Does Vertical Integration Increase Efficiency?

A Look at Ethanol Plants in the Center-South of Brazil

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1.0 Introduction

Brazil is one of the world's leading ethanol producer and was responsible for close to half of the world's sugarcane production in 2012 (Brazil 2013). Brazil is both a major ethanol and sugar producer (Babcock, Moreira and Peng 2013). The sugar-energy sector in Brazil accounts for approximately 2% of the country's Gross Domestic Product (Neves, Trombin, Consoli 2011). Sugarcane is a perennial crop used in the production of ethanol and sugar. Sugarcane production in Brazil has expanded from the North-Northeast region to the Center-South region, since its introduction in the country (Granco et al 2015). In Brazil, 40% of the sugarcane used in the production of ethanol and sugar comes from independent producers and 60% comes from land owned or rented by the mills (Chaddad 2013). Sugarcane production is limited to a certain radius of the mill to, not only, minimize transportation costs, but also to avoid sugarcane quality losses (Chaddad 2016). The distance and harvest timeline limitations aligned with the desire to guarantee sugarcane supply or to create barrier of entry to competing firms make vertical integration, a common practice for mills in Brazil. A question that remains unanswered is whether upstream vertical integration in the sugar and ethanol industries impacts the mill's efficiency. The purpose of this study is to estimate the impact of upstream vertical integration on output-oriented technical efficiency in mills in the Center-South of Brazil.

Vertical integration is the common ownership of successive production stages, as opposed to horizontal integration, that refers to the common ownership of similar or even equal businesses. In this study, vertical integration is considered, as opposed to "vertical combination". Vertical integration refers to substitution of market exchanges for internal exchanges, while "vertical combination" refers to the case where the firm sells output from subsidiary firms to other markets (Perry 1989). Vertical integration can be justified in the presence of technological economies, transaction costs and market failure (Perry 1989). It may occur upstream or downstream. Downstream integration occurs when a firm acquires a stage of production that is closer to the final consumer, while upstream integration occurs when the firm acquires a production stage further away from the consumer. In this study, mills often produce their own raw product so it is vertically integrating upstream.

Vertical integration is chosen when there are costs from the lack of coordination of the steps along the vertical production chain, when there is lack of transparency between trade partners and, when there are transaction costs involved (Besanko, Dranove and Shanley 2009). By deciding to vertically integrate upstream, mills gain greater control over sugarcane production, harvest and processing, thus avoiding transaction costs and quality loss. The benefits from control over the coordination of harvesting, hauling and transportation are: (1) it minimizes transportation costs of a low-value and high-volume crop; (2) it reduces quality losses (harvested sugarcane must be processed within 72 hours to avoid sugar content losses) (Chaddad 2016)[1]. In addition, there is evidence that mills have higher sugarcane yields than independent farmers, 81 tons per hectare versus 75 tons per hectare respectively (Cargo 2010). While vertical integration has the benefit of providing the mill with full control over the supply and coordination of sugarcane production it requires additional 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 does increase transactions costs associated with harvest coordination and contract enforcement.

[1] The higher the sugar content in the sugarcane the higher its quality.

Examples of transaction costs ranges from the costs associated with writing and enforcing contracts to those incurred when one of the parties acts opportunistically (Besanko, Dranove and Shanley 2009). Firms may act opportunistically in the presence of incomplete contracts by exploiting flaws in the contracts to their own benefit. Measures to avoid opportunistic behavior can also result in transaction costs (Besanko, Dranove and Shanley 2009). In certain areas of the country the sugarcane spot market is not large enough for mills to procure all the sugarcane needed in their production (e.g. states of Goias and Mato Grosso do Sul). In these states, mills rely on contracts to procure sugarcane. In other states, such as in Sao Paulo, there is a large sugarcane spot market and mills do not need to rely on contracts to secure sugarcane supply. Thus, in areas where the sugarcane spot market is inexistent mills may prefer to sign land lease contracts and grow their own sugarcane than to sign contracts with an independent producer, as land rental contracts may require less specifications than supply contracts. Contracts with less specifications implies in lower transection costs.

Asset specificity plays an important role in a firm's decision to vertically integrate in transaction economies (Perry 1989). Asset specificity refers to investments made from a down- or upstream firm that brings gains of trade in exchanges between these two firms (Perry 1989). These investments may be in physical or human capital, site specific, in dedicated capital, or in the brand (Perry 1989). For example, Brazilian mills in Mato Grosso do Sul and Goias have, at times, paved roads, supplied sugarcane seedlings and even loans or payment advances to farmers to reduce the infrastructure and investment associated with sugarcane production (Sant'Anna et al. 2016). This investment or "asset specificity" increases the value of the exchange only when it occurs between the farmer and the mill.

Uncertainties, for instance, in the economic environment may cause either party to attempt to extract more from the other by threatening to dissolve the bilateral relationship in place (Perry 1989). This is described as a "hold up" problem by Goldberg (1976). In the case of Brazil, "hold up" problems may arise from the lack of trust of farmers in the mills. For example, farmers in Brazil complain about the lack of access to the mills' decisions in the marketing of the final products and the lack of transparency in process of quality inspection of the sugarcane, among others (Belik et al. 2012). This information is important as it is used to calculate the price the supplier receives for sugarcane. Furthermore, with the closure of more than 40 mills from 2008 to 2014 due to financial problems (Barros 2014), farmers fear the financial instability of the mills. In a survey conducted with farmers and landowners in Goias and Mato Grosso do Sul, Sant'Anna et al (2016) found that the financial instability of the mill was high in the list of concerns of the farmers.

Vertical integration may also be justified if the processor is trying to create barriers to entry for competing firms. For instance, by integrating backwards, a processor may control the supply of an input making it difficult for another mill to locate in the same region (Besanko, Dranove and Shanley 2009). In this case, the control of a portion of the sugarcane may be enough to impede a competing firm to expand without significantly driving up input prices (Besanko, Dranove and Shanley 2009). Similarly, in the case of Brazil, since sugarcane supply can only occur relatively close to the mill, by controlling the sugarcane production, mills can create barriers to entry for new mills.

Uncertainties in sugarcane commercialization, its oligopsony structure[2] and the high level of specialization and investments involved in the production of sugarcane makes it difficult for a

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

strong and stable network of sugarcane suppliers to develop (Bastos 2013, Sant'Anna et al 2016). Bastos (2013) argues that more vertically integrated mills are generally in areas that did not have a sugarcane production before the Statute of the Sugarcane (*Estatuto da Lavoura Canavieira*). The Statute of Sugarcane, passed in 1941, set that 40% of the sugarcane processed by mills had to come from independent sugarcane producers (Brazil 1941). When the amount of sugarcane supplied by independent producers is below 40% allocation, mills can supplement that with sugarcane produced in their lands. Furthermore, mills operating in 1941 with over 40% of their sugarcane supply coming from independent producers, had to maintain that percentage (Brazil 1941). A consequence, therefore, of the Statute was the establishment of a strong supply chain in areas (e.g. Sao Paulo) with tradition in sugarcane production before 1941 (Bastos 2013).

No study has looked at the impact of vertical integration on the technical efficiency of ethanol and sugar processors in Brazil. There have been studies, though, looking at relationship between vertical integration and efficiency in the Italian machine tool industry (Pieri and Zaninotto 2013, Federico 2010), in manufacturing in Japan (Tomiura 2007) and, in manufacturing in Australia (Bakhtiari 2011). Pieri and Zaninotto (2013) conclude that most efficient firms decide to vertically integrate but they cannot show evidence of an impact of vertical integration on efficiency. Federico (2010) finds a positive relationship between efficiency and the decision to vertically integrate. Tomiura (2007) and Bakhtiari (2011) find that firms that are more efficient prefer to vertically integrate. Or study contributes to this line of research by investigating if efficiency is impacted by the firms' decision to vertically integrate. In particular, or study differs from previous ones in that the mills decide to vertically integrate from an industrial sector (i.e. ethanol and sugar processing) into an agricultural sector (i.e. growing sugarcane).

In Brazil, vertical integration and the efficiency of ethanol plants have been the topic of previous studies, though always analyzed 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. Salgado Junior et al. (2014), when analyzing the efficiency of Brazilian mills, find a higher concentration of efficient mills in the state of Sao Paulo, the largest sugarcane producing state. Torquato, Martins and Ramos (2009) conclude that mills in counties, in the state of Sao Paulo, with a tradition of growing sugarcane are more homogeneous and closer to the efficiency frontier than those in counties where sugarcane production is more recent.

2.0 Sugarcane Production and Vertical Integration in the Brazil

During the 21st century, Brazil increased its ethanol production capacity by expanding into the Cerrado region, located in the center of the country. Although over 50% of the production comes from the state of Sao Paulo, the states of Goias, Mato Grosso and Mato Grosso do Sul have increased their sugarcane production fivefold between 2000 and 2013 (IBGE 2014). These two states had little tradition in planting sugarcane until the late 1990s (Silva and Miziara 2011). This study focuses on the major producers of sugarcane in the Center-South of Brazil (Figure 1). The study is limited to Sao Paulo and connecting states, as well as, Goias and Mato Grosso.

(Figure 1)

Technological changes in production (e.g. development of mills that produce both ethanol and sugar) and vertical integration in the industry played a role in the sugarcane expansion (Günther et al. 2008). In most of the states of the sugarcane “frontier” (i.e. Goias, Mato Grosso and Mato Grosso do Sul) vertical integration is higher than the average observed in Brazil (Table 3). Bastos (2013) found that new plants adopt this strategy due to uncertainties with sugarcane supply. Thus, it is more common for mills to grow their own sugarcane in regions where sugarcane is not a common crop (CONAB 2013). For instance, in Sao Paulo, a state with more tradition in sugarcane production, the ratio of supply of sugarcane from the mill to that from the producer is of 57% to 43%. In Mato Grosso do Sul, where sugarcane production has grown only in the past 10 years the same ratio is of 73% to 26%.

(Table 3)

3.0 Data

Data for this study come from the 2013 Brazilian Sugar and Ethanol Guide (ProCana 2013) (Table 4). Information on mills in the Center-South states of Sao Paulo, Goias, Mato Grosso, Mato Grosso do Sul, Parana and Minas Gerais were collected. Together these states account for 75% of the mills in Brazil. Unfortunately, from the 319 mills in the guide, only 154 had all the information needed for the study[3]. Two inputs: land and crushed sugarcane, and two outputs: sugar and ethanol were modeled in an output-oriented DEA[4] (see Table 1). Of the 154 mills, 41 produced only ethanol and one only sugar, while the others produced both ethanol and sugar. Information on area harvested (i.e. land) was estimated for mills where the information was not present. Land was estimated by dividing the crushed sugarcane amount by the average sugarcane yield statistics from the county where the mill is located. Information on the average sugarcane yield in the county was obtained from the Agricultural Municipal Survey (IBGE 2014).

[3] 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.
[4] 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.

(Table 2)

The second stage of the analysis used the calculated output-oriented technical efficiency scores along with other data from the 2013 Brazilian Sugar and Ethanol Guide to determine variables correlated with efficiency. The independent variables of the second stage are the percentage of crushed sugarcane produced by mills out of the total amount of sugarcane used (*Share mill*), a dummy indicating if the mill is located in the Center-West (CW), a dummy indicating if the mill is located in Sao Paulo (*SP*), a dummy that takes on the value of 1 if the mill only produces one product (i.e. sugar or ethanol) and 0 if it produces both and the mill's daily sugarcane crushing capacity (Table 5).

(Table 5)

In the sample there are mills that are totally vertically integrated (i.e. *Share Mill* is 100%) and those that have all their sugarcane supplied by a third party (i.e. *Share Mill* is 0%). The daily sugarcane crushing capacity of the mills range from 800 to 42000 tons of sugarcane per day. The majority of the mills in the sample, 76 mills, are in Sao Paulo, a state responsible for over 50% of the sugarcane produced in the country. From the Center-West, an area that has recently experience sugarcane expansion, there are 40 mills in the sample.

4.0 Method

A two-stage analysis is used to verify how the share of sugarcane planted by the mill over the total amount of sugarcane used impacts its technical efficiency level. In the first stage data envelopment analysis (DEA) is used to obtain efficiency scores for each of the mills, while in the second stage, a tobit model is estimated using the efficiency scores as the dependent variable.

The data envelopment analysis (DEA) used for this study is an output-oriented model allowing for variable returns to scale. The 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 analysis is that no assumptions about the relationships between inputs and outputs are needed (Zhou et al. 2008). The DEA output-oriented model measures efficiency by the firm's ability to maximize the quantity of outputs given a fixed quantity of inputs (Färe, Grosskopf and Lovell 1994). In this study there are *n* DMU and *m* inputs. The *m* fixed inputs are needed for the production of *s* outputs. The model determines the level of output $(y_{s,n}, \eta_n)$ each DMU could produce to be efficient. This is done through the following maximization problem (Färe, Grosskopf and Lovell 1994):

$$\max_{\eta_n, \mu_k} \eta_n \tag{1}$$

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

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

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

$$(\mu_1, \mu_2, \dots, \mu_N) \geq 0$$

where $(\mu_1, \mu_2, \dots, \mu_N)$ are weights estimated by the model, $x_{m,k}$ are the inputs and $y_{s,k}$ the outputs. η_n is the output-oriented technical efficiency of the plant *n* where η_n ranges from 1 to infinity. The closer η_n is to one the more efficient a plant is (Färe, Grosskopf and Lovell 1994). Plants with η_n of 1 are fully efficient.

Once the technical efficiency for each DMU has been calculated, the effect of the percentage of vertical integration on the efficiency of the mill was estimated. One of the ways to measure vertical integration is in terms of the quantity of a good transferred in the firm from one stage to the other (Perry 1989). Similarly, we measure vertical integration as the *share* of the total crushed sugarcane used in the production of ethanol and/or sugar that was produced by the mill on land it owns or rents. In this case, mills with higher shares on owned sugarcane production are more vertically integrated than those with lower shares.

The impact of vertical integration on the efficiency score is measured using a one sided tobit regression with an upper limit censuring of 1. The reciprocal of the efficiency score is the dependent variable such that mills with an efficiency score closer to one are closer to the efficiency frontier. The reciprocal of the efficiency scores takes on the values ranging between 0 and 1. Although the use of the tobit model may not be the best option, since there is no censuring in the data generation, Hoff (2006) argues that it is sufficient for modeling DEA scores against exogenous variables. With this in mind the tobit model estimated in this study was:

$$\frac{1}{\eta_i} = \alpha_i + \beta_1 share_i + \beta_2 type_i + \beta_3 SP_i + \beta_4 CW_i + \beta_7 Capacity_i + e_i \qquad (2)$$

where *share* is the percentage of crushed sugarcane produced by mills, *type* is a dummy that is 1 if the mill produces only ethanol or only sugar and 0 if the mill produces both ethanol and sugar, *SP* is a dummy that is 1 if mill is in the state of Sao Paulo and 0 otherwise, *CW* is a dummy that is 1 if the mill is in the Center-West region and 0 otherwise and *capacity* is the daily sugarcane crushing capacity of the mill (see Table 5 for summary statistics of the variables).

Previous studies guided the choice of the exogenous variables. Salgado Junior et al (2014) find that more efficient mills have higher sugarcane crushing capacity and are prominent in areas where climate and soil promote sugarcane production. Therefore, the location of mills in Sao Paulo and in the Center-West, areas with very diverse soil and climate, are controlled for. We control for the mills in Sao Paulo since this region is the largest sugar, ethanol and sugarcane producer in Brazil. Also, Bastos (2013) finds that mills in Sao Paulo are less vertically integrated and Salgado Junior et al. (2014) find mills in Sao Paulo to be more efficient than in other Brazilian states. Thus, we expect that mills in Sao Paulo to have a higher technical efficiency than those elsewhere. We also controlled for the mills in the Center-West region, as this region has experienced a recent sugarcane expansion. Since the 2000 there have been over 40 new mills installed in this region (Sant'Anna et al. 2016). In addition, the capacity of the mill is also controlled for. The type of mill was also controlled for in order to account for the differences in the mills in terms of the diversity of their output production.

We expect capacity to have a positive impact on efficiency scores, bringing the mill closer to the efficiency frontier and, *type* to have a negative effect (i.e. mills that produce only one product are less efficient than those that produce both sugar and ethanol). The impact of *Share* is ambiguous. If by vertically integrating mills gain more efficiency by having a higher control over the coordination of planting, harvesting and hauling of sugarcane, then *Share* would be positive. If there is another reason to vertically integrate (e.g. reduce transaction costs) then *Share* could either have a negative or positive impact on the efficiency of the mill.

5.0 Results

Results from the output-oriented DEA show that out of 154 plants analyzed, 13 were found to be efficient. Table 6 displays information on the efficiency of mills by state and region.

Here efficient firms, those on the efficiency frontier have a score of 1. Scores above 1 mean the mill is farther away from the frontier and more inefficient. The most inefficient firm had an output-oriented technical efficiency score of 1.89 and is located in the state of Minas Gerais. There were efficient mills in the states of Minas Gerais, Sao Paulo, Goias and Mato Grosso do Sul. Considering the standard deviation, mills in the South and Center-West regions appear to have similar efficiency scores, while mills in the state of Minas Gerais appear to be more heterogeneous in terms of efficiency scores. On average, mills in the South, appear to be more inefficient than the rest, while mills in the Center-West region are the most efficient (Table 6).

(Table 6)

Considering the total sample, mills on average have an output-oriented technical efficiency score of 1.12 and a standard deviation of 0.10. The size of the standard deviation is, most likely, impacted by the high standard deviation between mills in Minas Gerais. There are 16 firms in the top 10th percentile and 48 in the 50th percentile. The cumulative distribution function (cdf) of the reciprocal of the output-oriented technical efficiency is presented in Figure 2. Mills on the efficiency frontier have a score of one and those away from the frontier, the inefficient mills, have a score below one. 90% of the mills have a technical efficiency score between 0.99 and 1, while less than 4% of the mills have an efficiency score below 0.8 (Figure 2).

(Figure 2)

Technical efficiency scores were regressed against share of sugarcane produced by the mill, controlling for the type of the mill, if the mill is located in Sao Paulo (SP), if it is located in the Center-West (CW) and its daily sugarcane crushing capacity. The sample for the tobit regression was smaller, 143 mills, as not all information on capacity and on origin of the sugarcane was available for all mills. Results from the tobit regression are found in Table 7.

(Table 5)

Factors found to have a statistical significance on the output-oriented technical efficiency score were the type of mill (i.e. whether it only produced one product or both ethanol and sugar), the percentage of sugarcane produced by the mill and the daily sugarcane crushing capacity of the mill. The coefficient related to vertical integration is statistically significant and was found to have a negative impact on efficiency. It appears that the reason mills decide to vertically integrate is not related to efficiency gains from the coordination of planting, harvesting, hauling delivery and processing of sugarcane. It is, thus, more likely that mills vertically integrate in order to minimize transaction costs (e.g. contract related transaction costs). The effect of capacity on efficiency is significant but smaller than *type*. As expected, the fact that the mill can produce both ethanol and sugar has a positive effect on efficiency. Also, mills located in the Center-West have a positive effect on efficiency. This is probably due to the fact that mills in this area are newer than elsewhere. It was expected that the dummy SP, indicating mills in the state of Sao Paulo, would have a positive effect on efficiency. The coefficient though is not statistically significant. A reason for the negative and statistically insignificant coefficient may be that our sample has a wider range of mills efficiency scores. As Torquato, Martins and Ramos (2009) find Sao Paulo has more efficient firms in areas with tradition in growing sugarcanes and less efficient in areas that have only recently started to grow sugarcane. From Table 6 we notice how the efficiency scores in Sao Paulo range from 1 to 1.40, while there are other states with a much higher concentration of efficient firms (e.g. Mato Grosso and Mato Grosso do Sul).

(Table 8)

Differently from Pieri and Zaninotto (2013) who do not find an impact from vertically integrating on efficiency, we find that an increase in one percent in the share of the sugarcane produced by the mill, decreases the output-oriented technical efficiency by 0.0001 (Table 8). This impact is statistically significant at 10% level of significance. Hence, vertical integration appears to impact the level of output-oriented technical efficiency in ethanol and sugar production. This is a surprising result as it would have been expected that the greater control over the coordination of harvesting, hauling and delivery would increase the mill's efficiency. After all mills can produce sugarcane with higher yields than independent farmers (Cargo 2010).

This result does not contradict previous studies (Federico 2010, Tomiura 2007 and Bakhtiari 2011). The fact that size of the impact is small does not rule out efficient firms from deciding to vertically integrate. It appears that the choice to vertically integrate upstream is due to reasons other than that of increasing efficiency. In fact, mills may be willing to forgo this efficiency gain in production in order to avoid transaction costs and to guarantee input supply (Besanko, Dranove and Shanley 2009, Carlton 1979). Vertical integration could be implemented as a risk management tool (e.g. to avoid sugarcane supply shortages) instead of an efficiency tool. Hence, in seeking to avoid the high cost of input shortage mills opt to vertically integrate (Teece 1976).

Another reason to vertically integrate may be to create barriers of entry to other mills. Recall that mills acquire sugarcane from land within a certain radius in order to minimize transportation costs and to maximize sugarcane quality. If the mill secures the land surround it for its own production it limits other competing firms in establishing a mill in that area. A firm deciding to establish a mill will probably choose an area with a higher availability of land or sugarcane suppliers.

The fact that a mill only produces either ethanol or sugar decreases its efficiency score by 0.0041 moving the mill further away from the efficiency frontier. As expected, the ability to producing two goods instead of one, increases efficiency. Producing both ethanol and sugar may increase sugarcane's marginal productivity as each product requires a different amount of sugarcane to be produced. In this way mills can split the input between ethanol and sugar production efficiency, considering the market prices for these products.

An increase in 1000 tons in sugarcane crushing capacity increases the efficiency score by 0.0007. Mills with higher crushing daily capacity produce larger volumes of output. Also, by having a larger crushing capacity they can crush sugarcane in a shorter time reducing quality losses from the harvested sugarcane. The longer the harvested sugarcane stays without being processed, the more sugar content it loses, reducing the quantity of ethanol and/or sugar it can produce. This result is similar to findings by Salgado Junior et al (2014). They find that efficient mills are the ones with higher crushing capacity and are located in areas more suited for sugarcane production. The marginal effects of the location of the mill (i.e. *SP* and *CW*) were not found to be statistically significant at the 10% level.

6.0 Conclusion

The purpose of this study was to estimate the impact of upstream vertical integration on output-oriented technical efficiency using an output-oriented DEA analysis and a tobit censured model. Inputs considered in the DEA model were the amount of crushed sugarcane and the land used in the sugarcane production. Outputs were the quantities of ethanol and sugar produced. A sample of 154 mills located in the Center-South area of Brazil were considered in this study. The tobit censured model controlled for the percentage of crushed sugarcane produced on lands owned or rented by mills, type of mill, if the mill was in the of Sao Paulo, if it was in the Center-West region and its daily sugarcane crushing capacity.

Results indicate that an increase in the percentage of the vertical integration decreases output oriented technical efficiency of the mill and is statistically significant. Crushing capacity has a positive statistically significant impact on efficiency. The ability to produce only one product instead of two has a negative effect on efficiency that was statistically significant. The location of the mill was not found to have a statistically significant impact on efficiency. While the fact that mills located in the Center-West impact positively efficiency, mills located in the state of Sao Paulo impact negatively the efficiency score.

These results imply that mills can increase their technical efficiency by procuring sugarcane from independent producers, focus on increasing their daily sugarcane crushing capacity and, ensuring the ability to produce both sugar and ethanol. The common practice of vertical integration, aligned with the results from the study, further implies that mills are adopting this strategy for reasons other than gains in efficiency. Results from this study do not contradict previous studies that found a positive relationship between vertical integration and efficiency. Our results do not point to whether or not efficient mills are the ones vertically integrating. In fact, it may be that firms close to the efficiency frontier are willing to forgo the marginal gain in efficiency from procuring sugarcane from independent producers to avoid transaction costs. By vertically integrating mills minimize the transaction costs. Vertical integration may also be adopted as a strategy to reduce "hold up" problems or to create barriers of entry to new competing firms. By creating barriers to entry mills can have greater control over the prices of inputs (i.e. land and sugarcane prices).

If vertical integration upstream is occurring due to transaction costs (e.g. transaction costs in contract negotiations) or as a means to ensure sugarcane supply, the government may be to reduce vertical integration by subsidizing sugarcane producers and applying contract enforcement measures. Furthermore, public policies could aim at reducing the “hold up” problems by providing farmers with adequate infrastructure (e.g. paved roads). These measure could increase the number of sugarcane suppliers and eliminate barriers to entry created by mills. Future studies should consider the role of contract negotiations and other transaction costs on the mill’s decision to vertically integrate. Studies could also investigate the role of efficiency on vertical integration in the Brazilian ethanol industry.

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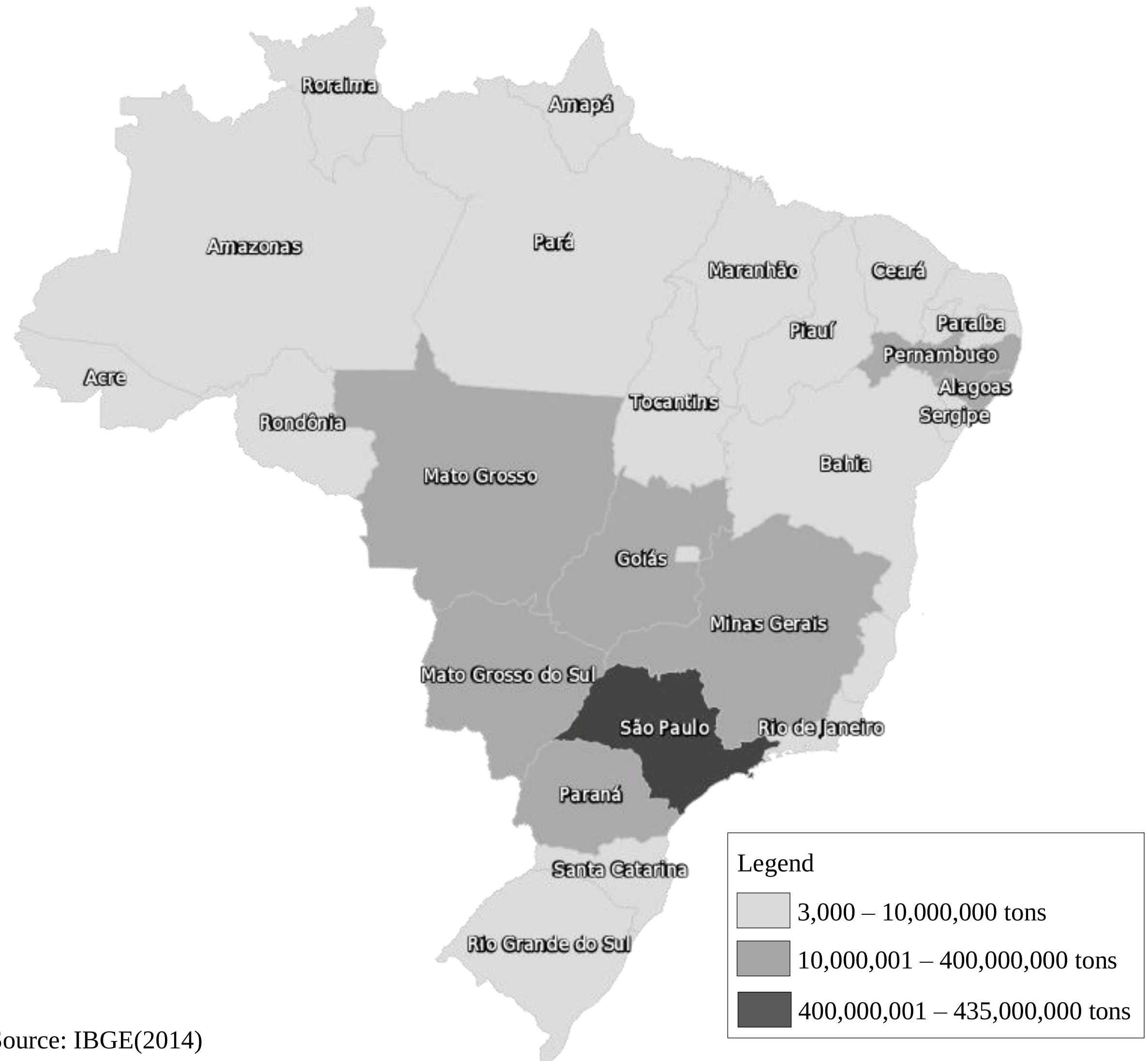

Source: IBGE(2014)

Figure 1: Sugarcane production in the Center-South of Brazil in the crop year 2011/12.

Table 3: Sugarcane supply share and average area cultivated by farmers and mills in the crop year 2011/12

State	Cane production share		Average land cultivated by	
	Mill(%)	Farmer(%)	Mills (ha)	Farmers (ha)
Sao Paulo	57%	43%	14680.91	10971.56
Parana	90%	10%	18272.56	2127.75
Minas Gerais	58%	42%	9470.81	6960.16
Mato Grosso do Sul	73%	27%	16806.98	5671.26
Goias	77%	23%	15126.91	4184.86
Mato Grosso	87%	13%	21705.23	3024.44
Brazil	64%	36%	20.458,56	7.348,45

Source: CONAB (2013)

Table 4: Summary statistics of inputs and outputs of the DEA model.

Variables	Description	Minimum	Mean	Maximum	Standard Deviation
Input					
Sugarcane	Amount in 1,000 tons of sugarcane crushed by the DMU	177	2,007	18,141	1,911
Area	Area from which the sugarcane crushed was harvested in 1,000 hectares	2	25	217	23
Output					
Ethanol	Amount of ethanol produced in 1,000 metric liters by each DMU	2	83	424	60
Sugar	Amount of sugar produced in 1,000 tons by each DMU	0	114	639	120

Table 5: Summary of the variables in the tobit model

Variables	Unit	Minimum	Mean	Maximum	Standard Deviation
Share mill	%	0	66	100	30
Type	Dummy	0	0.72	1	0.45
Sao Paulo	Dummy	0	0.49	1	0.50
Center-West	Dummy	0	0.26	1	0.44
Capacity	Tons/day	800	11669.3	42000	7157.32

Table 6: Output-oriented efficiency scores by region and state with variable returns to scale.

Variables	N	Minimum	Mean	Maximum	Standard Deviation
South	11	1.09	1.17	1.26	0.06
Parana	11	1.09	1.17	1.26	0.06
South-East	103	1.00	1.12	1.89	0.11
Minas Gerais	27	1.00	1.13	1.89	0.17
Sao Paulo	76	1.00	1.12	1.40	0.07
Center-West	40	1.00	1.10	1.29	0.07
Goias	21	1.00	1.09	1.29	0.08
Mato Grosso	9	1.00	1.11	1.20	0.06
Mato Grosso do Sul	10	1.00	1.11	1.22	0.07

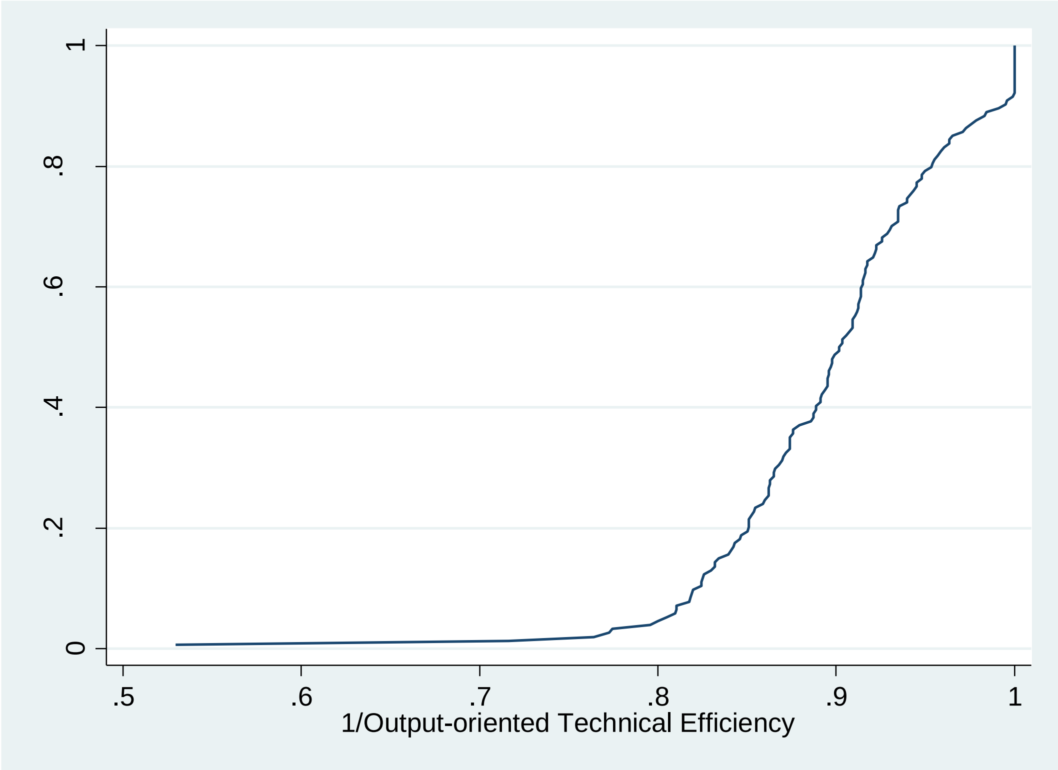

Figure 2: Cumulative distribution function of the reciprocal of the output-oriented technical efficiency measure under variable returns to scale.

Table 7: Results from the tobit regression with the reciprocal of efficiency as the dependent variable.

	Coefficient	Bootstrapped Standard Error	95% Confidence Interval	
Share	-0.0004 *	0.0002	-0.0008	0.0001
Type	-0.0262 *	0.0155	-0.0565	0.0041
SP	-0.0025	0.0147	-0.0314	0.0263
CW	0.0135	0.0209	-0.0275	0.0544
Capacity	0.0043 **	0.0008	0.0027	0.0059
Constant	0.8930	0.0260	0.8421	0.9439
Sigma	0.0649	0.0073	0.0506	0.0792
Wald chi^2 (5)				33.64
Prob>chi^2				0.00
N				143

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

Table 8: Marginal Effects from the tobit model

	Coefficient	Delta-method Standard Error	95% Confidence Interval	
Share	-0.0001 *	0.0000	-0.0001	0.0000
Type	-0.0041 *	0.0023	-0.0086	0.0005
SP	-0.0004	0.0023	-0.0049	0.0041
CW	0.0021	0.0033	-0.0044	0.0086
Capacity	0.0007 **	0.0002	0.0004	0.0010

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