Ownership Structure and Economic Outcomes: The Case of Sugarcane Mills in India*

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Abstract

We examine the effect of firm ownership structure on firm behavior and economic outcomes of upstream suppliers (farmers), using a geographic regression discontinuity design to overcome identification concerns. Our econometric strategy exploits the "command area" zoning system - whereby farmers living within a zone are required to sell sugar to the mill designated to that zone - by surveying farmers at the boundaries of these specified areas. We use two unique sets of data - satellite images merged with digital maps of command area borders to measure crop choices along the borders, and a survey to determine the effects of crop choices on farmer welfare. We find that private mills encourage sugarcane production, and that this effect is concentrated on farmers that own less land. Private mills appear to provide more loans for poorer farmers, thereby encouraging them to cultivate cane. Consumption is also relatively higher for poorer farmers living on the private side of the border. Soil testing confirms that results are not driven simply by variation in soil quality.

JEL codes: D29, L23, L33, O25

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1 Introduction

How does organizational form affect firm behavior and performance? While this question has received much theoretical attention, empirical analysis is challenging because of endogeneity concerns related to the choice of the organizational form. Answering the question "How does the performance of a firm that adopted a particular arrangement compare with how *that same firm* would have performed had it adopted an alternative?" (Masten, 2002) thus represents a formidable barrier.

In this paper we examine empirically how variation along an important dimension of organizational form – ownership structure – affects firm behavior and economic outcomes of upstream suppliers (farmers), using a natural experiment created by regulation governing the formation of South Indian sugar mills to address the econometric challenge. Mills are subject to a zoning system wherein every farmer in a given "command area" must sell to an associated mill; these areas are historically fixed, clearly delineated and the borders can be considered to be randomly placed. Command area boundaries provide a regression discontinuity design since farmers on either side of the boundary must sell to mills of different ownership types - cooperative, private, and public - even though other factors such as weather, soil quality, institutions, etc. are constant across the borders. Thus any differences in farmer outcomes will be associated with differences in ownership structure right at the border.[1]

An old theoretical and empirical literature[2] has struggled with the question of how ownership structure matters. This issue is particularly important in the presence of market failures, where government or cooperative ownership is often viewed as ameliorating these problems. In the case of agriculture, for example, raw produce takes a long time to grow but must be processed immediately after harvest and processing plants require large-scale investments. The resulting threat of monopoly causes many governments to nationalize processing plants or convert them into cooperatives.[3] Recently, the fair trade movement has become synonymous with small farmer cooperatives, in the process channeling large amounts of funds and technical assistance to these associations.[4]

Conceptually, however, the benefits of government or cooperative ownership are un-

[1] The empirical strategy and background sections below describe how we deal with potential problems with the design: for example, cases where command area boundaries coincide with other administrative boundaries, migration and land sales, and enforcement of zoning regulations.

[2] Shleifer (1998) and Megginson and Netter (2001) review the theoretical and empirical literature.

[3] This is similar to the example outlined by Hansmann (1990), who suggests that worker ownership of firms may (in theory) provide benefits when management can opportunistically set terms of employment when workers are "locked-in" to the firm for various reasons (e.g. firm-specific human capital investments).

[4] See, for example, a background paper commissioned by Committee for the Promotion and Advancement of Cooperatives Develtere and Pollet (2005); information from the Cooperative Development Foundation (`http://www.cdf.coop/`); and the websites of numerous organizations promoting fair trade: `http://www.globalexchange.org/fairtrade/coffee/cooperatives`, `http://www.globalexchange.org/fairtrade/cocoa/cooperatives`, `http://www.greenamerica.org/programs/fairtrade/whattoknow/`.

clear since some theories emphasize efficiency gains while others emphasize capture. Cooperatives, for example, have rarely been successful in their aims of uplifting the rural poor (Simmons and Birchall, 2008). Often, they are subject to capture by powerful landowners, politicians and the rural elite (Banerjee et al., 2001; Sukhtankar, 2012); in general, aggregating preferences and collective-decision making within cooperatives may be problematic when members do not have homogenous preferences (Hansmann, 1990). Management failures are common, necessitating government subsidies and support to keep the cooperative afloat. On the other hand, the problems seen as characteristic of private firms - monopsony power, hold-up, etc - may in fact be mitigated by repeated interactions between these firms and farmers. Whether governments should subsidize and promote cooperatives is therefore an empirical question, one that assumes significant importance in developing nations where rural growth lags far behind urban growth and with histories of missteps in agricultural policy.

In addition to the econometric advantages, the sugar industry has several other features to commend it as a setting in which to examine government intervention.[5] Sugarcane is one of the biggest cash crops in India, and the sugar industry employs a substantial number of the rural population. The technology of sugar production means that opportunities for monopsony power and ex post hold up by mills exist. Since sugarcane must be crushed as soon as it is harvested, farmers cannot sell their cane to mills that are far away, and mills thus have local monopsony power and the opportunity to hold up farmers ex-post. Farmers may anticipate these problems and undersupply cane, and one might expect this problem to affect private mills more than it does cooperatives.

Our study uses several unique sets of data. First, we overlay multi-spectral satellite images – i.e. images that include multiple bands of light, including those beyond the visible spectrum – on digital maps of command area borders. We convert these light bands into a vegetation index (NDVI), and calibrate a digital "signature" of sugarcane on the index by observing NDVI values of known sugarcane fields, which allows us to directly observe crop choices along the borders. Second, we conducted a survey to determine the effects of crop choices on farmer welfare, asking detailed questions about both income and farming practices to tease out the mechanisms. Finally, we conducted soil testing to ensure that results are not driven simply by variation in soil quality.

We find that private mills encourage sugarcane production more than cooperative mills. Overlaying satellite images on maps of command areas, we determine that the sides of the borders owned by private mills are actually planted with a greater proportion of sugarcane than those owned by cooperative or government mills (by about 2 percentage points or 5 percent). This result is mirrored in the surveys of farmers with plots that are close to the borders, although the results from the survey analysis are less precise.

[5]Other important cash crops processed under the cooperative model include coffee and cocoa.

Conditional on owning or renting land, farmers are more likely to have cultivated sugarcane on the private side of the border. Further, we find that the effect is concentrated on farmers that own less land.

Delving deeper into the data, we find that private mills appear to possibly provide more loans for poorer farmers, thereby encouraging them to cultivate cane. Consumption is also relatively higher for poorer farmers living on the private side of the border, while literacy for sugarcane farmers and amount of land owned for all farmers is higher as well. Meanwhile, soil testing confirms that there are no differences in soil quality across borders. These results are consistent with the simplest models of monopsony purchase, as these would suggest that more efficient private mills both purchase more inputs and pay higher prices. However, the results are somewhat noisy, and not always strongly statistically significant. Subject to these caveats, this paper suggests that institutional structures could affect not only welfare but also the long-term distribution of land and human capital.

while a vast theoretical literature exists,[6] clean empirical estimates of the impact of organizational form on economic outcomes are not as common. Masten (2002) nicely summarizes the conceptual challenge of determining the importance of organizational form on performance: if theory suggests that one organizational form dominates, then observing variation in the form will be difficult; if on the other hand variation in observational form is observed, this likely indicates that organizational form is unimportant. In the particular case of firm ownership, Megginson and Netter (2001) suggest two other practical reasons for the lack of clean empirical analyses: first, it is difficult to find comparison private firms especially in developing nations, and second endogeneity concerns plague these estimates (for example, selection - governments may choose to sell the worst-performing units - or corruption - the value of state units may be deliberately suppressed).[7] Thus while a large amount of valuable empirical works exists there is till room for improvement in terms of causal inference.

Our paper introduces empirical innovations on two margins. First, with the regression discontinuity design, it expands the causal inference frontier in a particularly important context. In terms of the language above, using an institutional quirk that forces

[6]See, for example, Hart et al. (1997); Boycko et al. (1996); Hart (2003); Laffont and Tirole (1991, 1993); Stiglitz (1994); Schmidt (1996)

[7]The challenges they highlight are applicable to industry studies in which the authors compare productivity in state-owned and private enterprises via structural models of cost structure (Ehrlich et al., 1994; Porta et al., 2002); to country-specific studies in which the profitability of existing state-owned, mixed, and private enterprises is compared (Majumdar, 1996; Tian, 2001; Boardman and Vining, 1989, 1992; Dewenter and Malatesta, 1997); and to comparisons of privatized and remaining state firms in the transitional economies of Eastern Europe (Frydman et al., 1999). The empirical methods in these studies are dominated by cross-sectional comparisons or difference-in-differences methods; even when selection bias is explicitly considered (Frydman et al., 1999) via firm-fixed effects, strong assumptions on parallel trends in a changing economy are required.

co-existence of a variety of organizational forms even when a particular form might be better assists us in discerning the importance of governance. Second, the combined use of satellite and survey data to observe sugarcane provides a methodological proof-of-concept that can be extended to gathering data on other crops. While economists have previously used multi-spectral satellite images to measure forest cover Foster and Rosenzweig (2003); Burgess et al. (2012), we use higher resolution (23.5m) data and actual field measurements to calibrate and measure the extent of sugarcane grown, thus conducting (to our knowledge) the first such analysis in the economics literature. Finally, the paper also speaks to the debate over privatization of government and cooperative firms, which is extremely lively in policy circles. As a number of state-owned and cooperative firms are up for privatization in India and elsewhere, this question takes on acute relevance. Given the recent interest in fair trade cooperatives and the large amounts of funding these organizations receive, it is surprising that there has been little rigorous empirical evidence on whether they actually promote farmer welfare, and this paper also takes a first step in that direction.

The rest of the paper proceeds as follows. Section 2 provides some background on the zoning system and the sugar industry in Tamil Nadu. Section 3 describes the empirical strategy and shows that a discontinuity does indeed exist at the border. Section 4 presents the sample selection procedure and summary statistics. Section 5 discusses the results, and section 6 concludes.

2 Background

2.1 The Sugar Industry and Ownership Structure

Sugarcane is a cash crop that is grown in large parts of India, from the semi-arid tropics in the south to the sub-tropical plains of the north. The sugar industry emerged in north India after sugar tariffs were imposed in the 1930s, with the establishment of private British and Indian sugar producing factories in Uttar Pradesh and Bihar. After Independence, the federal government as well as state governments made their way into sugar production. The cooperative sector burgeoned in the western state of Maharashtra in the 1950s, from where it spread to other states. [8]

Historically, cooperatives were a response to the government's distrust of powerful landowners and private industry. Public funds were (and still are) used to set up mills, provide bailouts when they faced threats of bankruptcy, provide subsidized loans for operation, as well as provide state guaranteed loans for many other purposes. In addition to funding cooperatives, both State and Central governments have also heavily regulated

[8] For more on the history of the Indian sugar industry, see Baru (1990).

the sugar industry.

The historical context has affected current distribution of mills across India. While ninety percent of the mills in Maharashtra are cooperatives, the story is different in the north. The majority of the mills are privately owned, with the remainder split between government and cooperatives. Only in the southern states of Karnataka and Tamil Nadu do we see a more even distribution of private and cooperative mills.[9] Table 1 presents the list of operating mills in Tamil Nadu as of 2010, along with their ownership structure.

2.2 The Sugar Production Process

Sugarcane is a water and fertilizer intensive crop that takes a year to grow. Irrigation is usually necessary, although rainfall is also important since it reduces irrigation costs. Sugar is made by crushing sugarcane via massive rollers to extract sucrose-rich juice. Lime is then added to the juice to balance pH and clump together impurities, sulphur is bubbled through to bleach it, and the juice is boiled and refined to make processed crystalline sugar.

While the intrinsic sucrose and water content of sugarcane determine the potential amount of sugar that can be extracted from it, a large role is played by the efficiency and organization of the mill. Once cane is harvested, it dries out rapidly, and hence must be crushed within hours of cutting. Given the generally poor transportation infrastructure in rural India, this means that farms cannot be located more than 15-20 kilometers from the factory. The coordination and efficiency of the mill determine how much sugar is obtained per ton of cane crushed. Mills need to coordinate cane harvesting in order to run the factory exactly at capacity every day. If too much cane arrives at the factory gates daily, some of it cannot be crushed and dries out. If too little cane arrives, recovery is also lower due to the fixed width between the rollers. Moreover, keeping the rollers running is costly, so it may not be cost effective to run the machinery for small quantities of cane. Machinery breakdowns are also extremely costly, since the cane at the factory starts drying out, and the harvesting schedule must be readjusted.

There are two sugarcane harvesting cycles in Tamil Nadu. The vast majority of cane is harvested starting in December, after the North-east monsoon has deposited most of its precipitation on the state, and continuing through April. Later harvesting dates in this season translate to drier and lighter cane. Since prices paid to the farmer are per tonne of cane (regardless of quality), drier cane brings in less to farmers. A smaller quantity of cane is also harvested in July and August. In order to ensure a regular supply of good quality cane, mills provide seeds, loans, and agricultural extension services to farmers. Each factory pays its farmers a unique price per metric tonne of cane. A single price for

[9] Source: Indian Sugar Mills Association Yearbook, 2006.

sugarcane is paid per year on the basis of weight alone. Usually, a price is announced just before the beginning of the season (in September/October), and adjustments (upwards only) made at the end of the season. Sugar prices and rainfall affect cane prices, as does the recovery rate of the mill, as statutory prices are tied to this recovery rate.

2.3 The Command Area System

The constraints imposed by the fact that cane must be crushed immediately after harvest means that sugar factories cannot bring in cane from large distances. Moreover, there are large economies of scale in cane crushing, and thus gains to be had from building large factories. Finally, unlike in Brazil where cane is grown in plantations owned by the sugar factories themselves, cane in India is grown by a large number of individual farmers. Combined, these factors mean that ensuring adequate supplies of cane is a first-order problem for sugar mills in India.

The government's solution to this problem was to designate reserved sugarcane zones for each mill, thereby limiting competition between mills for cane and providing incentives for the mill to assist in cane development within their zones. This was an old idea; in a meeting of the Sugar Committee in 1933, a Mr. Noel Deerr noted that:

> With the adoption of a zone system, that is to say, with an area given over to the miller to develop in sympathy with the small holder, there should follow at once an association of agriculture and manufacture for the common benefit of both interests. It will be the object of the mill to reduce the price of the raw material and this can best be done by increasing the production per acre, and with an increment in the yield the net income of the small holder will increase even with a decrease in the rate paid per unit of raw material. (as cited in Baru (1990), p 33)

The policing of the command areas is left to the mills, who have strong incentives to ensure that farmers do not sell their cane to other mills. In practice, the complex relationship a cane farmer needs to have with the mill to procure seed, fertilizer, credit, pesticide etc effectively binds her to her current mill. The agricultural extension officers that mills send to assist farmers with growing cane also help the mill monitor farmers; moreover, because the cane must be crushed immediately after harvesting farmers cannot simply harvest their cane and show up at another mills door to sell it. In order to control supply of cane arriving at the factory, mills assign particular "cutting dates" to farmers.

In order to protect farmers from the monopsony power thus created, the government would set a floor for the price of cane to be paid by each mill, depending on the recovery rate of cane achieved by the mill. Currently, cane prices are regulated by both the national government, which sets a price floor called the Statutory Minimum Price (SMP), and state governments, which usually add to this with a State Advisory Price (SAP). Sale of processed sugar is also restricted, with a certain proportion (which varies over the years, currently 10%) to be sold at a low rate ("levy price") to the Central Government, and the rest on the open market (at the "free price").

While some states have now abolished the command area system, replacing it with looser rules that require new factories to be built at least a certain distance (20-25km) away from existing factories, the system still exists in the state of Tamil Nadu. Most of the boundaries of the command areas of the 36 operating sugar mills in the state were historically set. Some followed natural geographical features, like rivers, canals, or hills. Others were set to equate the number of villages neighboring mills had in their command areas. Anyone who wished to establish a new mill had to obtain permission from the sugar commissioner, proving that she had the potential to obtain adequate supplies of cane from a heretofore undesignated command area, or that existing mills were not using cane from their currently assigned areas.[10] It is, of course, possible and likely that these command areas differ in various characteristics: however, as the section below explains, what is important for our empirical strategy is that the areas close to borders between private and cooperative/government sugar mills are not different from each other.[11]

3 Empirical Framework

3.1 Empirical Strategy

The approach to estimating the effect of ownership structures on farmer outcomes involves using regression discontinuity, similar to that followed by Black (1999) and Bayer et al. (2007). This approach takes advantage of a discontinuity in ownership structure at the border, while other characteristics – such as weather, soil quality, pest exposure, the institutional environment, etc – are continuous. The advantage of this approach over that of simply comparing farmers outcomes in areas served by private and cooperative mills respectively is that it is difficult to control for all pertinent characteristics that may affect these outcomes. Thus instead of estimating:

$$Y_{ij} = \alpha + X'_{ij}\beta + A'_{j}\gamma + \delta Private_{j} + \epsilon_{ij} \tag{3.1}$$

where Y is an outcome of interest for farmer i in area j, X are individual farmer characteristics, and A are area characteristics, and the outcome of interest is coefficient δ

[10] Notes from meeting with Tamil Nadu Sugar Commissioner Mr. Sandeep Saxena and Tamil Nadu Sugar Corporation's Chief Cane Development Officer Dr. A. Sekar.

[11] To make the argument that – for example – a mill assigned a relatively less fertile area overall may perform worse than a mill assigned a relatively more fertile area overall, even though the border areas are equally fertile and all outcomes are measured at these border areas, would have to rely on assumptions that the mill is otherwise constrained on some dimensions – for example financially.

on a dummy variable indicating whether the area is served by a private mill, we estimate:

$$Y_{ib} = \alpha + X'_{ib}\beta + \sum_{1}^{B} \gamma_b + \delta Private_b + \epsilon_{ib} \tag{3.2}$$

where b is a particular border and a series of indicator variables γ control for characteristics that vary at the border. This approach makes sense when comparing the entirety of border areas, which we do in the satellite data analysis. However, our survey is based on sampling a few pairs of villages that are directly across from each other on different sides of the border; some borders may be very long, and there may be significant differences in characteristics on different parts of the border. In order to account for these differences, instead of indicator variables for the border, we include indicator variables for the village pairs, and estimate:

$$Y_{ipb} = \alpha + X'_{ipb}\beta + \sum_{1}^{P} \nu_p + \delta Private_b + \epsilon_{ipb} \tag{3.3}$$

where p refers to the village pair.

In all estimations, we cluster standard errors at the mill level. While in principle the satellite data analysis covers the entire population of border villages, and hence there is no sampling error, other sources of error – such as differences in atmospheric conditions affecting the satellite images – remain. Hence we present very conservative estimates in the satellite data analysis: we first aggregate all data to the village level (rather than using each pixel as a separate observation), and we continue to cluster standard errors by mill.

3.2 First Stage

This empirical strategy is valid if there is actually a discontinuity in ownership structure at the border and continuities in other characteristics. Whereas the law says that farmers must sell to the mill whose command areas their land is located in, it is possible that this law is flouted in practice. Some flexibility in this law may also be possible in case of cane shortages or overages on different sides of the border. We first check that the a discontinuity does indeed exist at the border; that is, farmers on one side of the border sell to the mill on their own side and not the other side. Moreover, we also check that other variables do not display a discontinuity at the border.

Data for these checks come from a small survey of 80 households implemented prior to the main survey. Sugarcane growers at various distances from the border (at a set of different borders) were asked about which mills they had sold sugarcane to in the last five years, their yields, and their land ownership and rental details. Not a single respondent claimed to sell sugarcane *regularly* to the mill on the other side of the border. There are, however, farmers who have sold cane to the mill on the other side of the border occasionally over the last five years. Figure 3 represents the proportion of farmers who sell cane exclusively to their own mill. The x-axis measures distance from the border. Whereas the proportion drops to lower than one as we get closer to the border, it is still very high, as over 80 percent of farmers sell exclusively to their own mill.

Figure 4 presents these results by designating one of the pair of mills as Mill A and the mill on the other side of the border as Mill B. This figure is very conservative and biased against demonstrating a discontinuity, since it shows the proportion of respondents with land in the command area of Mill A who have *ever* sold cane to Mill B on the left hand side of the graph, compared against those who exclusively sell to Mill B on the right hand side of the graph. Despite this bias, however, the discontinuity at the border is clear. Since no one on the side of Mill A sells exclusively to Mill B, there will clearly be an even sharper discontinuity at the border if this metric were used instead.

3.3 Threats to Discontinuity Design

Regression discontinuity designs that include geographical discontinuities must carefully consider three sets of issues: the process of boundary creation, the endogenous sorting of economic actors across boundaries, and differences between regions other than the treatment of interest (Lee and Lemieux, 2010). We next explicitly consider these threats to internal validity and explain how this project deals with them. In addition, we also consider a common criticism of regression discontinuity-type designs, namely the external validity of the results.

1. **Process of Boundary Creation** As described above, the boundaries of command areas were historically set and are clearly delineated. We will also directly test observable characteristics to ensure that they do not vary across borders. Moreover, as is standard in these analyses, we will exclude any parts of boundaries that follow natural borders such as lakes, rivers, hills, etc. Finally, all decisions about which parts to include or exclude are transparent and available to anyone using Google Earth. Figure 5 presents a sample *taluk* (sub-district) split between two mills, showing how it is basically split in the middle into two mills' command areas. Figure 6 shows the distribution of mill border areas across Tamil Nadu.

2. **Endogenous Location of Farmers** Given that the boundaries have been historically set, it is possible that farmers selectively move across borders by purchasing land. For example, farmers that work harder might move to mills that reward effort. However, this is not a threat to the validity of estimates but rather an interpretational issue. If farmers move because certain mills reward effort, this can still be interpreted as the causal impact of ownership structure, although due to selection

rather than other mechanisms. Moreover, this kind of mobility can be measured to some extent by asking farmers: while we did not directly ask about migration, we did ask about land sales, and the vast majority (75%) of farmers note that the land they farm was simply inherited rather than purchased. Thus it is unlikely that endogenous movement of farmers drives the results.

3. **Other Differences between Regions** We directly test other relevant characteristics to ensure that they do not jump discontinuously across borders. The most obvious characteristic is soil, and we can directly measure soil traits such as granularity and chemical content that would affect crop choices and yields. Some of these characteristics, for example the mineral content of the soil, might be affected by farmer effort such as application of fertilizer and indeed by ownership structure. However, other characteristics such as the nature of soil and the size of soil grains are not affected by farmer effort. A remaining possible difference is that one side of the border is further away from its mill than the other side; we control non-parametrically for distance and also show that results are not different when restricted to borders located at similar distances from mills.

4. **External Validity** Since regression discontinuity estimates relate to observations close to the discontinuity, one concern is that they have limited external validity. Certainly in some contexts where the marginal complier is questionable or different from the rest of the population - for example a student in an ability distribution with high variance where the cutoff is some score - this concern is valid. However, in the sugarcane farmers context it is difficult to imagine that farmers close to the border are systematically different from those who are not. It is possible that mills treat farmers who are close to the border in a different way than they treat other farmers, perhaps due to competition across the border; results from a small and hence admittedly underpowered survey of farmers at various distances from the mill do not show in differences in agricultural extension services provided by mills based on distance. Finally, these results from the sugarcane industry are applicable to various similar industries in India and elsewhere - for example dairy and coffee.

4 Sample Selection and Data Description

Table 1 presents the list of sugar mills in the state of Tamil Nadu as of 2010. From the universe of potential borders between these mills, we did not consider those borders that were along a river, or separated by large geographic features like canals or mountains where the two sides are likely to be very different. We further considered only borders which did not overlap district/sub-district borders, since this would mean that the two sides are in different administrative divisions. In addition, we also collected soil samples from a subset of farmers, and tested these samples for various physical and chemical characteristics. Finally, we purchased satellite images from the National Remote Sensing Centre (NRSC) of India in order to determine how much sugarcane was grown on either side of the border.

4.1 Survey Data

For our survey, we sampled pairs of villages across from each other along command area boundaries that did not overlap any major administrative divisions. This gave us 32 village pairs (64 villages) along 20 mill pair borders. Within these villages, we compiled a list of all plots that were within a kilometer of the border by obtaining land records from the Village Administrative Officer (VAO). The VAOs also denoted whether the plots were farmed with sugarcane or not. Based on this information, we picked a stratified random sample of sugarcane growers and non-growers, aiming to survey 25 sugarcane farmers and 15 non-sugarcane farmers in each village. All regressions are weighted to account for these differential sampling probabilities.

Table 2 presents summary statistics, divided by whether the mill whose command area respondents are in is privately owned or not. In general, the different areas appear to be balanced. The only obvious differences are in the average amount of land owned, and loans provided by mills; both these outcomes are discussed further in the results section below.

4.2 Soil Sampling

For a subsection of the surveyed farmers – approximately 3 per village – we collected soil samples from their fields. The samples were collected according to the procedures set forth by the Tamil Nadu Agricultural University on the following website: `http://agritech.tnau.ac.in/agriculture/agri_soil_sampling.html`. The same institution conducted the analysis on the samples, providing us with data on the texture, type of soil, available amounts of nitrogen, phosphorus, and potassium, as well as the electrical conductivity and ph of the soil samples.

4.3 Satellite Data Collection and Analysis

We obtained multi-spectral satellite images of the state of Tamil Nadu from the National Remote Sensing Centre (NRSC). These images were of 23.5m resolution, which corresponds to 1/8th of an acre on the ground. For comparison, the average number of acres owned or rented in the survey was about 6, and even if this land were to be divided into 5 plots, each pixel of resolution would amount to about 1/10th of these plots, allowing us to precisely identify sugarcane through the satellite images. The images were all captured by satellite IRS-P6 in October 2010. The particular month was chosen since a) all sugarcane that will be crushed in the season has been planted and is growing but not yet harvested by October and b) our field teams were on the ground at the time, allowing us to match crops on the ground with the satellite data.

In order to digitally distinguish vegetation as well as separate sugarcane from other crops, we make use of the multi-spectral nature of these images, and in particular the fact that different crops will have different digital spectral signatures.[12] More broadly, we take advantage of the fact that chlorophyll in vegetation absorbs visible light – especially light in the red frequency – for photosynthesis but does not absorb near-infrared light (since the energy in near-infrared light would destroy proteins in the leaf). The near-infrared light is then reflected or transmitted, with denser canopies of vegetation reflecting more light since light that is transmitted by one leaf might be reflected by the leaf below it, and captured by satellite sensors. The sensor captures the strength of the electromagnetic radiation within each wavelength band, with values ranging from 0-255. An index called the Normalized Difference Vegetation Index (NDVI) transforms the near-infrared (NIR) and red wavelengths of the satellite images into a single dimension ranging from -1 to 1 according to the simple formula below:

$$NDVI = \frac{NIR - Red}{NIR + Red} \tag{4.1}$$

NDVI values in general above 0 represent vegetation since vegetation has low red reflectance but high NIR reflectance. Moreover, different crops correspond to different ranges of NDVI, with denser vegetation like thick tree canopies having higher values. This fact allows us to distinguish sugarcane from rice, the other main crop in sugarcane growing areas. Figure 7 illustrates how a sugarcane plant has a much denser canopy that is higher off the ground than a rice plant. In order to identify the exact NDVI thresholds for sugarcane, we follow standard procedures in remote sensing (see, for example, Rao et al. (2002); Rehman et al. (2004); Mehta et al. (2006)) that involve calibrating NDVI values by individual image by referencing coordinates of sample fields. We obtained GPS coordinates of over 200 fields in Tamil Nadu in October-December 2010 – at the same time the satellite images were captured – and calibrated NDVI values for sugarcane fields by image. Each image will have slightly different NDVI ranges for a crop due to differences in atmospheric conditions that scatter and reflect light differentially over time and space. Since we are comparing very localized areas this does not pose a problem; we only compare border pairs within images.

Overlaying the calibrated images over GIS maps of the borders allows us to determine how much sugarcane is growing on each side. We included only villages that were on the

[12] For more on remote sensing of vegetation, see Jensen (2007).

borders of command areas, and calculated the number of pixels in these villages that were crops in general and sugarcane, and then the proportion of crops that were sugarcane. We excluded any pixels with negative NDVI values, as these correspond to clouds or water bodies. Since the border area was highly localized, in general cloud cover affected both sides of the border (see Appendix A for sample images and more details on the procedure).

5 Results

5.1 Preliminaries

We first checked that the soil quality was indeed the same across either side of the border. Table 3 presents the results, which show no significant differences between private and cooperative/public mills. The coefficient on any of the soil characteristics is smaller than 5% of the standard deviation of one of these variables. Another way to gauge the magnitude of this coefficient is project what it means to income, by multiplying it with the coefficient on the regression of farm income on the given characteristic. For example, soil on the private side of the border has 17 kg/hectare more nitrogen. An additional kg/hectare of nitrogen is associated with a Rs. 31.8 increase in annual farm income. Thus the difference between the private and cooperative soil samples corresponds to about Rs. 500 in annual farm income, which is only 1% of mean annual farm income.

5.2 Do Private Mills Discourage Cane Production?

The perception amongst governments that fund cooperatives is that incentives for private mills to hold up farmers are higher and will hence result in an undersupply of cane to these mills. However, we find exactly the opposite result: private mills seem to encourage production of cane. Both satellite and survey data are consistent in this regard.

5.2.1 Satellite Data Analysis

The satellite analysis suggests that villages on the private side of the border have a higher proportion of cane planted on all vegetated land, by about 2.3 percentage points, or 3.8% (Table 4). Moreover, using the same technique as that used for identifying sugarcane, we distinguish land planted with any crops by simply observing NDVI value ranges of all observed crops by image; it appears as though more of the land on the private side of the border is planted with any crops (1.6 percentage points, or about 2%). Finally, farmers on the private side of the border also plant more cane as a proportion of all planted crops (outcome in column 1 divided by outcome in column 2), by 1.6 percentage points or about

2.4%. While these magnitudes might appear small, it is important to note that the two areas are practically identical in underlying characteristics.

5.2.2 Survey Data Analysis

The satellite data analysis is corroborated by the survey, with similar observed magnitudes. The survey data suggests that farmers on the private side of the border plant about 0.34 additional acres of sugarcane, corresponding to about 5.6% more sugarcane on owned or rented land (Table 5). This number compares reasonably to the 3.8% additional sugarcane on all vegetated land observed via satellite.

In addition to planting more of their land with cane conditional on owning or renting land, farmers are more likely to grow sugarcane at all on the private mill side of the border. Farmers are 2 percentage points (7%) more likely to have cultivated sugarcane in the past five years on the private side of the border, and 2.9 percentage points (12%) more likely to be growing sugarcane at the time of the survey. These results are not statistically significant, but the sign and magnitude of the coefficients are consistent with the results above.

5.3 What Assistance do Farmers Receive from Mills?

What do private mills do differently that encourages farmers to grow sugarcane? Sugarcane is a lumpy crop, and farmers often require credit in order to pay for seeds and fertilizer. Overall, the amount of financial assistance provided by both types of mills is very similar: however, controlling for acreage, it appears as though land-poor farmers receive more loans from private mills (Table 6). The story is similar for the cane price: while overall there are few differences, once we control for acreage land-poor farmers seem to get slightly higher prices from private mills. This is consistent with stories in which cooperative mills are captured by richer farmers. Other aspects of mill performance which might encourage sugarcane production – such as paying on time and delays from optimal harvesting dates for farmers – do not seem particularly different, although the data are noisy and missing observations preclude precise analysis.

5.4 Farmer Characteristics

While differences in mill performance may lead to differences in sugarcane production, differences in farmer characteristics may also play a role. Since we do not have any information on the landless, it is difficult to separate out the compositional effects of people drawn into farming. Note, however, that this is an issue of interpretation: if certain types of people are drawn into farming because certain mills reward effort, this can still be interpreted as the causal impact of ownership structure. Table 7 presents results on farmer characteristics, separated into all farmers and cane farmers.

Overall, farmers appear to be similar on both sides of the border, with some important differences. Farmers on the private side of the border have more land than those on the cooperative side, while sugarcane farmers on the private side seem to be more literate. A strong and consistent difference is that private mills seem to be located farther from farmer's plots; to the extent that mills find it easier to provide services to farmers that are close by, this would bias us against finding results in favor of private mills overall.

5.5 How is Overall Welfare Affected?

Finally, we consider the effects on overall welfare of farmers. Sugarcane is an extremely lucrative cash crop. Farmers may choose not to plant it if they have no source of irrigation, or are liquidity constrained and cannot afford the upfront costs of seed and fertilizer, or fear that sugar mills may not purchase their cane or hold them up ex post. Therefore if poorer farmers are indeed able to plant cane, this could have significant effects on their overall income and consumption.

The fact that poorer farmers grow sugarcane on the private side does appear to have some effect on their incomes (Table 8). Once we control for land owned, income, harvest income, and consumption seem to be higher on the private side of the border (only the last result is statistically significant). Moreover, land-poor farmers on the private side of the border seem to be better off in terms of both income and consumption than their counterparts on the cooperative side. This set of results is particularly important, since rhetoric often argues that cooperatives and nationalized firms are set up in order to help poorer farmers.

6 Conclusion

This project attempts to step back from theory and ask a simple question: does organizational form matter for firm behavior? The uniqueness and simplicity of the situation - where we see dissimilarly governed firms performing the same economically significant yet simple activity in the same place at the same time - allows us the opportunity to answer this question.

We find evidence consistent with the importance of ownership structure for economic outcomes: private mills encourage sugarcane production. Farmers are more likely to have cultivated sugarcane on the private side of the border, and devote a larger proportion of their land to sugarcane. Further, we find that the effect is concentrated on farmers that own less land. Delving deeper into the data, we find that private mills appear to provide more loans for poorer farmers, thereby encouraging them to cultivate cane. Consumption is also relatively higher for poorer farmers living on the private side of the border. Since all of these analyses control for the village pair - that is, two villages on either side of the border - we ensure that these results are not driven by differences in local conditions.

Contrary to popular perception, it does not seem as though the monopoly power wielded by private mills hurts poor farmers, nor does it lead to under-provision of sugarcane. Given these facts, it appears as though various state governments' policies to run publicly owned mills and/or to massively subsidize cooperative mills are unnecessary. Given the high costs - one estimate puts the state government of Maharashtra's guarantees to be paid to mill at Rs. 4000 million - these policies seem particularly indefensible.

The main mechanism for encouraging sugarcane production appears to be loans. Sugarcane has a yearly harvest, hence the income stream of its farmers is lumpy, and providing loans can ameliorate cash flow constraints and encourage productive activities. However, private mills seem to be just as good at making these loans as cooperate and public mills, even without access to the massive agricultural credit flows that cooperative and public mills enjoy. Given that subsidized agricultural credit tends to be politically motivated and often wasted (Cole 2010), perhaps these policies should be abandoned as well.

The lessons from this study are applicable to various other realms where governments feel forced to intervene in agricultural markets in developing countries due to the threat of market failure. These interventions are costly, and the benefits of the intervention are likely to be captured by special interests. Therefore firm empirical evidence on the productivity or equity gains of these interventions is essential before they proceed.

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Details of Satellite Analysis Procedure

Below is the step-by-step description of the procedure used to determine the proportion of sugarcane grown in border areas. Python scripts available on request.

1. Convert Red and Near-Infrared Band satellite image into vegetation Index (NDVI): As noted above, the Normalized Difference Vegetation Index (NDVI) transforms the near-infrared (NIR) and red wavelengths of the satellite images into a single dimension ranging from -1 to 1 according to the simple formula below:

$$NDVI = \frac{NIR - Red}{NIR + Red} \tag{.1}$$

   We use this formula to convert the following six images from Satellite IRS-P6 taken in October 2010 (first number denotes flight path, second number denotes image row) – 100-66, 101-65, 101-66, 102-64, 102-65, 102-66 – over Tamil Nadu.

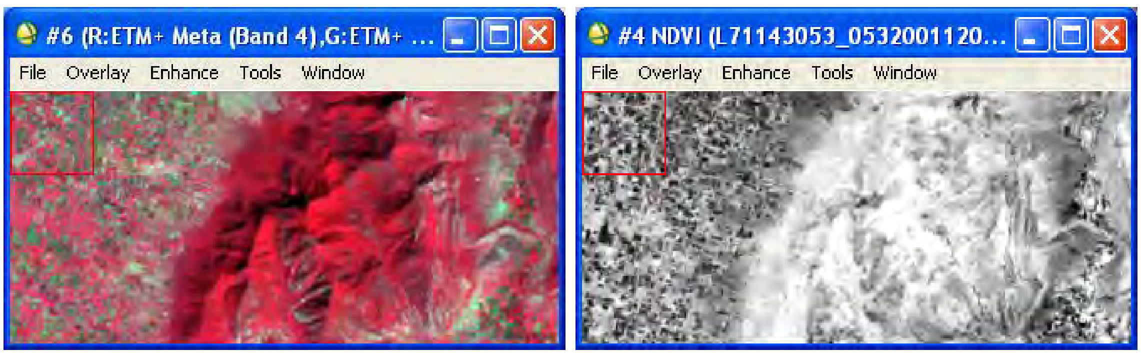

Figure 1: Raw image converted to NDVI

2. Calibrate NDVI values of sugarcane using GPS coordinates of actual fields: We captured the GPS coordinates and noted the current growing crop of 203 fields in border areas. Overlaying these fields on the NDVI images, we determined the NDVI ranges, by image, of fields growing sugarcane. We repeated this exercise for all observed crops.
3. Classify NDVI images into sugarcane/non-sugarcane based on these values: Using the NDVI range for sugarcane for each image observed above, we classified the images into pixels that represented sugarcane and those that did not. We also repeated this exercise for each observed crop.
4. Restrict images to positive NDVI values for vegetated areas: Restricting the coverage of images to positive NDVI values, as noted above, determines land that is covered with vegetation. In addition, this restriction also automatically excludes cloud cover and water bodies, since these have negative NDVI values.
5. Overlay border areas on classified sugarcane and vegetated area images to determine proportion cane by village: Finally, we overlay the GIS maps of border areas on the classified sugarcane and vegetation images, and count the number of pixels per village that are classified as sugarcane, other planted crops, and all vegetation respective. Note that the same border area may be covered by multiple images,

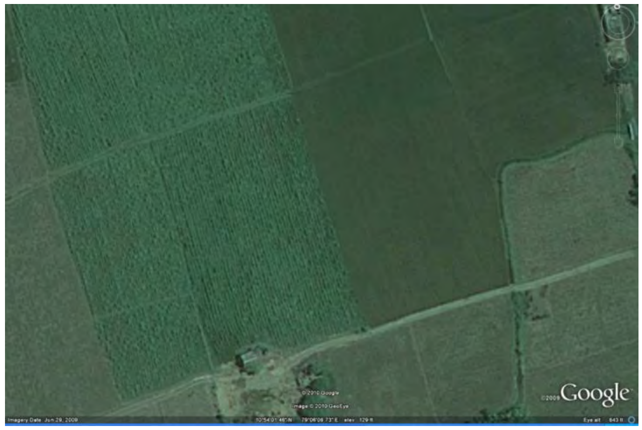

Figure 2: Photo Showing Distinct Sugarcane Field on Right

since there is some overlap between the vertical paths that the satellite travels on. We included all observations as long as the image covered both sides of the border area in its entirety, and included image fixed effects since the NDVI ranges will differ by image due to atmospheric variance.

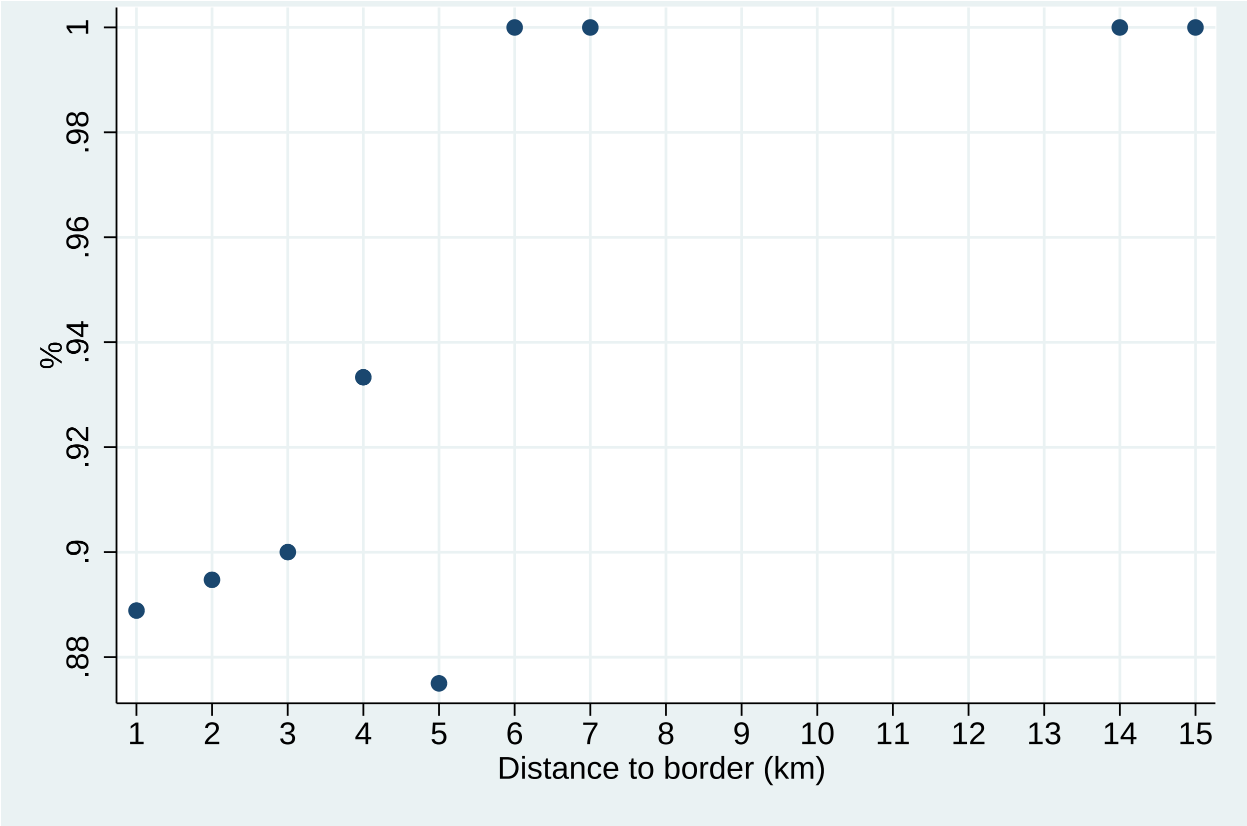

Figure 3: Proportion of Farmers Selling Exclusively to Own Mill

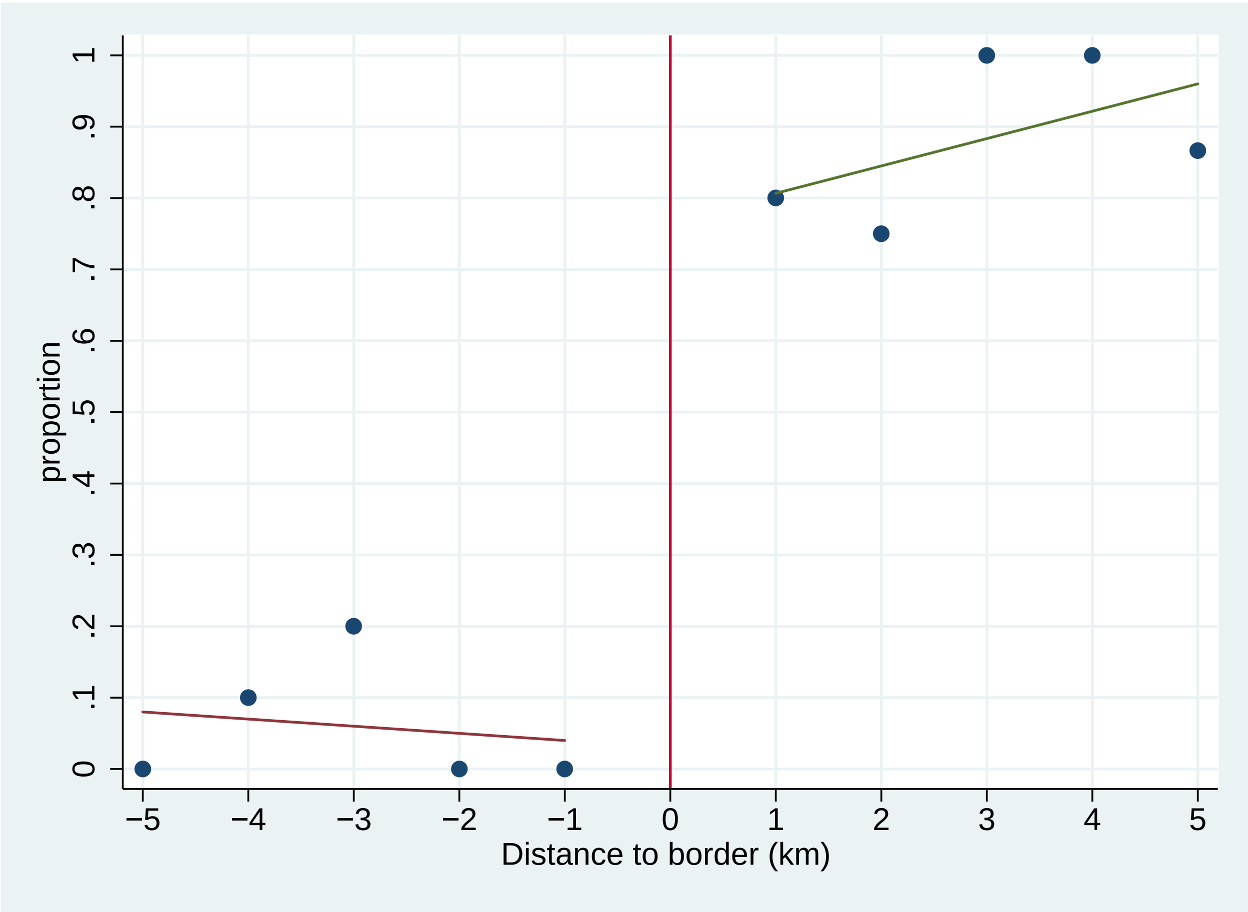

Figure 4: Proportion of Farmers Selling to Mill B

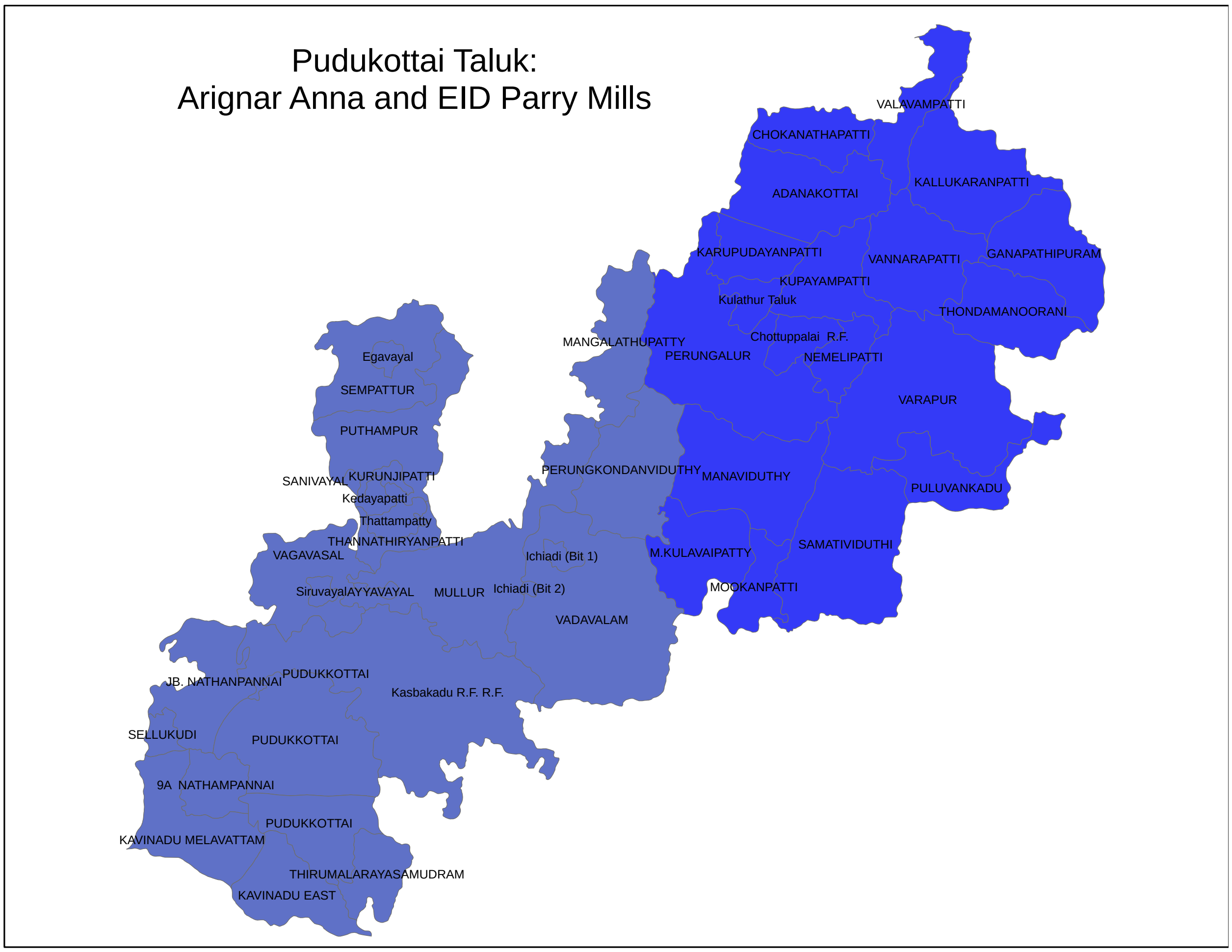

Figure 5: Sample Border Area within Taluk (sub-district)

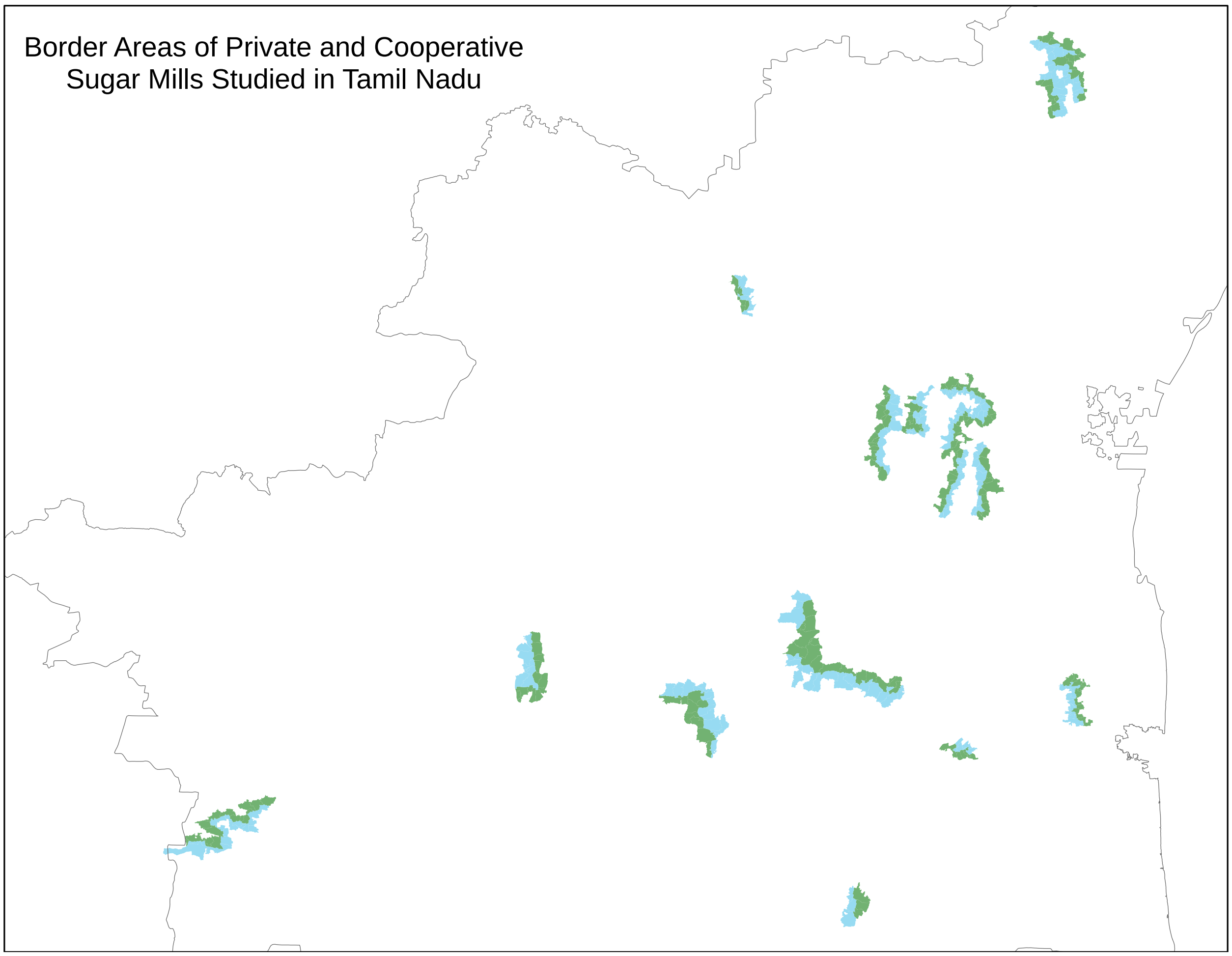

Figure 6: Border Areas in Tamil Nadu

Areas in dark green belong to cooperative/government mills, while those in light blue belong to private mills.

Figure 7: Sugarcane vs Rice plants

Table 1: List of Sugar Mills in Tamil Nadu

Mill	Type	In Sample?	New mill?
Amaravathy (Krishnapuram)	Coop	Yes	No
Ambur (Vadapudupattu)	Coop	No	No
Arignar Anna (Kurungulam)	Public	Yes	No
Banniyariamman (Sathiyamangalam)	Private	Yes	No
Chengalrayan (Periyasevalai)	Coop	Yes	No
Cheyyar (Anakavoor)	Coop	No	No
Dhanalakshmi Srinivasan	Private	Yes	Yes
Dharani Unit I	Private	No	No
Dharani Unit II (Polur)	Private	No	No
Dharani Unit III	Private	Yes	Yes
EID Parry (Nellikuppam)	Private	No	No
EID Parry (Pettavaithalai)	Private	No	No
EID Parry (Pudukkottai)	Private	Yes	No
EID Parry (Pugalur)	Private	Yes	No
Kallakurichi I (Moongilthuraipattu)	Coop	Yes	No
Kallakurichi II (Kachirapalayam)	Coop	Yes	No
Kothari	Private	No	No
KRR Ramasamy (Thalaignairu)	Coop	Yes	No
MRK (Sethiathope)	Coop	No	No
National (B. Mettupatti)	Coop	No	No
Perambalur (Eraiyur)	Public	Yes	No
Ponni (Odapalli)	Private	Yes	No
Rajshree Unit I (Varadaraj Nagar)	Private	No	No
Rajshree Unit II (Mundiyampakkam)	Private	No	No
S.V. Sugars (Palayaseevaram)	Private	Yes	No
Sakthi (Sakthinagar)	Private	No	No
Sakthi (Sivaganga)	Private	No	No
Salem (Mohanur)	Coop	Yes	No
Shree Ambika (Pennadam)	Private	No	No
Shree Ambika (Thugili)	Private	Yes	No
Subramania Siva (Gopalapuram)	Coop	Yes	No
Thiruarooran (A.Chithoor)	Private	Yes	No
Thiruarooran (Thirumandangudi)	Private	Yes	No
Tirupattur (Kethandapatti)	Coop	Yes	No
Tiruttani (Tiruvalangadu)	Coop	Yes	No
Vellore (Ammundi)	Coop	Yes	No

Table 2: Summary Statistics

	Coop/Government			Private		
	Mean	SD	N	Mean	SD	N
Texture	2.35	1.32	77	2.64	1.34	69
Conductivity	.195	.231	77	.144	.136	69
Nitrogen	268	83.7	77	274	218	69
Phosphorus	48.4	83.5	77	56.5	94.5	69
Potassium	191	102	77	235	208	69
Acreage	5.23	8.14	603	6.81	15.2	614
Acres owned	4.76	7.5	603	6.3	15	614
Acres rented	.471	1.91	603	.505	3.19	614
Land value	71,791	254,522	585	75,102	278,466	593
Irrigated	.349	.477	603	.289	.454	614
Mill distance	36.8	17.7	603	48.2	33.7	614
Literacy	.722	.448	602	.701	.458	606
Grew cane recently	.278	.448	599	.284	.451	604
Grow cane now	.244	.43	589	.269	.444	593
Cane acreage	.31	1.04	603	.71	5.59	612
Apply fertilizer	.446	.498	210	.364	.482	222
Apply pesticide	.198	.399	210	.163	.37	222
Paid on time	.935	.248	95	.766	.426	78
Cutting delayed	.842	.367	100	.849	.36	84
Yield	37	11.7	105	36.4	14.6	86
Price	1,553	353	101	1,523	336	86
Loans	96,450	181,069	603	83,905	137,222	614
Mill loans	11,750	44,291	596	9,564	38,535	610
Ln Income	12.4	.872	596	12.2	.852	604
Ln Consumption	10.9	.553	589	10.9	.546	603
Ln Havest Income	11	1.09	550	10.8	1.09	558

Probability weighted

Table 3: Soil Quality Does Not Vary Across Borders

	(1) Texture	(2) Conductivity	(3) Nitrogen	(4) Phosphorus	(5) Potassium	(6) ph
Private	.229	-.00313	16.9	12.4	8.1	.0456
	(.148)	(.0152)	(32.8)	(8.02)	(28.3)	(.122)
Observations	146	146	146	146	146	146
R^2	0.448	0.469	0.138	0.703	0.255	0.480

This table presents regressions of various indicators of soil quality on an indicator for being on the private side of the border ("Private"). "Texture" refers to the size of the grain of soil. "Conductivity" is the electrical conductivity measured in deci-Siemens/meter; range is .01-1.39. "Nitrogen" is the kg/hectare content of nitrogen; range is 70-1989. "Phosphorus" is the kg/hectare content of phosphorus; range is 8-455. "Potassium" is the kg/hectare content of potassium; range is 35-1456. "Ph" measures acidity/alkalinity; it ranges from 1-14. All regressions include indicators for village pairs. Standard errors clustered at the mill level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Crops Planted as Viewed from Satellites

	(1) Cane	(2) Planted	(3) Cane/Planted
Private	.023*	.016*	.016*
	(.013)	(.0089)	(.0084)
Observations	306	306	304
R^2	0.907	0.720	0.927

The dependent variable in column 1 is the proportion of land which corresponds to NDVI values representative of sugarcane. In column 2, it is the proportion of land which corresponds to NDVI values of all observed crops. In column 3, it is the amount of land corresponding to NDVI values of sugarcane divided by the amount of land which corresponds to NDVI values of all observed crops. The main independent variable is an indicator for being on the private side of the border ("Private"). All regressions include indicators for mill border pairs, as well as indicators for each different satellite image, and an indicator for new mills. Standard errors clustered at the mill level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Do Private Mills Encourage Sugarcane Production?

	Grew Cane Recently		Grows Cane Now		Proportion Cane	
	(1)	(2)	(3)	(4)	(5)	(6)
Private	.0197	.0184	.0287	.0302	.339*	-.98
	(.0278)	(.0383)	(.0222)	(.0312)	(.171)	(.99)
Acreage		.00455		.00375		.00696
		(.00288)		(.00283)		(.0121)
Private*Acreage		-.000527		-.000867		.21
		(.00397)		(.00338)		(.16)
Observations	1203	1203	1182	1182	1215	1215
R^2	0.390	0.402	0.401	0.408	0.069	0.352

Columns 1-2 are linear probability estimations of whether respondent has ever grown sugarcane in the last 5 years, columns 3-4 are linear probability estimations of whether the respondent is currently growing sugarcane, and columns 5-6 are estimations of the proportion of land devoted to sugarcane, all on on an indicator for being on the private side of the border ("Private"). "Acreage" refers to the number of acres owned or rented. All regressions include indicators for village pairs as well as non-parametric controls for distance from the mill. Standard errors clustered at the mill level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Mill Assistance

	Total Loans		Mill Loans		Cane Price		Paid on Time		Cutting Date Delay	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Private	-6,302	15,096	-310	4,124	-56.9	12.1	-.158	-.181	-.185	-.257
	(8,463)	(17,837)	(2,120)	(3,534)	(107)	(70)	(.136)	(.147)	(.161)	(.25)
Acreage		4,755		1,128**		3.38		-.00964		-.00548
		(2,827)		(486)		(2.78)		(.00601)		(.00333)
Private*Acreage		-4,172		-887*		-6.56*		.00928		.00871
		(2,844)		(506)		(3.09)		(.00773)		(.00552)
Observations	1217	1217	1206	1206	187	187	173	173	184	184
R^2	0.069	0.097	0.117	0.144	0.331	0.336	0.557	0.569	0.281	0.290

This table presents regressions of mill financial relationships with farmers on an indicator for being on the private side of the border ("Private"). "Total loans" is the household's total debt. "Mill loans" refer to the total amount lent by the sugar mill. "Cane price" is the price per ton of cane paid by the mill. "Paid on time" refers to whether the mill paid the farmer on time for sugarcane delivered. "Cutting date delay" is the delay, in months, between farmers' ideal harvesting dates and the dates assigned to them by the mill. All regressions include indicators for village pairs as well as non-parametric controls for distance from the mill. Standard errors clustered at the mill level in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 7: Farmer Characteristics

	Acres Owned		Acres Rented		Land Value		Irrigation		Distance to Mill		Literacy	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Private	.995*	3.21	.0316	.0681	16,844	12,423	-.0197	.0203	17.3**	14.7***	-.00685	.089*
	(.509)	(1.97)	(.0961)	(.125)	(13,508)	(8,804)	(.0246)	(.0257)	(6.28)	(4.72)	(.0332)	(.0446)
Observations	1,217	492	1,217	492	1,178	479	1,217	492	1,217	492	1,208	491
R-squared	.0739	.0917	.038	.058	.258	.152	.674	.595	.707	.647	.0917	.12
Farmer Sample	All	Cane	All	Cane	All	Cane	All	Cane	All	Cane	All	Cane

This table presents regressions of farmer characteristics on an indicator for being on the private side of the border ("Private"). "Acres owned" is the total amount of land owned by the household. "Acres rented" is the total amount of land rented or sharecropped. "Land value" is the average value per acre of owned land. "Irrigation" refers to whether the sampled plot was on irrigated land. "Distance to mill" is the distance from the farmers' plots to the sugar mill. "Literacy" refers to whether the respondent can read. All regressions include indicators for village pairs. Standard errors clustered at the mill level in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: Farmer Welfare

	Ln Income		Ln Farm Income		Ln Consumption	
	(1)	(2)	(3)	(4)	(5)	(6)
Private	-.0719	.0585	-.0132	.0776	.0387	.111*
	(.0463)	(.0788)	(.0677)	(.136)	(.0338)	(.0574)
Acreage		.0192		.0289*		.0136*
		(.0123)		(.0165)		(.00688)
Private*Acreage		-.0238*		-.02		-.0137*
		(.0129)		(.0198)		(.00708)
Observations	1200	1200	1108	1108	1192	1192
R^2	0.153	0.172	0.179	0.205	0.123	0.142

This table presents regressions of overall farmer outcomes on an indicator for being on the private side of the border ("Private"). "Ln income" is log overall income over the previous year. "Ln farm income" is log income from crop harvests over the last year. "Ln Consumption" refers to total regular consumption over the last year. All regressions include indicators for village pairs as well as non-parametric controls for distance from the mill. Standard errors clustered at the mill level in parentheses. *** p<0.01, ** p<0.05, * p<0.1