.75	.
Para	1	0.85	0.85	0.85	.
Rondonia	1	0.70	0.70	0.70	.
Northeast	50	0.60	0.88	1.00	0.09
Alagoas	20	0.80	0.92	1.00	0.06
Bahia	6	0.60	0.72	0.85	0.09
Paraiba	6	0.80	0.90	1.00	0.08
Pernambuco	12	0.74	0.88	1.00	0.06
Piaui	1	0.84	0.84	0.84	.
Rio Grande do Norte	1	0.72	0.72	0.72	.
Sergipe	4	0.87	0.92	0.96	0.04
Southeast	101	0.53	0.88	1.00	0.08
São Paulo	69	0.71	0.89	1.00	0.06
Minas Gerais	26	0.53	0.88	1.00	0.10
Espirito Santo	4	0.73	0.75	0.76	0.01
Rio de Janeiro	2	0.81	0.82	0.83	0.01
South	12	0.78	0.86	1.00	0.06
Parana	11	0.78	0.85	0.91	0.05
Rio Grande do Sul	1	1.00	1.00	1.00	.
Center West	37	0.77	0.91	1.00	0.06
Mato Grosso do Sul	9	0.81	0.90	1.00	0.06
Goiás	19	0.77	0.91	1.00	0.07
Mato Grosso	9	0.83	0.90	1.00	0.05
Brazil	204	0.53	0.88	1.00	0.08

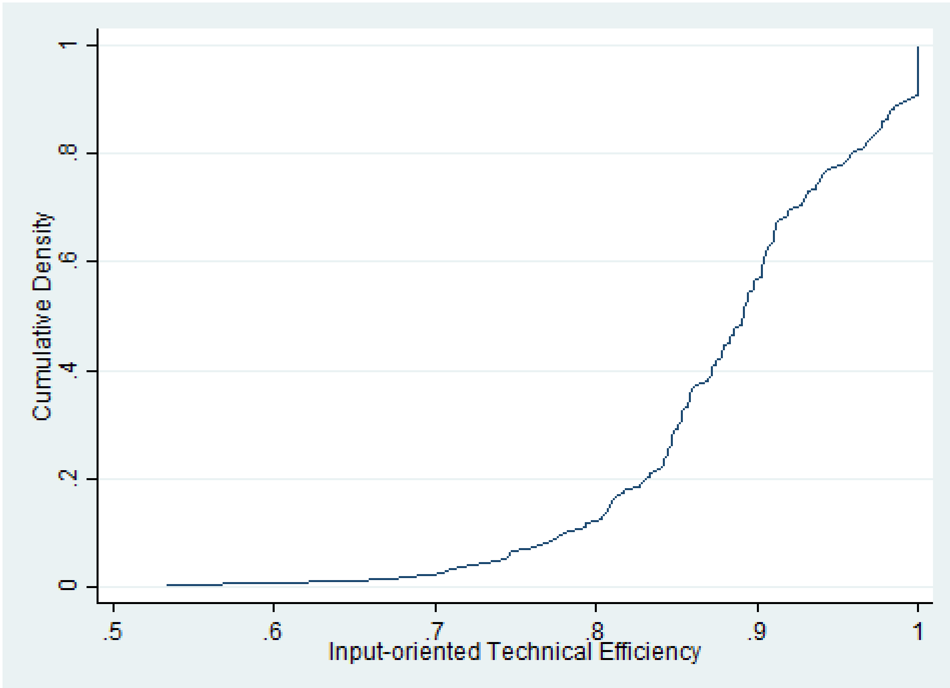


Figure 4.3: Cumulative distribution function of the reciprocal of the input-oriented technical efficiency measure under variable returns to scale.

Table 4.4: Results for the Tobit, Simar Wilson and Fractional regression models

	Tobit		Simar Wilson Alg #1		Fractional Regression	
Perown	-0.0006		-0.0004		-0.0044	
	(0.0004)		(0.0003)		(0.0031)	
Mixed	0.0118		0.0489	***	0.1576	
	(0.0159)		(0.0160)		(0.1336)	
Cw	0.0294		0.0205		0.2536	
	(0.0665)		(0.0608)		(0.6619)	
Sp	0.0063		0.0013		0.0638	
	(0.0361)		(0.0376)		(0.3072)	
Alpe	0.1482	*	0.0964		1.6323	*
	(0.0902)		(0.0928)		(0.8485)	
Age	-0.0002		-0.0004		-0.0024	
	(0.0003)		(0.0003)		(0.00279)	
cw*perown	0.0005		0.0009		0.0047	
	(0.0008)		(0.0007)		(0.0076)	
sp*perown	0.0006		0.0008		0.0052	
	(0.0005)		(0.0005)		(0.0043)	
alpe*perown	-0.0013		-0.0004		-0.0157	
	(0.0003)		(0.0013)		(0.0115)	
Constant	0.885	***	0.8444	***	1.9624	***
	(0.0314)		(0.0250)		(0.2585)	
Sigma	0.082		0.078			
	(0.0054)		(0.0057)			
Wald chi^2 (7)	17.94		35.282		23.47	
Prob>chi^2	0.036		0.000		0.005	

Note: Standard errors are in parenthesis.
Significant levels: *** is 1%, ** is 5%, * is 10%.

Table 4.5: Marginal effects from Tobit, Simar Wilson and Fractional regression models

	Tobit		Simar Wilson Alg #1		Fractional regression	
Perown	-0.0004	*	-0.00004		-0.0004	***
	(0.0002)		(0.0003)		(0.0002)	
mixed	0.0107		0.0489	***	0.0160	
	(0.0144)		(0.0160)		(0.0136)	
cw	0.0526	***	0.0801	***	0.0505	***
	(0.0189)		(0.0236)		(0.0182)	
sp	0.0401	***	0.0540	***	0.0385	***
	(0.0123)		(0.0165)		(0.0113)	
alpe	0.0513	***	0.0723	***	0.0479	***
	(0.0161)		(0.0259)		(0.0156)	
age	-0.0002		-0.0004		-0.0002	
	(0.0003)		(0.0003)		(0.0003)	
Interactions						
cw*perown	0.0005		0.0009		0.0005	
	(0.0006)		(0.0007)		(0.0006)	
sp*perown	0.0006		0.0008		0.0006	
	(0.0004)		(0.0005)		(0.0004)	
alpe*perown	-0.0009		-0.0004		-0.0010	
	(0.0009)		(0.0013)		(0.0009)	

Note: Standard errors are in parenthesis.
Significant levels: *** is 1%, ** is 5%, * is 10%.

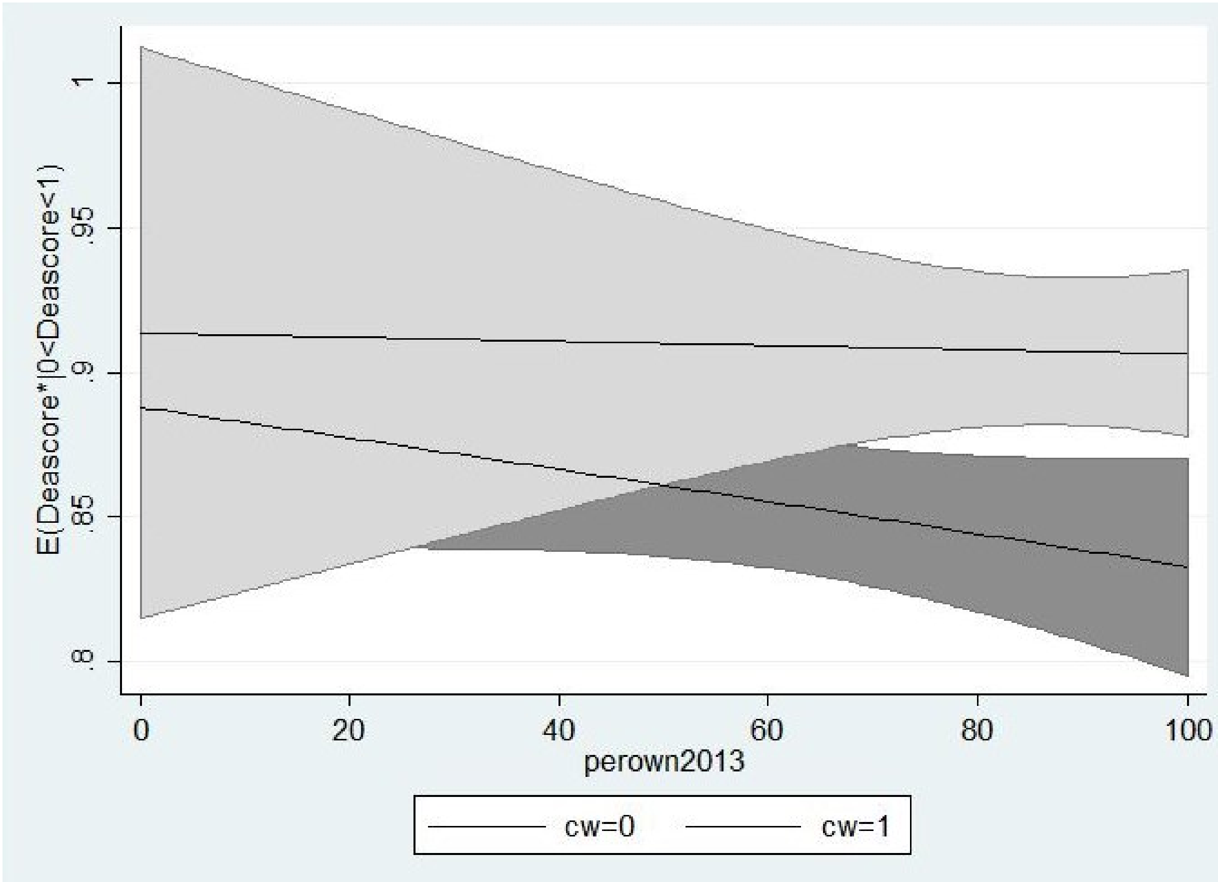


Figure 4.4: Predicted efficiency scores at a 95% confidence interval for different levels of vertical integration for mixed mills in the Center-West (cw=1) and outside (cw=0)

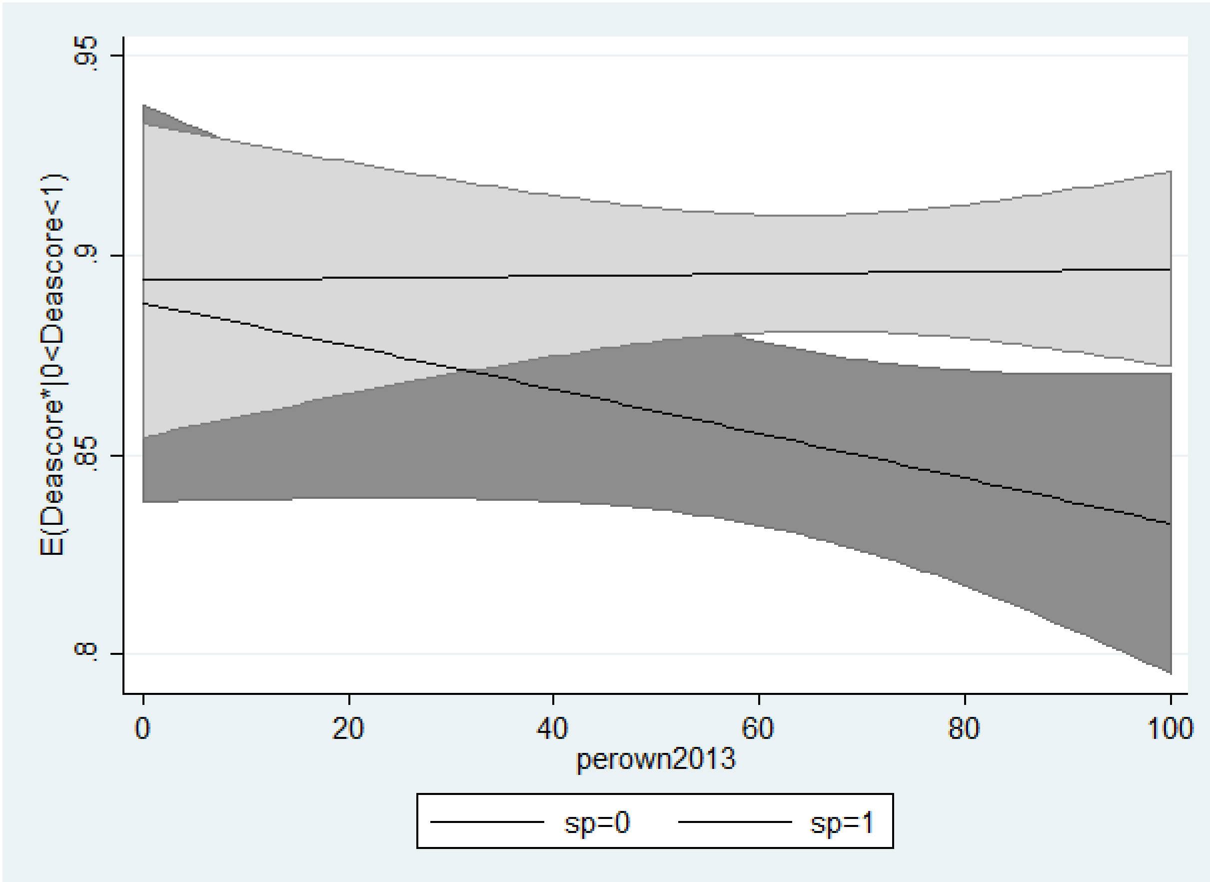


Figure 4.5: Predicted efficiency scores at 95% confidence interval for different levels of vertical integration for mixed mills in São Paulo (sp=1) and outside (sp=0)

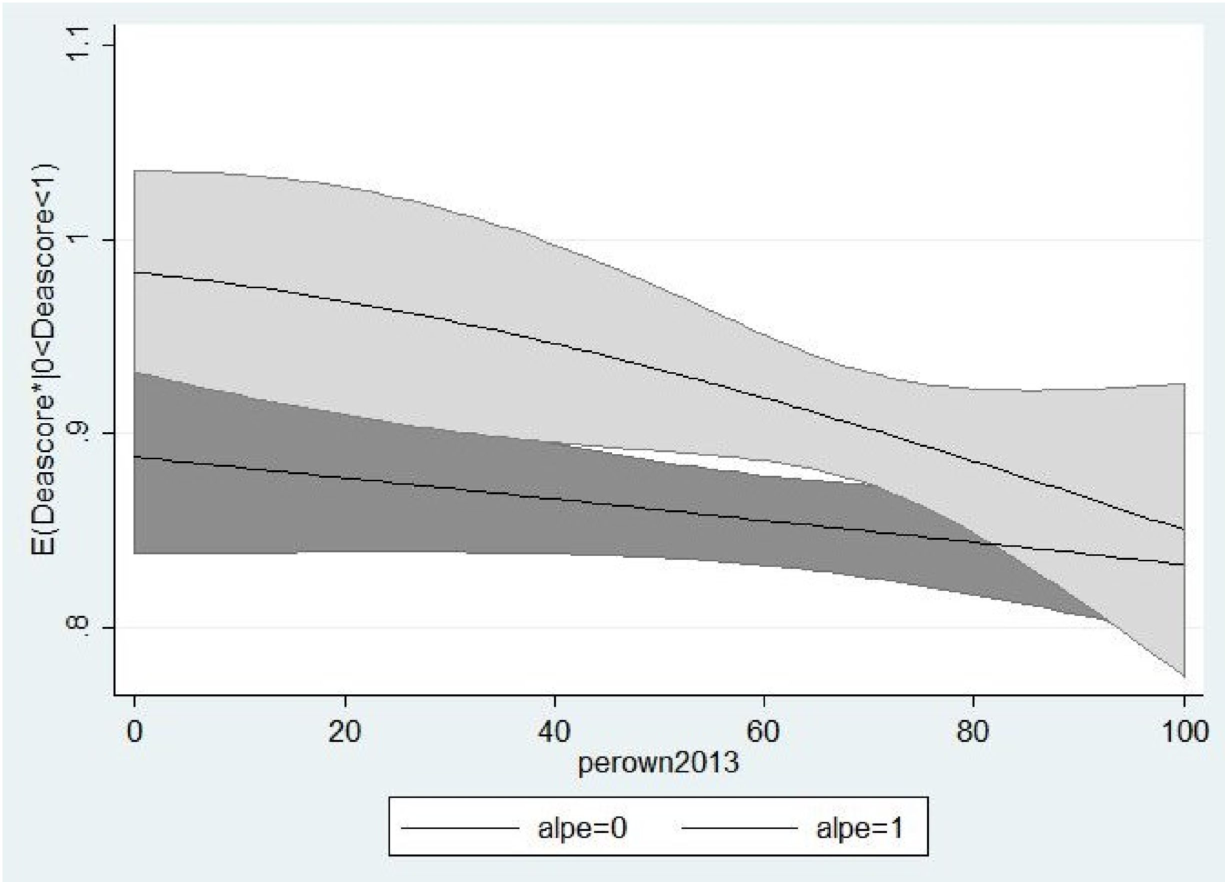


Figure 4.6: Predicted efficiency scores at 95% confidence interval for different levels of vertical integration for mixed mills in Alagoas or Pernambuco (alpe=1) and outside (alpe=0)

Appendix A - Misspecification tests

This appendix presents the misspecification tests conducted for each of the equations in the system. The results presented are the ones for the final equations estimated. Equations were corrected to achieve statistical reliability of the results.

We tested the residuals from all equations after 3SLS. Except for sugar supply to the rest of the world, residuals from all equations passed the normality assumption. Given the results from past studies we do not believe this jeopardizes the validity of our results.

A.1 Sugar demand equation

In order to correct for serial correlation in the residuals, lags for two and three months were added to the sugar demand equation. To control for lower sugar consumption in the month of February a dummy was added. A trend squared was added to control for the growth in sugar demand over time. Misspecification test results are in table A.1.

A.2 Sugar supply equation

In order to control for serial correlation a one-month lag of sugar supply was added to the sugar supply equation. A dummy was added to control for outliers in sugar supply (i.e. dum3). Another dummy was added to control for a structural break in sugar supply, as well as its iteration with the lag of sugar supply. Further misspecification test results are in table A.2.

A.3 Sugar supply to the rest of the world

In order to control for serial correlation a one-month lag of sugar exports was added to the equation. In addition, dummies (dum3, dum4 and dum7) were added to control for usual patterns in sugar exports. It was not possible to correct the heteroskedasticity and normality issues. We tried using weighted least squares to correct for the heteroscedasticity, but it did not result in a good fit for the model. In addition, other tests indicated misspecification of the weighted least squares model. Further misspecification test results are in table A.3.

A.4 Ethanol supply

In the case of the ethanol supply equation one and three-month lags of ethanol supply were added as instruments of the 3sls equation to correct for serial autocorrelation. Hydrous prices squared were also added to the ethanol supply equation to control for the nonlinear relationship between ethanol supply and prices. Further misspecification test results are in table A.4.

A.5 Anhydrous ethanol demand

In the anhydrous demand, a squared trend is added to control for growth in anhydrous ethanol demand. In addition, a dummy was added to control for outliers. Further misspecification test results are in table A.5.

A.6 Hydrous ethanol demand

In the hydrous ethanol demand, a dummy was added to control for times when hydrous ethanol consumption was lower than usual (i.e. February 2010 and March and April 2011). Although the hydrous ethanol demand equation does not pass the normality of the residuals test as an individual ordinary least squares equation, the residuals do pass normality tests as a 3SLS. Further misspecification test results are in table A.6.

Table A.1: Misspecification test results for the sugar demand equation

Assumption	Test Used	Test Statistic	P-value	Conclusion of Test
Normality	Shapiro-Francia test	$\chi^2 = 2.67$	0.2630	Fail to reject null, support for normality
	Shapiro-Wilk test	1.21	0.07	Fail to reject null, support for normality
Specification	Ramsey regression specification-error test	F(3,179)=1.21	0.3093	Fail to reject null, support for lack of omitted variables
	Linktest	Insignificant hat^2	0.269	Support for a correctly specified model
Heteroskedasticity	Breusch-Pagan and Cook-Weisberg tests	$\chi^2 = 0.99$	0.3193	Fail to reject null, support for constant variance
	Information Matrix	$\chi^2 = 77.36$	0.000	Rejects null, no support for constant variance
Serial correlation	Kendall's rank correlation		0.1732	Fail to reject null, support for independence
R^2			0.96	

Table A.2: Misspecification test results for the sugar supply equation

Assumption	Test Used	Test Statistic	P-value	Conclusion of Test
Normality	Shapiro-Francia test	$\chi^2 = 4.77$	0.092	Fail to reject null, support for normality
	Shapiro-Wilk test	1.541	0.06	Fail to reject null, support for normality
Specification	Ramsey regression specification-error test	F(3,177)=0.93	0.429	Fail to reject null, support for lack of omitted variables
	Linktest	Insignificant hat^2	0.909	Support for a correctly specified model
Heteroskedasticity	Breusch-Pagan and Cook-Weisberg tests	$\chi^2 = 3.56$	0.0592	Fail to reject null, support for constant variance
	Information Matrix	$\chi^2 = 55.12$	0.688	Fail to reject null, support for constant variance
Serial correlation	Kendall's rank correlation		0.9418	Fail to reject null, support for independence
R^2			0.87	

Table A.3: Misspecification test results for the sugar supply to the rest of the world equation

Assumption	Test Used	Test Statistic	P-value	Conclusion of Test
Normality	Shapiro-Francia test	$\chi^2 = 13.12$	0.004	Rejects null, no support for normality
	Shapiro-Wilk test	3.59	0.0001	Rejects null, no support for normality
Specification	Ramsey regression specification-error test	F(3,179)=1.36	0.256	Fail to reject null, support for lack of omitted variables
	Linktest	Insignificant hat^2	0.655	Support for a correctly specified model
Heteroskedasticity	Breusch-Pagan and Cook-Weisberg tests	$\chi^2 = 9.70$	0.002	Rejects null, no support for constant variance
	Information Matrix	$\chi^2 = 56.05$	0.047	Rejects null, no support for constant variance
Serial correlation	Kendall's rank correlation		0.5393	Fail to reject null, support for independence
R^2			0.78	

Table A.4: Misspecification test results for the ethanol supply equation

Assumption	Test Used	Test Statistic	P-value	Conclusion of Test
Normality	Shapiro-Francia test	$\chi^2 = 0.89$	0.639	Fail to reject null, support for normality
	Shapiro-Wilk test	0.145	0.44	Fail to reject null, support for normality
Specification	Ramsey regression specification-error test	F(3,174)=1.50	0.2166	Fail to reject null, support for lack of omitted variables
	Linktest	Insignificant hat^2	0.477	Support for a correctly specified model
Heteroskedasticity	Breusch-Pagan and Cook-Weisberg tests	$\chi^2 = 0.66$	0.415	Fail to reject null, support for constant variance
	Information Matrix	$\chi^2 = 108.36$	0.038	Rejects null, no support for constant variance
Serial correlation	Kendall's rank correlation		0.173	Fail to reject null, support for independence
R^2			0.97	

Table A.5: Misspecification test results for the anhydrous ethanol demand equation

Assumption	Test Used	Test Statistic	P-value	Conclusion of Test
Normality	Shapiro-Francia test	$\chi^2 = 0.06$	0.97	Fail to reject null, support for normality
	Shapiro-Wilk test	0.245	0.40	Fail to reject null, support for normality
Specification	Ramsey regression specification-error test	F(3,179)=2.09	0.104	Fail to reject null, support for lack of omitted variables
	Linktest	Insignificant hat^2	0.797	Support for a correctly specified model
Heteroskedasticity	Breusch-Pagan and Cook-Weisberg tests	$\chi^2 = 0.73$	0.3919	Fail to reject null, support for constant variance
	Information Matrix	$\chi^2 = 39.41$	0.205	Fail to reject null, support for constant variance
Autocorrelation	Kendall's rank correlation		0.576	Fail to reject null, support for independence
R^2			0.94	

Table A.6: Misspecification test results for the hydrous ethanol demand equation

Assumption	Test Used	Test Statistic	P-value	Conclusion of Test
Normality	Shapiro-Francia test	$\chi^2 = 17.98$	0.0001	Rejects null, no support for normality
	Shapiro-Wilk test	3.433	0.0003	Rejects null, no support for normality
Specification	Ramsey regression specification-error test	F(3,182)=2.45	0.065	Rejects null, indication of omitted variables
	Linktest	Insignificant hat^2	0.184	Support for a correctly specified model
Heteroskedasticity	Breusch-Pagan and Cook-Weisberg tests	$\chi^2 = 1.58$	0.21	Fail to reject null, support for constant variance
	Information Matrix	$\chi^2 = 87.05$	0.000	Rejects null, no support for constant variance
Autocorrelation	Kendall's rank correlation		0.082	Fail to reject null, support for independence
R^2			0.97	

Appendix B - The role of trust and welfare on contract choice

In the *Cerrado* region it has been reported that the mills' arrival may bring benefits to the community as well as to the farmer (Sant'Anna, Granco, et al. 2016). Also, farmers in this region stress the importance of trust and a having a good relationship with the local mill (Sant'Anna et al. 2016). Sartorius and Kirsten (2007) find that trust can affect the attributes in a sugarcane supply contract. They also argue that the presence of trust reduces the necessity for detailed and costly contracts and the likelihood of exploitation due to asymmetric information.

In this appendix, we discuss the impact of trust and the relationship between the local mill and the community of farmers. The main objective is to investigate whether trust and welfare, from the relationship with the local mill, can change the farmer's contract preferences. We account for trust and the relationship between the mill and the rural community, or famer, by estimating indices using factorial analysis. The indices are used to model heterogeneity in the means of the random parameters in the two opt-out model.

Trust and welfare form a strong basis of the relationship between a local mill and the farming community and can affect farmers' contract choices. Sartorius and Kirsten (2007) find that trust can affect the attributes of sugarcane supply contracts in developing countries. Fischer (2013) argues that trust is a vital element for commercial exchange. Trust is of special importance when contracts are incomplete (Fischer 2013). Personal characteristics of the trade partner and communication help build trust (Fischer 2013). In our case, we believe that changes in the welfare of the community and in the welfare of the farmer can affect their trust in the local mill, as well as, their contract choice.

A factorial analysis was conducted in Stata 14 using answers to questions related to the relationships between local mills and the community and local mills and farmers. In particular, the questions focused on transparency, welfare, distrust and bargaining power (Table B.1). We conducted factor analysis using varimax rotations to produce uncorrelated orthogonal factors (Kim and Mueller 1978; StataCorp 2015). Factors one and two had eigenvalues of 3.09 and 1.22, respectively. Together they explain over 60% of the variation in the data. Factor one explains 36% and factor two 24%. Results from the pattern mix indicate that factor 1 is mostly defined by questions related to the relationship between the mill and farmers (trust), while factor 2 is mostly related to the questions related to welfare. Factor 1 was defined mainly be questions 4, 14, 15 and Factor 2 by questions 2, 3 and 12. These are all questions related to private benefits of the farmer and social welfare.

Cronbach's Alpha was measured to determine the reliability of the scales. Computing the cronbach's alpha involves correlating the values for each scale item with the sum of all scores and comparing that to the variance for individual scores (Goforth 2015; Weesie 1997):

$$\alpha = \frac{k * \bar{c}}{\bar{v} + (k-1)\bar{c}} \tag{B.1}$$

where k is the number of scales, $\bar{c}$ the mean of all covariances and $\bar{v}$ the mean of each items variance. Cronbach's alpha was 0.67 which lies in the recommended minimum range of 0.65 and 0.8 (Goforth 2015).

Results from the factor analysis were used to create indices for trust (factor 1) and for welfare (factor 2). Indices were estimated using regression techniques after normalizing all variables used to estimate the factors by subtracting its mean and dividing by its standard deviation (StataCorp 2015). These indices were used as independent variables in the random parameters logit model to define the conditional random parameters, such that equations (3.8-3.12) now become:

$$a_{0i} = \alpha_0 + \alpha_1 trust_i + \alpha_2 welfare_i + \sigma_a \mu_{ai}, \tag{B.2}$$

$$b_{0i} = \beta_0 + \beta_1 trust_i + \beta_2 welfare_i + \sigma_b \mu_{bi}, \tag{B.3}$$

$$c_{0i} = \tau_0 + \tau_1 trust_i + \tau_2 welfare_i + \sigma_c \mu_{ci}, \tag{B.4}$$

$$d_{0i} = \delta_0 + \delta_1 trust_i + \delta_2 welfare_i + \sigma_d \mu_{di}, \text{ and} \tag{B.5}$$

$$e_{0i} = \varepsilon_0 + \varepsilon_1 trust_i + \varepsilon_2 welfare_i + \sigma_e \mu_{ei}. \tag{B.6}$$

where $(\alpha, \beta, \tau, \delta, \varepsilon)$ are the means of the ASCs; $\boldsymbol{\mu_{ai}, \mu_{bi}, \mu_{ci}, \mu_{di}, \mu_{ei}}$ are random terms**,** which are assumed to have a normal distribution N(0,1); and $\boldsymbol{\sigma_a, \sigma_b, \sigma_c, \sigma_d, \sigma_e}$ represent the standard deviation of the distribution of each ASC (Louviere, Hensher and Swait 2000). Differently from the random parameters in equations equations (3.8) to (3.12) in the paper, these are conditioned on the indices for trust and welfare, trying to explain preference heterogeneity across contract options at the mean (Hensher, Rose and Greene 2015). The rest of the two opt-out model specification and estimation follows the discussion presented in the empirical model and estimation section 5.0. Direct and cross-elasticities were calculated using equations (3.15) and (3.16) and the willingness to pay was estimated using equations (3.17) and (3.18).

The number of observations in the model that considers trust and welfare is lower than that in the previous two opt-out models. This is due to missing answers to the questions considered. Individuals that did not answer the questions considered in the factor analysis were dropped. Nevertheless, the McFadden R^2 is higher in the model that controls for trust and welfare, while the

AIC is lower. This indicates that this model is a good fit for the data. Results are reported in tables B.2 to B.7.

Trust and welfare have a statistically significant impact on the ASCs of the land rental contract and the option not to grow sugarcane (Table B.3). Coefficients on the trust and welfare measure the sensitivity of marginal utility of the ASC to changes in trust and welfare. These changes have a higher impact on the decision not to grow sugarcane. As farmers form greater trust in the mill they have more disutility from choosing not to grow sugarcane or from choosing contracts with less autonomy (i.e. the land rental contract). It is likely that as farmers gain trust in the mill, they prefer contracts that involve working closer with the mill (e.g. agricultural partnership). If there are increases in welfare from the arrival of the mill in a county, then farmers' disutility from not growing sugarcane increases.

Modeling the random parameters with trust and welfare caused changes to the two opt-out model coefficients and willingness to pay for contract attributes (Table 3.5 and B.2). The intercepts from the contract generate less disutility to the farmer, except for the case of the supply contract. Hence, contracts in the hypothetical experiment bring less disutility, than in the previous two opt-out models, in comparison to a farmer's current contract. Controlling for trust reduces the disutility from longer contracts. The coefficients related to risk (i.e. probability of late payment) also provide less disutility than in the previous two opt-out model for the land rental and the agricultural partnership contracts. This coincides with a lower willingness to pay for a lower probability of late payments. Considering the supply contract, the coefficients related to planting, harvesting and delivery are greater in size then in the two opt-out model without trust and welfare indices. The contract attribute of the mill buying all the production (i.e. mill buys all), on the other hand, has a lower marginal utility than before. In terms of the option not to grow sugarcane, controlling for trust and welfare decreases the disutility from the presence of more than 1 mill in the area.

Trust and welfare reduce the magnitude of the negative elasticities and increase the magnitude of the positive elasticities (Table B.4). Similar to the two opt-out model without the modeling of the random parameters, farmers are willing to switch from their current contract when offered higher returns. Changes in the attributes related to returns (i.e. rate in the land rental contract and, TRS and share pay in the agricultural partnership and supply contracts) decrease the probability of the farmer preferring to keep his current contract and increase the probability of him preferring another contract. Offering harvesting and planting services increases the probability of the farmer choosing the supply contract. These elasticities are greater than in the previous two opt-out model.

To summarize, between the two types of two opt-out models, the signs of the coefficients and elasticities remain unchanged. Nevertheless, by conditioning the random parameter on trust and welfare indices, the magnitude of the coefficients and the elasticities change. With trust and welfare, attributes in the previous two opt-out model, that brought utility, are larger, while those that bring disutility are smaller. The same occurs for the elasticities. Changes in beneficial attributes (e.g. rate) increases even more the probability of a contract being signed (for the case of the direct elasticities). The fact that the ASC from land rental is sensitive to changes in trust may point to the farmers' preference for contracts involving more collaboration with the mill (e.g. agricultural partnership) as their trust in the mill increases. The option not to grow sugarcane is more sensitive to changes in trust and welfare. Changes in these increases the disutility from not growing sugarcane. The conditioning of the random parameters on trust and welfare highlights how farmers in the *Cerrado* region are willing to grow sugarcane, and prefer to sign a contract with a mill they trust and have a relationship with.

Table B.1: Questions representing trust and welfare and, factor 1 and 2 loadings

Questions	Scaling	Factor 1	Factor 2
1. The mill is owned by a	(1) Brazilian Company, (0) otherweise	-0.01	0.16
Do you agree with:			
2. "The mill has contributed to the well-being of my community"	(1) Agree, (0) Disagree	0.19	0.63
3. "The mill has contributed to my well-being"	(1) Agree, (0) Disagree	0.28	0.73
How do you feel about the following:			
4. "Farmers in the region feel they cannot trust the local mill"	(1) Agree, (0) Disagree	-0.45	-0.06
5. "The local mill reports back to the farmers on the quality of their sugarcane"	(1) Agree, (0) Disagree	0.06	0.20
6. "Larger farms have higher bargaining power with the local mills when signing a contract"	(1) Agree, (0) Disagree	-0.10	-0.04
7. "Farms closer to local mills have higher bargaining power when signing a contract"	(1) Agree, (0) Disagree	-0.08	0.13
8. Do you feel that the mill has not fulfilled its side of the contract?	(1)No, (0) Yes	0.25	0.24
9. How many times has the mill been late with a payment?	Open Answer	0.04	0.08
10. How many times has the mill skipped a payment?	Open Answer	0.08	0.08
Indicate if you agree or disagree with the following:			
11. "I wish I could accomplish my objectives without signing a contract with the mill"	(1) Agree, (0) Disagree	-0.16	-0.12
12. "My profits have decreased since signing the contract with the mill"	(1) Agree, (0) Disagree	-0.14	-0.46
13. "Due to the contract I have a more constant income"	(1) Agree, (0) Disagree	0.38	0.28
14. "I trust the management of the mill"	(1) Agree, (0) Disagree	0.85	0.12
15. "I always trust that the direction of the mill will do as promissed"	(1) Agree, (0) Disagree	0.85	0.16
16. "It is difficult to communicate with the mill"	(1) Agree, (0) Disagree	-0.32	-0.22
17. "I am familiar with the business conducted by the mill: who they sell to, their management philosophy and practices"	(1) Agree, (0) Disagree	0.13	-0.09
18. "I receive a “fair” value for my sugarcane bought by the mill"	(1) Agree, (0) Disagree	0.15	0.11

Table B.2: Results from two opt-out model with random parameter modeled with trust and welfare indices and willingness to pay estimates

Attribute	Land Rental (LR)		Agricultural Partnership (AP)		Supply (S)		Not grow sugarcane
	Coefficient Estimate	Willingness to Pay	Coefficient Estimate	Willingness to Pay	Coefficient Estimate	Willingness to Pay	Coefficient Estimate
Intercept	-3.54 ***		-6.14 ***		-5.76 ***		-24.61 **
	(0.87)		(1.44)		(1.73)		(12.34)
Rate of LR	0.17 ***						
	(0.03)						
TRS			0.03 ***		0.02 *		
			(0.01)		(0.01)		
Late Payment	-0.05 ***	-0.31 **	-0.03	-1.08	-0.07 ***	-3.39	
	(0.02)	(0.14)	(0.03)	(0.96)	(0.02)	(2.34)	
Length	-0.98 ***	-5.78 **	-0.86 ***	-27.65 **	-1.09 ***	-56.25	
	(0.33)	(2.43)	(0.3)	(12.95)	(0.4)	(38.17)	
Share payment			0.04 ***	1.28 **			
			(0.01)	(0.56)			
Planting					0.76 *	39.20	
					(0.39)	(28.82)	
Harvesting					0.48	24.99	
					(0.38)	(23.25)	
Hauling and delivery					0.67 *	34.43	
					(0.41)	(30.71)	
Mill buys all					1.23 ***	63.70	
					(0.4)	(42.61)	
More than 1 Mill	0.36		-0.32		0.12		-8.66 **
	(0.85)		(0.7)		(0.74)		(4.19)
Distances of Random Parameters Standard Deviations							
Contract LR							3.50 ***
							(0.55)
Contract AP							2.85 ***
							(0.42)
Contract S							2.57 ***
							(0.49)
Opt Out							19.83 **
							(10.07)
Log-likelihood							-593.2
McFadden Pseud R^2							0.43
AIC							1254
Observations							648

Note: Standard error are in parenthesis. Significance Levels: *** is 1%, ** is 5%, * is 10%

Table B.3: Coefficients from modeling heterogeneity in the mean of the random parameter model

	Coefficient		Standard Error
Land Rental			
Welfare	-0.6226		(0.55)
Trust	-0.7238	*	(0.45)
Agricultural Partnership			
Welfare	-0.6832		(0.46)
Trust	0.60111		(0.40)
Supply			
Welfare	-0.3262		(0.48)
Trust	-0.1223		(0.38)
Not Grow Sugarcane			
Welfare	-17.225	**	(7.24)
Trust	-10.403	*	(6.03)

Significance Levels: *** is 1%, ** is 5%, * is 10%

Table B.4: Direct and cross-elasticities in the land rental contract

	Land Rental	Agricultural Partnership	Supply	Current Contract	Not grow Sugarcane
Rate	0.72	-0.15	-0.16	-0.23	-0.03
Risk	-0.16	0.03	0.05	0.05	0.01
Length	-0.07	0.02	0.02	0.03	0.00
More1	0.04	-0.01	-0.01	-0.01	0.00

Note: Length and More1 are arc elasticities since these are dummy variables.

Table B.5: Direct and cross-elasticities in the agricultural partnership contract

	Land Rental	Agricultural Partnership	Supply	Current Contract	Not grow Sugarcane
Risk	0.01	-0.06	0.01	0.02	0.00
Length	0.02	-0.09	0.03	0.04	0.00
Sharepay	-0.10	0.50	-0.13	-0.19	-0.02
TRS	-0.30	1.45	-0.38	-0.56	-0.06
More1	0.01	-0.03	0.01	0.01	0.00

Note: Length and More1 are arc elasticities since these are dummy variables.

Table B.6: Direct and cross-price elasticities in the supply contract

	Land Rental	Agricultural Partnership	Supply	Current Contract	Not grow Sugarcane
Risk	0.03	0.03	-0.28	0.06	0.00
Length	0.01	0.01	-0.09	0.02	0.00
TRS	-0.11	-0.13	1.21	-0.24	-0.02
Planting	-0.01	-0.01	0.11	-0.02	0.00
Harvesting	-0.01	-0.01	0.06	-0.01	0.00
Hauling and delivery	-0.01	-0.01	0.09	-0.02	0.00
Mill buys all	-0.01	-0.01	0.18	-0.03	0.00
More1	0.00	0.00	0.02	0.00	0.00

Note: Length, Planting, Harvesting, Hauling and delivery, Mill buys all and More1 are arc elasticities since these are dummy variables.

Table B.7: Direct and cross-price elasticities in the option not to grow sugarcane

	Land Rental	Agricultural Partnership	Supply	Current Contract	Not grow Sugarcane
More1	0.03	0.02	0.02	0.02	-0.10

Note: More1 are arc elasticities since these are dummy variables.

Appendix C - Testing for separability

Prior to running a second stage regression using DEA scores, a modeler must check if the separability assumption holds. This involves estimating conditional and unconditional DEAs. If the separability assumption holds, that is, if the environmental variables (i.e. vertical integration) do not impact the efficiency frontier, then the unconditional DEA scores can be used in the second stage regression.

Consider a vector of input quantities $X \epsilon R_{+}^{p}$, a vector of output quantities $Y \epsilon R_{+}^{q}$ and a vector of environmental variables $Z \epsilon R^{r}$. The environmental variables are variables not present in the vector of inputs nor of outputs but, nevertheless, may affect the distribution of the efficiency scores including the production possibility frontier (Daraio, Simar and Wilson 2015). The environmental variables can impact the production process through: (1) the set of feasible input and output combinations ψ^{Z}; (2) through the joint density function $f_{XYZ}(x, y, z)$; or (3) both (1) and (2) (Daraio, Simar and Wilson 2015). ψ^{Z} is the set of possible pairs of inputs and outputs for a firm when there are environmental variables *Z*. In this case (Daraio, Simar and Wilson 2015):

$$\psi^{Z} = \{(X, Y) | X \; produces \; Y \; when \; Z = z\} \qquad \text{(C.1)}$$

If environmental factors are not present, then the set of possible pairs of inputs and outputs for a firm becomes:

$$\psi = \{(X, Y) | X \; produces \; Y\} \qquad \text{(C.2)}$$

The separability test tests the null hypothesis of separability (i.e. $H_0: \psi^Z = \psi$) against the alternative hypothesis ($H_A: \psi^Z \neq \psi, for\ some\ z \in Z$) (Daraio, Simar and Wilson 2015). If the null hypothesis is rejected, meaning that the seperability assumption does not hold, the environmental variables must be accounted for in the DEA. This is done by using conditional DEA (Daraio, Simar and Wilson 2015).

To check for separability we compared the conditional efficiency scores with the unconditional efficiency scores. Conditional efficiency scores were obtained by splitting the sample into groups with different quantities of environmental variable factors Z. This means that DMU's were split into groups according to the percentage of sugarcane that was crushed that came from land under their control. First the unconditional DEA was estimated followed by the estimation of the conditional DEA. For the conditional DEA, the minimization problem described in (1) was run separately for each group. Conditional and unconditional scores were compared, as in Bădin, Daraio and Simar (2012), by taking the ratio (R_0) of the efficiency scores:

$$R_0(x, y|z) = \frac{\theta(x,y|z)}{\theta(x,y)} \qquad \text{(C.3)}$$

Conditional DEAs were run by splitting the sample into groups of 3, 4 and 5 depending on their percentage of crushed sugarcane that was produced by the mill. The groups and their sizes are presented in table C.1. In all cases the conditional efficiency scores matched that of the unconditional DEA. Groups contain over 30 DMUs in each subgroup to ensure that the DEA is relevant. Since the efficiency scores from the conditional DEAs and the unconditional DEAs were close to identical we decided that there was no need to run statistical tests. Results from the pooled and conditional DEA are presented in table C.2.

Table C.1: The characteristics of the groups considered in the conditional DEA

Groups	Category	N
3	[0%-50%]	52
	(50%-80%]	81
	(80%-100%]	75
4	[0%-50%]	52
	(50%-70%]	53
	(70%-85%]	46
	(85%-100%]	57
5	[0%-45%]	44
	(45%-65%]	44
	(65%-80%]	42
	(80%-95%]	38
	(95%-100%]	36

Table C.2: Comparison of the conditional and unconditional DEA efficiency scores

dmu	Unconditional	Conditional DEA in groups of			Ratios		
	DEA (1)	Three (3)	Four (4)	Five (5)	(1)/(3)	(1)/(4)	(1)/(5)
1	0.965	0.965	0.965	0.965	1.000	1.000	1.000
2	0.850	0.850	0.850	0.850	1.000	1.000	1.000
3	0.903	0.903	0.903	0.903	1.000	1.000	1.000
4	0.534	0.534	0.534	0.534	1.000	1.000	1.000
5	0.808	0.808	0.808	0.808	1.000	1.000	1.000
6	0.747	0.747	0.747	0.747	1.000	1.000	1.000
7	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	0.923	0.923	0.923	0.923	1.000	1.000	1.000
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10	0.710	0.710	0.710	0.710	1.000	1.000	1.000
11	0.878	0.878	0.878	0.878	1.000	1.000	1.000
12	0.775	0.775	0.775	0.775	1.000	1.000	1.000
13	0.793	0.793	0.793	0.793	1.000	1.000	1.000
14	0.847	0.847	0.847	0.847	1.000	1.000	1.000
15	0.806	0.806	0.806	0.806	1.000	1.000	1.000
16	0.814	0.814	0.814	0.814	1.000	1.000	1.000
17	0.858	0.858	0.858	0.858	1.000	1.000	1.000
18	0.929	0.929	0.929	0.929	1.000	1.000	1.000
19	0.927	0.927	0.927	0.927	1.000	1.000	1.000
20	0.877	0.877	0.877	0.877	1.000	1.000	1.000
21	0.872	0.872	0.872	0.872	1.000	1.000	1.000
22	0.898	0.898	0.898	0.898	1.000	1.000	1.000
23	0.911	0.911	0.911	0.911	1.000	1.000	1.000
24	0.894	0.894	0.894	0.894	1.000	1.000	1.000
25	0.839	0.839	0.839	0.839	1.000	1.000	1.000
26	0.891	0.891	0.891	0.891	1.000	1.000	1.000
27	0.878	0.878	0.878	0.878	1.000	1.000	1.000
28	0.891	0.891	0.891	0.891	1.000	1.000	1.000
29	0.845	0.845	0.845	0.845	1.000	1.000	1.000
30	0.817	0.817	0.817	0.817	1.000	1.000	1.000
31	0.852	0.852	0.852	0.852	1.000	1.000	1.000
32	0.931	0.931	0.931	0.931	1.000	1.000	1.000
33	0.903	0.903	0.903	0.903	1.000	1.000	1.000
34	0.959	0.959	0.959	0.959	1.000	1.000	1.000
35	0.874	0.874	0.874	0.874	1.000	1.000	1.000
36	0.870	0.870	0.870	0.870	1.000	1.000	1.000
37	0.883	0.883	0.883	0.883	1.000	1.000	1.000
38	0.842	0.842	0.842	0.842	1.000	1.000	1.000
39	0.967	0.967	0.967	0.967	1.000	1.000	1.000
40	0.855	0.855	0.855	0.855	1.000	1.000	1.000
41	0.953	0.953	0.953	0.953	1.000	1.000	1.000
42	0.708	0.708	0.708	0.708	1.000	1.000	1.000
43	0.810	0.810	0.810	0.810	1.000	1.000	1.000
44	0.858	0.858	0.858	0.858	1.000	1.000	1.000
45	0.892	0.892	0.892	0.892	1.000	1.000	1.000
46	0.971	0.971	0.971	0.971	1.000	1.000	1.000
47	0.847	0.847	0.847	0.847	1.000	1.000	1.000
48	0.811	0.811	0.811	0.811	1.000	1.000	1.000
49	0.801	0.801	0.801	0.801	1.000	1.000	1.000
50	0.986	0.986	0.986	0.986	1.000	1.000	1.000
51	0.978	0.978	0.978	0.978	1.000	1.000	1.000

(continued)

dmu	Unconditional DEA (1)	Conditional DEA in groups of Three (3)	Four (4)	Five (5)	Ratios (1)/(3)	(1)/(4)	(1)/(5)
52	0.879	0.879	0.879	0.879	1.000	1.000	1.000
53	0.847	0.847	0.847	0.847	1.000	1.000	1.000
54	0.947	0.947	0.947	0.947	1.000	1.000	1.000
55	0.888	0.888	0.888	0.888	1.000	1.000	1.000
56	0.783	0.783	0.783	0.783	1.000	1.000	1.000
57	1.000	1.000	1.000	1.000	1.000	1.000	1.000
58	0.778	0.778	0.778	0.778	1.000	1.000	1.000
59	0.905	0.905	0.905	0.905	1.000	1.000	1.000
60	0.858	0.858	0.858	0.858	1.000	1.000	1.000
61	0.908	0.908	0.908	0.908	1.000	1.000	1.000
62	0.898	0.898	0.898	0.898	1.000	1.000	1.000
63	0.894	0.894	0.894	0.894	1.000	1.000	1.000
64	0.859	0.859	0.859	0.859	1.000	1.000	1.000
65	0.930	0.930	0.930	0.930	1.000	1.000	1.000
66	0.856	0.856	0.856	0.856	1.000	1.000	1.000
67	0.834	0.834	0.834	0.834	1.000	1.000	1.000
68	0.857	0.857	0.857	0.857	1.000	1.000	1.000
69	0.910	0.910	0.910	0.910	1.000	1.000	1.000
70	0.794	0.794	0.794	0.794	1.000	1.000	1.000
71	0.809	0.809	0.809	0.809	1.000	1.000	1.000
72	0.919	0.919	0.919	0.919	1.000	1.000	1.000
73	0.812	0.812	0.812	0.812	1.000	1.000	1.000
74	0.898	0.898	0.898	0.898	1.000	1.000	1.000
75	0.882	0.882	0.882	0.882	1.000	1.000	1.000
76	0.842	0.842	0.842	0.842	1.000	1.000	1.000
77	0.912	0.912	0.912	0.912	1.000	1.000	1.000
78	0.770	0.770	0.770	0.770	1.000	1.000	1.000
79	0.931	0.931	0.931	0.931	1.000	1.000	1.000
80	0.886	0.886	0.886	0.886	1.000	1.000	1.000
81	0.883	0.883	0.883	0.883	1.000	1.000	1.000
82	0.837	0.837	0.837	0.837	1.000	1.000	1.000
83	0.818	0.818	0.818	0.818	1.000	1.000	1.000
84	0.918	0.918	0.918	0.918	1.000	1.000	1.000
85	0.827	0.827	0.827	0.827	1.000	1.000	1.000
86	0.912	0.912	0.912	0.912	1.000	1.000	1.000
87	0.845	0.845	0.845	0.845	1.000	1.000	1.000
88	0.885	0.885	0.885	0.885	1.000	1.000	1.000
89	0.894	0.894	0.894	0.894	1.000	1.000	1.000
90	0.977	0.977	0.977	0.977	1.000	1.000	1.000
91	0.880	0.880	0.880	0.880	1.000	1.000	1.000
92	0.833	0.833	0.833	0.833	1.000	1.000	1.000
93	0.844	0.844	0.844	0.844	1.000	1.000	1.000
94	0.872	0.872	0.872	0.872	1.000	1.000	1.000
95	0.920	0.920	0.920	0.920	1.000	1.000	1.000
96	0.937	0.937	0.937	0.937	1.000	1.000	1.000
97	0.985	0.985	0.985	0.985	1.000	1.000	1.000
98	0.853	0.853	0.853	0.853	1.000	1.000	1.000
99	0.937	0.937	0.937	0.937	1.000	1.000	1.000
100	0.789	0.789	0.789	0.789	1.000	1.000	1.000
101	0.853	0.853	0.853	0.853	1.000	1.000	1.000
102	0.862	0.862	0.862	0.862	1.000	1.000	1.000

(continued)

dmu	Unconditional DEA (1)	Conditional DEA in groups of Three (3)	Four (4)	Five (5)	Ratios (1)/(3)	(1)/(4)	(1)/(5)
103	0.973	0.973	0.973	0.973	1.000	1.000	1.000
104	1.000	1.000	1.000	1.000	1.000	1.000	1.000
105	1.000	1.000	1.000	1.000	1.000	1.000	1.000
106	0.939	0.939	0.939	0.939	1.000	1.000	1.000
107	0.859	0.859	0.859	0.859	1.000	1.000	1.000
108	0.890	0.890	0.890	0.890	1.000	1.000	1.000
109	0.903	0.903	0.903	0.903	1.000	1.000	1.000
110	1.000	1.000	1.000	1.000	1.000	1.000	1.000
111	0.885	0.885	0.885	0.885	1.000	1.000	1.000
112	0.891	0.891	0.891	0.891	1.000	1.000	1.000
113	0.938	0.938	0.938	0.938	1.000	1.000	1.000
114	0.847	0.847	0.847	0.847	1.000	1.000	1.000
115	0.874	0.874	0.874	0.874	1.000	1.000	1.000
116	0.919	0.919	0.919	0.919	1.000	1.000	1.000
117	0.961	0.961	0.961	0.961	1.000	1.000	1.000
118	0.904	0.904	0.904	0.904	1.000	1.000	1.000
119	0.957	0.957	0.957	0.957	1.000	1.000	1.000
120	0.954	0.954	0.954	0.954	1.000	1.000	1.000
121	0.879	0.879	0.879	0.879	1.000	1.000	1.000
122	0.981	0.981	0.981	0.981	1.000	1.000	1.000
123	0.893	0.893	0.893	0.893	1.000	1.000	1.000
124	1.000	1.000	1.000	1.000	1.000	1.000	1.000
125	0.969	0.969	0.969	0.969	1.000	1.000	1.000
126	0.997	0.997	0.997	0.997	1.000	1.000	1.000
127	0.983	0.983	0.983	0.983	1.000	1.000	1.000
128	0.911	0.911	0.911	0.911	1.000	1.000	1.000
129	0.904	0.904	0.904	0.904	1.000	1.000	1.000
130	0.974	0.974	0.974	0.974	1.000	1.000	1.000
131	0.941	0.941	0.941	0.941	1.000	1.000	1.000
132	0.929	0.929	0.929	0.929	1.000	1.000	1.000
133	1.000	1.000	1.000	1.000	1.000	1.000	1.000
134	0.905	0.905	0.905	0.905	1.000	1.000	1.000
135	1.000	1.000	1.000	1.000	1.000	1.000	1.000
136	0.906	0.906	0.906	0.906	1.000	1.000	1.000
137	1.000	1.000	1.000	1.000	1.000	1.000	1.000
138	0.942	0.942	0.942	0.942	1.000	1.000	1.000
139	0.854	0.854	0.854	0.854	1.000	1.000	1.000
140	0.981	0.981	0.981	0.981	1.000	1.000	1.000
141	1.000	1.000	1.000	1.000	1.000	1.000	1.000
142	0.990	0.990	0.990	0.990	1.000	1.000	1.000
143	1.000	1.000	1.000	1.000	1.000	1.000	1.000
144	1.000	1.000	1.000	1.000	1.000	1.000	1.000
145	1.000	1.000	1.000	1.000	1.000	1.000	1.000
146	1.000	1.000	1.000	1.000	1.000	1.000	1.000
147	0.854	0.854	0.854	0.854	1.000	1.000	1.000
148	0.977	0.977	0.977	0.977	1.000	1.000	1.000
149	0.830	0.830	0.830	0.830	1.000	1.000	1.000
150	0.872	0.872	0.872	0.872	1.000	1.000	1.000
151	0.803	0.803	0.803	0.803	1.000	1.000	1.000
152	0.900	0.900	0.900	0.900	1.000	1.000	1.000
153	1.000	1.000	1.000	1.000	1.000	1.000	1.000

(continued)

dmu	Unconditional DEA (1)	Conditional DEA in groups of Three (3)	Four (4)	Five (5)	Ratios (1)/(3)	(1)/(4)	(1)/(5)
154	0.940	0.940	0.940	0.940	1.000	1.000	1.000
155	0.892	0.892	0.892	0.892	1.000	1.000	1.000
156	0.991	0.991	0.991	0.991	1.000	1.000	1.000
157	0.858	0.858	0.858	0.858	1.000	1.000	1.000
158	0.891	0.891	0.891	0.891	1.000	1.000	1.000
159	0.967	0.967	0.967	0.967	1.000	1.000	1.000
160	0.910	0.910	0.910	0.910	1.000	1.000	1.000
161	1.000	1.000	1.000	1.000	1.000	1.000	1.000
162	0.912	0.912	0.912	0.912	1.000	1.000	1.000
163	0.976	0.976	0.976	0.976	1.000	1.000	1.000
164	0.845	0.845	0.845	0.845	1.000	1.000	1.000
165	0.747	0.747	0.747	0.747	1.000	1.000	1.000
166	0.848	0.848	0.848	0.848	1.000	1.000	1.000
167	0.680	0.680	0.680	0.680	1.000	1.000	1.000
168	0.677	0.677	0.677	0.677	1.000	1.000	1.000
169	0.764	0.764	0.764	0.764	1.000	1.000	1.000
170	0.776	0.776	0.776	0.776	1.000	1.000	1.000
171	0.603	0.603	0.603	0.603	1.000	1.000	1.000
172	0.749	0.749	0.749	0.749	1.000	1.000	1.000
173	0.763	0.763	0.763	0.763	1.000	1.000	1.000
174	0.739	0.739	0.739	0.739	1.000	1.000	1.000
175	0.731	0.731	0.731	0.731	1.000	1.000	1.000
176	0.850	0.850	0.850	0.850	1.000	1.000	1.000
177	0.898	0.898	0.898	0.898	1.000	1.000	1.000
178	0.983	0.983	0.983	0.983	1.000	1.000	1.000
179	1.000	1.000	1.000	1.000	1.000	1.000	1.000
180	0.910	0.910	0.910	0.910	1.000	1.000	1.000
181	0.831	0.831	0.831	0.831	1.000	1.000	1.000
182	0.805	0.805	0.805	0.805	1.000	1.000	1.000
183	0.744	0.744	0.744	0.744	1.000	1.000	1.000
184	0.904	0.904	0.904	0.904	1.000	1.000	1.000
185	1.000	1.000	1.000	1.000	1.000	1.000	1.000
186	0.869	0.869	0.869	0.869	1.000	1.000	1.000
187	0.902	0.902	0.902	0.902	1.000	1.000	1.000
188	0.842	0.842	0.842	0.842	1.000	1.000	1.000
189	0.902	0.902	0.902	0.902	1.000	1.000	1.000
190	0.892	0.892	0.892	0.892	1.000	1.000	1.000
191	0.913	0.913	0.913	0.913	1.000	1.000	1.000
192	0.894	0.894	0.894	0.894	1.000	1.000	1.000
193	0.848	0.848	0.848	0.848	1.000	1.000	1.000
194	0.872	0.872	0.872	0.872	1.000	1.000	1.000
195	0.844	0.844	0.844	0.844	1.000	1.000	1.000
196	0.807	0.807	0.807	0.807	1.000	1.000	1.000
197	0.827	0.827	0.827	0.827	1.000	1.000	1.000
198	0.716	0.716	0.716	0.716	1.000	1.000	1.000
199	1.000	1.000	1.000	1.000	1.000	1.000	1.000
200	0.699	0.699	0.699	0.699	1.000	1.000	1.000
201	0.867	0.867	0.867	0.867	1.000	1.000	1.000
202	0.906	0.906	0.906	0.906	1.000	1.000	1.000
203	0.956	0.956	0.956	0.956	1.000	1.000	1.000
204	0.944	0.944	0.944	0.944	1.000	1.000	1.000