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Institutional Arrangements Between Sugarcane Growers and Millers in Uganda and Implications for Grower Productivity and Profitability

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ABSTRACT

This study investigates sugarcane grower productivity and profitability in Uganda and whether and how they are influenced by institutional arrangements between sugarcane growers and millers. Analysis is based on primary data collected from 983 sugarcane growing farm households in the three main sugarcane-producing regions of Busoga, Buganda, and Bunyoro. The study finds evidence that use of key quality inputs and crop and soil management practices are associated with higher farmer cane yield. There is also a clear trade-off (an inverse relationship) between the level of competition between large and small cane mills in a region and the level of grower-miller coordination of market assurance and input access, as embodied by institutional arrangements between growers and millers. Better grower-miller coordination was associated with better grower access to a market for mature cane and access to key inputs and services such fresh, quality cane seedlings and cane-specific extension. In turn, better market access and higher yields are associated with higher farmer cane profits per acre. Revision of the existing policy framework and enabling environment of cane production and processing in Uganda is needed to resolve several contentious policy issues and provide public sector oversight of grower-miller relations and better coordination of the national supply of and demand for cane. Success of this policy reform is vital for the cane industry to remain both financially sustainable and inclusive.

Keywords: Crop productivity, agricultural technology, smallholder farmers, market participation, transactional relationships

JEL Classifications: Q00, Q13, Q12; Q10; L14

EXECUTIVE SUMMARY

This paper uses descriptive and econometric analysis of household survey data from the three main cane-growing regions of Uganda to provide empirical evidence of the key factors associated with improvements in grower cane productivity, the extent to which institutional arrangements between growers and millers influence growers' access to inputs and market assurance, and whether and how whether institutional arrangements influence cane growers' productivity and profitability. This analysis uses primary data collected from 931 cane growing households in the Busoga, Buganda, and Bunyoro regions of Uganda in November/December 2021 as well as qualitative focus group discussions with cane growers and key informants representing cane mills, cane grower associations, and government officials.

Productivity and input use

There are large differences in average and median farmer cane yield across the three regions. For example, the average cane yield of 50 tons/acre in Bunyoro is 31 percent higher than Buganda's mean of 38 tons/acre, and 84 percent higher than Busoga's mean of 27 tons/acre. There are also significant regional differences in input use, with Buganda and Bunyoro typically having more prevalent use of inputs and access to extension. For example, 45 and 34 percent of growers in Buganda and Bunyoro, respectively, used cane seedling from a large mill – compared to only 1 percent of plots in Busoga. Likewise, nearly half the plots in Bunyoro received inorganic fertilizer, compared with 28 percent in Buganda and 16 percent in Busoga. Finally, 64 and 68 percent of plots in Buganda and Bunyoro, respectively, were owned by farmers that had received a cane-specific extension visit in 2021 or prior, compared with 25 percent in Busoga.

Econometric analysis of cane yield finds four explanatory variables that have a statistically significant positive association with cane grower yield that are also within a farmer's control, including: use of cane seedling from a large mill, having a cane crop in ratoon, application rate of inorganic fertilizer, and total labor days used per acre. First, use of cane seedling from a mill is associated with 25 percent higher yield, on average, than use of seedling from another source – such as own seedlings or those purchased from a neighbor, farmer group, or trader. This result is consistent with key informant reports that fresh, quality seedlings provide better cane yield than seedlings that have been recycled for many harvests, and that many farmers have been recycling their seed for too long or buying over-recycled seedlings from others.

Second, a cane plot that is currently in ratoon has a 31 percent higher yield on average compared with plots not being ratooned. However, because ratooning is not expected to improve cane yield compared with a first cane harvest, it appears that the dummy variable used to indicate that a plot is ratooned is functioning as a proxy measure of farmer use of good crop, plot, and soil management practices. The survey data provides support for this interpretation as farmers with a cane plot in ratoon used an average of 4 of the 6 most recommended management practices for cane production. In addition, separate regression analysis of ratooned plots that includes a count variable "number of

practices used on the plot" finds that adopting an additional ratoon management practice is associated with 4 percent higher cane yield. That said, the magnitude of the positive yield gain from use of good management practices may be overstated to some degree due to the study's inability to fully observe and thus control for use of good management practices, as well as farm management skill.

Third, inorganic fertilizer has a statistically significant and positive association with yield, though the magnitude is small – as a 10% increase in the fertilizer rate is associated with only a 0.8 percentage point increase in yield. While this cane-fertilizer response rate doubles for farmers that also use quality seedlings from a mill, the magnitude of this association is still relatively small. Fourth, a 10 percent increase in labour is associated with a 2.1 percent increase in yield. This may be related to yield gain from implementing labor intensive plot management practices, timely weeding, or the ability to harvest quickly.

Fifth, even after controlling for input use and a range of other factors known to influence cane yield at the plot, household, and community level, Bunyoro cane growers still obtain 69 percent higher cane yields on average than those in Busoga and Buganda -- and the factors behind this additional yield difference are not observed. However, the two most likely explanations are that Bunyoro farmers have more consistent and better application of recommended crop, plot, and soil management practices and use of higher quality seedling material and inorganic fertilizer. This explanation is due to the fact that most farmers in Bunyoro are contracted with Kinyara and Hoima large mills, and under their contractual agreements, employees of the large mills perform land preparation, planting, input application, weeding, and harvest on contracted farmer cane fields – not the farmers themselves. Such employees and their supervisors would likely have better knowledge of good management practices and the equipment to implement them. Further research is warranted to better understand and explain why the yield gap between the Bunyoro region and Busoga and Buganda regions is so large, even after controlling for input use.

Sixth, access to quality extension can facilitate farmer adoption of good management practices. For example, a farmer-plot that has received a cane-specific extension visit in 2021 or before from a mill is associated with an additional 0.8 management practices adopted, on average, holding other factors constant, while a cane-specific extension visit from another source is associated with an additional 0.9 practices adopted.

Institutional arrangements, market assurance, and access to inputs and extension

In Uganda, there is a clear trade-off (an inverse relationship) between the level of competition between large and small mills in a region and the level of grower-miller coordination of market assurance and input access. Market assurance is a joint grower-miller commitment to the sale/purchase of a grower's cane as indicated by the "registration" of a grower's cane plot by a mill, while input access consists of "aid", such as quality inputs and/or extension, possibly on credit, that is offered by mills to select registered growers. For example, the region with the highest competition

between mills (Busoga) had the lowest grower-miller coordination, as only 8 percent of growers were registered-aided and 21 percent were registered. The region with more moderate miller competition (Buganda) had better coordination (57 percent of growers registered-aided and 8 percent registered), while the region with virtually no miller competition (Bunyoro) had much higher grower-miller coordination (86 percent of growers registered-aided and 1 percent registered). Likewise, the share of spot sellers – growers with no coordination with large or small mills for market assurance of input access prior to cane maturity -- is highest in the region with most competition (Busoga, at 65 percent) and lowest in the region with minimal competition (Bunyoro, at 11 percent).

Second, better grower-miller coordination was associated with better grower access to key inputs and services and with a higher likelihood of having a ratooned plot in 2021. For example, among plots managed by registered-aided farmers, 32 percent used cane seedling from a large mill, 67 percent received an extension visit from a large mill in 2021 or before, and 74 percent had a ratoon crop. By contrast, among plots managed by spot seller farmers, only 3 percent used cane seedlings from a mill, 21 percent received an extension visit from a large mill, and 57 percent had a ratoon crop.

Third, better grower-miller coordination was also associated with much better market access for mature cane in 2021. For example, the region with the highest coordination, Bunyoro, had the highest share of mature plots that were harvested and sold (59 percent) in 2021 and the lowest share of plots that were sold unharvested (i.e. at a very low price) at only 0.2 percent. By contrast, the region with the lowest level of coordination, Busoga, had the lowest share of mature plots that were harvested and sold (36 percent) and the highest share of plots that were sold unharvested (21 percent). Nevertheless, farmers in all three regions were adversely affected by the significant oversupply of cane in 2021 as demonstrated by the fact that 41 to 44 percent of plots at or beyond maturity in 2021, depending on region, were not harvested due to lack of a buyer and/or a reasonable cane price offer. This oversupply represented a failure of adequate coordination by the public sector and the industry of the supply of and demand for cane at both regional and national levels.

Profitability

There was a considerable difference in mean and median cane profits per acre by region in 2021, as cane profit per acre in Buganda (1,241,772 Ush/acre) was nearly double the mean from Busoga (683,668 Ush/acre). Profit per acre in Bunyoro was even higher than that of Buganda, though it is not cited here given uncertainty regarding the likely underreporting of costs of production in Bunyoro.

These regional differences in profitability were driven primarily by differences in levels of grower-miller coordination, as better coordination was associated with better market access and input access. For example, plots of farmers that harvested and sold cane to a mill or another buyer – i.e.

good market access -- earned an average profit of 1,423,440 Ush/acre compared with an average profit/acre of -296,662 Ush/acre (a loss) for farmers who were forced to sell unharvested cane in their field to a buyer – i.e. poor market access. The gross revenue earned by farmers selling unharvested cane was so low that such sales appear to have been made in financial desperation. These were likely farmers with cane many months beyond maturity who could not afford to wait any longer for a buyer, so they decided to cut their losses and sell the cane for whatever they could get, if only to free up the land for a different crop. This highlights just how important market access is to growers, particularly during a period when cane supply significantly exceeds demand.

Differences in coordination by region also influenced the average cane prices received by growers received who were able to harvest and sell to a mill or other buyer. For example, while the large mills in Busoga and Buganda paid similar cane prices on average of 95,614 Ush/ton, the mean cane price in Busoga (80,126 Ush/ton) was about 18 percent lower than in Buganda (95,421 Ush/ton). The reason is that 30 percent of Busoga growers sold their cane to a trader, whose average cane price was 75,113 Ush/ton, and 12 percent sold to a transporter, whose average price was even lower at 25,420 Ush/ton. By contrast, 12 percent of Buganda growers sold to a trader, and none sold to a transporter. Higher average cane prices and cane yields resulted in significantly higher gross revenue per acre for Buganda growers compared with Busoga, though Buganda's higher costs of production per acre tempered this advantage to some extent.

Policy implications

The evidence in this study shows how important strong coordination between growers and millers are for market assurance and grower access to quality inputs and extension. It also demonstrates that better access to and use of quality inputs and crop, plot, and soil management practices are associated with higher cane yield, and that better market access for growers is associated with higher farmer cane profits/acre. Fortunately, the oversupply of cane in 2021 eventually fell back to the level demanded in 2022, millers subsequently began to raise their purchase prices and buy cane again, and growers with old cane were eventually able to sell it (reportedly). Yet, the policy and enabling environment framework that enabled such an imbalance in grower-miller coordination of cane supply and demand to occur between 2018 and 2021 – along with significant financial losses for many growers – is still in place. That framework also enabled a near collapse of large mill provision of quality seedlings, inorganic fertilizer, and extension on credit to registered-aided growers in Busoga, and this appears to explain in part why their yields are considerably lower than those of Buganda and Bunyoro.

In response to the unprecedented financial and coordination challenges faced by the industry in the past few years (Mbowa et al, 2023), government and industry stakeholders are reviewing that framework in the recognition that it needs to be updated to reflect structural and institutional changes in the industry since the adoption of the 2010 National Sugar Policy and The Sugar Act of 2020 (Mbowa et al., 2023). The revised policy framework and enabling environment will require not only resolution and clarification of several contentious policy issues but also public sector oversight

of grower-miller relations and better coordination of the national supply of and demand for cane (ibid, 2023). The success of this policy reform and implementation process is paramount if the industry is going to remain both financially sustainable and inclusive, as the outgrower scheme is the predominant way in which growth of the sugar industry can promote rural transformation and improve rural household incomes.

In response to the unprecedented financial and coordination challenges faced by the industry in the past few years (Mbowa et al, 2023), government and industry stakeholders are reviewing that framework with the recognition that it needs to be updated to reflect structural and institutional changes in the industry since the adoption of the 2010 National Sugar Policy and The Sugar Act of 2020 (Mbowa et al., 2023). The revised policy framework and enabling environment will require not only resolution of several contentious policy issues but also public sector oversight of grower-miller relations and better coordination of the national supply of and demand for cane (ibid, 2023). The success of this policy reform and implementation process is paramount if the industry is going to remain both financially sustainable and inclusive, as the outgrower scheme is the predominant way in which growth of the sugar industry can promote rural transformation and improve rural household incomes.

While farmer use of fresh, quality seedlings is vital to improving their cane productivity, a minority of plots (30 to 40 percent) used them in Buganda and Bunyoro in 2021 and only 3 percent in Busoga. Nearly all seedlings provided by a mill are from the large mills, which is likely due to the fact that propagation of quality seedlings entails an upfront investment that is far too large for small mills given their lack of a nucleus estate. However, not all growers would or could obtain such seedlings via registration and aid with a large mill, and small mills are not able to provide this input. Because cane seedlings can be recycled by growers, agricultural research to develop and extension services to disseminate and promote them have characteristics of a public good. Given significant funding challenges faced by the National Agricultural Research Organization (NARO) of Uganda and the relatively small number of cane growers relative to those producing food crops, is it probably not realistic to expect the public sector to do much varietal work on cane. However, there are institutional modalities that have worked for other cash crops where a small levy (tax) on growers and millers is collected by the industry or government and reinvested back into development programs for the industry. Assuming an organization could be staffed and government by representatives of growers, millers, and government, it could potentially contract out varietal development and propagation to large millers and even large cane growers and be funded by the industry levy. Another reason that varietal development beyond that controlled by large mills is needed is because, in recent years, the large mills have adapted some 12-month cane varieties for use on their nucleus estates, but they have not shared any of this material with growers. Grower access to a shorter duration variety could theoretically improve their incomes and income stability over time by enabling them to harvest cane more frequently.

Second, better coordination between farmers and quality, cane-specific extension services are vital for improving farmer cane productivity over time. The public agricultural extension system in Uganda is woefully underfunded for its existing crop mandate, and training public extensionists in cane productivity issues would not likely make sense anyway from a cost-benefit perspective, given how few cane growers there are compared with growers of food crops. Most cane-specific extension comes from large mills. This implies that a policy environment that improves coordination between farmers and large mills is a cost-effective way for cane growers to receive quality, cane-specific extension advice. However, because not all growers would or could be registered-aided with a large mill, a cane industry development fund could provide financing to grower associations, who could in turn hire private sector extensionists and coordinate provision of extension to farmers not registered-aided by a large mill. That said, this would be a significant challenge in practice as cane grower associations in these regions are quite weak currently, and the history of public sector interventions to build the capacity of grower associations has generally not been positive, though Tanzania has one cane grower association that manages to provide transportation services for grower delivery of harvested cane to mills.

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ACRONYMS AND ABBREVIATIONS

CF	Contract Farming
EPRC	Economic Policy Research Center (Uganda)
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
GDP	Gross Domestic Product
IA	Institutional Arrangement
IFPRI	International Food Policy Research Institute
KII	Key Informant Interview
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries of Uganda
MT	Metric Tons
MTIC	Ministry of Trade, Industry and Cooperative of Uganda
MSU	Michigan State University
NGO	Non-Governmental Organization
OLS	Ordinary Least Squares
PRCI	Feed the Future Innovation Lab for Food Security Research, Capacity, and Influence
UBOS	Uganda Bureau of Statistics
USH	Ugandan Shillings

I. Introduction

There has been a long-standing debate on whether smallholder participation in contract farming (CF) arrangements results in positive or negative changes in household welfare in practice. For example, many recent empirical studies find that CF can have positive impacts on welfare indicators such as farm productivity, household income, and food security. (Bernard et al., 2019; Harou, Walker, & Barrett, 2017; Maertens & Velde, 2017; Mishra et al., 2018b; Dubbert, 2015; Bellemare, 2012; and Miyata et al., 2009). In addition, an extensive review of literature by Otsuka, Nakano & Takahasi (2016) found that in most cases, CF improved farmers' income by introducing them to higher-return crops and yield-enhancing production technologies, yet they noted that CF alone was not always sufficient to lift the smallest farmers out of poverty – complementary public policies, investments and interventions were sometimes required. Yet, some studies continue to find evidence that CF does not improve the wellbeing of participating smallholders and further argue that their land and labour can be exploited by contracting agribusiness firms or processors (Ragasa, Lambrecht & Kufoalor, 2018; Abdulai & Al-hassan, 2016; Mwambi et al., 2016). In addition, a recent review of CF studies argued that the evidence remains inconclusive because too few of the existing studies that claim to provide a causal link between participation in a CF scheme and farmer outcomes have not used data and/or methods sufficient to make that claim (Bellemare, 2018). From the perspective of New Institutional Economics, it should not be surprising that evidence on smallholder outcomes from participation in CF arrangements is mixed, given that the success or failure of an outgrower CF scheme and the distribution of benefits and costs between outgrowers and firms/processors depend on several factors that vary by the local context. Among these factors are the nature of the crop, the nature of institutional arrangements between growers and firms/processors (Poulton, 2004), and the extent of public sector oversight and enforcement of those arrangements (Mbowa et al, 2023).

Sugarcane is a high-value crop that can improve growers' farm income and access to yield-enhancing crop production technologies and management practices, which can subsequently improve their crop productivity and food security. It can also generate on- and off-farm employment and value addition within the rural economy. As in most of Africa, sugarcane production in Uganda is undertaken on both nucleus estates owned by large sugarcane mills and by outgrowers, which include small, medium, and large-scale farmers (Okumu, 2015). Continued participation of outgrowers in the sugarcane industry is vital to the government's economic development objectives in sugarcane-producing regions of the country, as it is the primary means by which the sugarcane subsector can generate inclusive rural economic growth and reduce rural poverty and food insecurity in those areas (Mbowa et al., 2023).

Uganda's sugarcane subsector has grown consistently since it was liberalized in 1986, particularly over the past 20 years as cane production increased from 1.5 million MT (metric tons) in 2000 to 5.8 million MT in 2020. This increase was almost entirely driven by an increase in cane acreage (i.e. extensification) from approximately 20,000 ha in 2000 to over 81,000 ha in 2020 (FAOSTAT, 2021). Two main factors drove this increase in cane acreage: a continued increase in domestic demand for

sugar and sugar byproducts, and the entry of 12 new small-scale mills to the sugarcane milling industry between 2005 and 2018, all of which located in areas near the existing three large-scale mills (Mbowa et al, 2023). Ensuing competition between large and small mills for cane from farmers and increasing demand for sugar significantly increased the demand for cane, leading to significant increases in the cane price. This drew many new farmers into cane production and led some existing growers to expand their cane acreage.

Despite this impressive growth, two main challenges have persisted or developed over this 20-year period that threaten the long-term sustainability and viability of both the outgrower scheme and the sugarcane subsector. The first is that farmer cane productivity has not improved since 2000, remaining stagnant at 28 MT/acre - a level well below potential (ibid, 2023). The second is that the expansion or boom period eventually ended in a bust in 2021, due to a steady decline in coordination between growers and millers from 2012 to 2021 and between the supply of and demand for cane at the regional and national levels. This lack of coordination resulted in an oversupply of cane for several years, which resulted in a significant decline in cane prices from 2018 to 2021, when it reached levels at which cane was not profitable for some growers. During this period, some growers suffered significant financial losses, particularly in 2021 when many growers with mature cane could not find a mill willing to buy it. The decline in cane prices and increase in market uncertainty for growers also led 24 percent to abandon cane (ibid, 2023).

While cane prices began to rise again in 2022, the challenge of low farmer cane productivity remains a serious impediment to the profitability of cane production for farmers and the potential aggregate economic benefits and inclusiveness of the outgrower scheme. In addition, the underlying policy and public governance environment that enabled the boom and bust to occur remains the same, though the government is currently reviewing policies and oversight of the cane subsector. Given these two persistent challenges, Ugandan policymakers and stakeholders are concerned about the long-term productivity and profitability of farmer cane production in Uganda.

Despite challenges with a breakdown in coordination through the weakening or abandonment of grower-miller institutional arrangements in the sugarcane industry of Uganda in recent years, without improved grower-miller coordination, small to medium-scale growers are unlikely be able to access or afford the inputs and quality extension advice (Poulton et al., 2004) needed for them to improve their cane productivity and profitability (Mbowa et al., 2023). However, there has been no research to date based on household survey data that has investigated cane grower access to and use of yield enhancing inputs, recommended crop and soil management practices, and access to cane-specific extension in Uganda. Likewise, there is no research to date on the extent to which existing grower-miller IAs improve farmer access to and use of inputs and extension in cane production in Uganda, as predicted by theory and prior research from similar crops in other countries. Finally, there is also no research on the determinants of cane yield in Uganda under farmer management and conditions. Such research is essential given that it is well-known that crop yield response to input use and complementary crop and soil management practices is quite often lower under smallholder farmer

conditions and management as compared with those from carefully controlled yield trials managed by trained agronomists and staff at a public or private agricultural extension station.

Evidence on the three research gaps noted above is needed by policymakers and cane subsector stakeholders to inform the ongoing assessment of the existing policy and governance environment for the cane subsector in Uganda. Findings from research on the questions above may provide information on which inputs and management practices are most likely to improve farmer cane yields, how do farmers obtain them, and to what extent to existing institutional arrangements between growers and millers facilitate farmer access to them. In addition, evidence is needed on cane prices received by growers, their costs of production, the profitability of their cane production, and the extent to which institutional arrangements influence cane prices and costs of production, which, together with farmer yield, determine farmer profitability. It should be noted that while coordination between growers and millers in 2021 was considerably weaker in some areas of Uganda than it had been prior to 2012, this regional variation in the strength of grower-miller coordination is helpful as it provides a natural experiment in which to study the relationship between differences in IAs, farmer access to inputs and extension, and farmer productivity and profitability.

This paper addresses these research gaps by addressing three research questions. First, what are the key factors associated with improvements in grower cane productivity? Second, to what extent do institutional arrangements between growers and millers influence growers' access to inputs, market assurance, their cane productivity? Third, is cane production in Uganda profitable, what factors explain variation in profitability, and what kinds of farmers are more likely to grow cane profitably? This paper also contributes to the debate within international development literature on whether and how CF improves household welfare for participating smallholder farmers.

This study is based on primary data collected from 931 cane growing households in the Busoga, Buganda, and Bunyoro regions of Uganda in November/December 2021 as well as qualitative focus group discussions with cane growers and key informant interviews with large and small cane mills, cane grower associations, and relevant government officials. The study addresses the three research questions using descriptive and econometric analysis of this quantitative and qualitative data.

The rest of this paper is organized as follows. Section 2 provides background on the history of institutional arrangements between sugarcane growers and millers in Uganda and how structural changes in the milling industry affected them. Section 3 then describes the methods and data used to address the research questions. Section 4 provides results of descriptive analysis of cane grower productivity, market access, and input use and Section 5 provides results of econometric analysis of cane grower productivity. Section 6 provides results of descriptive analysis of cane grower profitability, which is followed by conclusions and policy implications in Section 7.

II. Background

Introduction

The physical and economic nature of sugarcane production, harvesting, and milling inherently creates a strong interdependency between the production and processing of sugarcane. These factors explain why a nucleus-outgrower model is used by cane industries in Uganda and throughout Africa to coordinate and manage that interdependency, and why most cane growers in Africa engage in contract farming arrangements with local cane mills (Mbowa et a, 2023). The nature of this interdependency must be understood in order to understand why these cane outgrower schemes and grower-miller institutional arrangements are used in cane industries across Africa and how such arrangements may improve grower access to inputs, extension, and markets, and subsequently, farmer cane productivity and profitability[1].

Physical nature of harvested cane

Harvested cane is highly perishable

About 24 hours after cane is harvested, the extractable sucrose (sugar) content in each ton of harvested cane begins to decline very rapidly. While sucrose is not the only product of potential value from harvested cane[2], it is the most valuable. Subsequently, harvested cane must be transported to a mill and processed within 24 hours of being cut, otherwise its commercial value will decline rapidly. Harvested cane is also very heavy, which means that the unit cost (per ton) per kilometer of transporting it is very high. In addition, the *value-to-weight ratio (value per ton) of harvested cane is quite low*, compared with most crops. The significant weight and low value per ton of harvested cane imply that it is cost-prohibitive for a farmer to transport his/her harvested cane very far – such as to another region of Uganda.

These characteristics of harvested cane have profound implications for the relationship between cane growing farmers and millers (Mbowa et al, 2023). First, cane's highly perishability implies that a cane grower cannot afford to harvest his cane without first obtaining the commitment from a mill to purchase to his cane within a mutually agreeable time-period after the farmer's harvest. Second, the significant weight of harvested cane and its low value-to-weight ratio imply that a grower's only profitable marketing option is to sell his cane to a mill relatively close to his cane field(s). Thus, a cane grower's profitability is highly dependent upon assurance that a nearby mill will purchase his cane within 24 hours of its harvest. A grower who waited to find a buyer only after harvesting his

[1] Section 2 relies upon insights developed by Mbowa et al (2023).

[2] Processing harvested cane produces sucrose and two main by-products, bagasse and molasses. Bagasse is the fibrous material remaining after harvested cane has been crushed, soaked, and squeezed to extract its juice (which contains sucrose). The most economic and typical use of bagasse for mills is to generate steam and electric power for their milling equipment, though it can also be used to produce particle board or paper (Paturau, 1988). Molasses is a by-product of processing raw sugar into refined (white) sugar and can be used as an animal feed or fermented to produce ethyl alcohol, which is used in sanitizers (ibid, 1998). Cane juice, cane syrup, or molasses can be fermented to produce spirits such as rum or gin (ibid, 1988).

cane would lose most if not all of his price bargaining leverage vis a vis a cane mill, as a mill buying agent who decided to act opportunistically would recognize that the farmer would have little choice but to accept an unfairly low cane price, or risk losing the opportunity of earning revenue from the harvested cane. This situation is termed "hold up" in New Institutional Economics, which is a literal reference to being robbed by a thief and having no recourse.

One implication of the strong interdependence between the production and processing of cane is that growers have a strong incentive to enter into a binding arrangement with a nearby mill – either before planting or soon after -- in which the mill provides a commitment to both (a) purchase a farmer's cane when it is mature[3]; and (b) arrange a mutually-agreeable time period during which the mill will purchase his cane. Such an arrangement can protect a farmer from inadvertently finding themselves in a situation in which they are "held up" by a mill (Rogerson, 1992). In exchange, the farmer commits to sell cane harvested from a registered/contracted field to that mill alone (i.e. not to a competing mill). In Uganda, "registration" of a farmer and specific fields or parcels by a mill is intended to provide this market assurance to each party[4]. A second implication is that a mill can only feasibly source an adequate quantity of cane from land that is relatively close to its mill – whether from its own nucleus estate (i.e. plantation) and/or from nearby cane growers. Thus, large-scale mills that are at least partially dependent upon cane input from private growers also have a strong incentive to enter into a binding agreement with nearby outgrowers to provide the mill with input market assurance.

Cane loses extractable sucrose content over time if it remains unharvested after reaching maturity

In practice, a grower will not harvest his cane unless he has secured a commitment from a buyer who agrees to purchase the cane within a day or so of it being harvested. Yet, while cane sugar content does not deteriorate rapidly until it is harvested, once cane reaches maturity (17-18 months after planting for varieties grown by Ugandan farmers), it begins to deteriorate slowly. The implication is that, months before a farmer's cane reaches maturity, farmers who do not have market assurance through "registration" with a mill may find themselves without a buyer for their cane once it reaches maturity. The longer they have to wait until a mill decides to purchase it, the lower the sugar content of their cane will be. As cane ages beyond optimal maturity, the sugar content and weight of the cane declines. Because Ugandan mills approximate the sugar content of any given load of harvested cane based on its weight (Mbowa et al, 2023), farmers who have no buyer until months after optimal harvest time will invariably receive less revenue for their cane, as it will not weigh as much as it would have at 17-18 months.

[3] Cane varieties grown by Ugandan farmers reach maturity about 18 months after planting – the point at which it typically has the maximum quantity of extractable sucrose per ton of cane (Mbowa et al, 2023).

[4] In practice, registration does not appear to have been a legally binding commitment between Kakira or Scoul-Lugazi and their growers but was rather a statement of intent that a mill planned to buy a pre-approved acreage of a grower's cane. With the exception of the 2018-2021 period, registering with a mill did appear to significantly improve the probability that a grower could sell to that mill when their cane was mature, in practice. By contrast, farmers registering with Kinyara had to sign a 24-page legal contract.

There are various reasons why large and small mills may not buy a non-registered farmer's cane upon its maturity: (a) the large mill may prioritize the crushing (processing) of cane from its nuclear estate at that time; (b) large or small mills may not have adequate crushing capacity to meet their commitments to registered growers whose cane reaches maturity at the same time; and/or (c) if there is a regional or national oversupply of cane at any given point in time (as there was in 2021), then unregistered farmers may have to wait many months for a mill to agree to buy their cane.

High and asset-specific fixed costs of entry into the sugarcane processing industry

A private firm that wishes to engage especially in large-scale, commercial sugarcane processing must make a very large fixed (up-front) investment in milling and other processing equipment, a building to house it, and land for both the building and for a plantation (nucleus estate) on which to grow cane (Mbowa et al, 2023). The processing equipment used in large-scale sugar milling is both very expensive and highly specific to its designed tasks, such as: (a) crushing, soaking, and squeezing cane; and (b) processing cane juice into raw sugar; then raw sugar into refined sugar and molasses. Because the value of this equipment for a use other than processing cane is quite low, it can be described as having "high asset specificity" (Williamson, 1975)[5].

To operate profitably throughout the year, a mill requires a minimum quantity of harvested cane from month to month so that gross revenues of milling per week/month are equal to or higher than the mill's monthly and annual operating costs. An implication of the high fixed costs and asset specificity of cane milling equipment and land is that once an agribusiness makes such a large investment, it must be able to profitably operate the mill for many years in order to pay off its fixed costs (repaying any loans they obtained to purchase the land, building, and processing equipment) and pay on-going operating costs each month, while also earning a reasonable return (profit) on its investment. In practice, no large-scale sugarcane mill in Africa relies entirely on nearby outgrowers for cane input. This is due to the mill's strong incentive to ensure some minimum quantity of cane input each year and the impracticality and risk of assuming that outgrower farmers nearby will choose to continue to grow cane for many years. It is important to note that the larger a mill's nucleus estate becomes relative to its annual cane input needs, the less cane it will need from outgrower farmers – and thus the less dependence upon outgrower farmers it will have.

It should be noted that farmers that choose to grow cane must also make a significant investment (i.e., incur significant fixed costs) to cultivate cane, as this perennial crop occupies their field for at least 18 months until the first harvest (Mbowa et al, 2023). Cane growers that apply appropriate levels of inputs and adopt good management practices can expect to have 3-4 ratoons (re-sprouts) after each harvest (Yang, et al, 2021; Niu, 2007). Thus, sugarcane can potentially tie up a given parcel for 5 to 8 years. Ratooning provides several advantages compared with replanting a cane parcel

[5] This means that the equipment (asset) is highly specific for processing of harvested cane and thus its value for any other activity is considerably less, as modifications would have to be made for that equipment to be used for other purposes.

anew, as the labour and fixed costs of cane planting (cane seedlings, soil tillage) are significant (Singh, et al., 2008; Radha, 2007). This amounts to a cost reduction of 45 percent compared with newly planted cane, and thus higher expected net returns per acre (Pawar, *et al.*, 2000).

In addition, sugarcane has the initial labor and cash costs of field preparation, inputs for planting cane (seedlings and fertilizer), and planting are significant. While a mill may provide some of those inputs to the farmer on credit, the farmer is then obligated to repay that input loan by selling his harvested cane to the mill that provided him inputs.

Coordination of local cane supply and demand through registration of farmer cane fields by mills

As in most other African countries, sugar mills in Uganda that own a nucleus estate are not able to source all the cane they require from their own estate (Okumu, 2015). They also purchase cane from independent farmers within a limited distance of the mill, many of whom are small to medium scale. Each large mill must coordinate the supply of cane they expect to purchase from outgrowers over time to ensure that the monthly and annual quantity of cane they access from the combination of farmers and their own estate is adequate to keep the mill running profitably.

The most common and successful form of coordination of farmer cane production and miller demand for harvested cane is through legally binding and enforceable contracts between a mill and a cane outgrower. These typically include: the acreage that a grower has (or will) plant to cane, an agreement as to how the purchase price will be determined, a commitment by the farmer to sell his/her cane to the mill in 18 months' as well as a commitment by the mill to purchase cane harvested from the agreed-upon acreage at that time, using the agreed method of determining the purchase price. However, in the absence of cost-effective and fair local judicial systems and/or an effective public regulatory body or agency, such contracts may not be enforceable by one or both parties, which is the case for contract farming in Uganda and many developing countries. In addition, small and medium-scale farmers in developing countries typically face a significant disadvantage in negotiating contracting terms with a mill given farmers' relatively poorer access to market information, limited experience with legal contracts and procedures, and often insufficient levels of education or training to read and/or adequately understand the contract terms.

In Uganda, large-scale mills and farmers have historically used the process of "registration" to coordinate the mills' need for assured cane input and farmers' need for an assured market (Mbowa et al, 2023). Registration is a process whereby a mill representative meets with a smallholder interested in or already growing cane, records the acreage of the smallholder's cane garden(s), and enters into a formal agreement with the farmer in which the mill commits to buying cane harvested by the farmer from his registered gardens over a specified time period (typically thru the first harvest, though sometimes longer). In turn, the farmer commits to harvesting his/her cane when it

matures (18 months) and selling all of it to that mill[6]. Like contracting, registration helps to manage the co-dependency between a mill and cane growers to the benefit of both by coordinating and balancing the supply of farmers' cane and the demand for it by mills. Registration thus serves as an institutional production-marketing arrangement and commitment between a mill and an individual grower that most often is the best interests of each party.

Role of registration in coordinating cane grower access to inputs and extension services

In addition to registration, these mills also offered other kinds of support to some (not all) registered growers, such as extension services; access to inputs (often on credit) such as seedlings, inorganic fertilizers, and pesticides; and access to finance, in some cases (Mbowa et al, 2023). Because many small and medium-scale farmers in the cane producing regions have limited access to seasonal credit for agricultural inputs, large mills provided these services and inputs to growers on credit. This was done with the understanding that "aided" growers would sell their cane to the mill, and then millers would deduct the cost of these services/inputs from the gross sales revenue of each grower. This support from mills is in farmers' interests because cane farmers have very limited access to public extension specific to cane production and marketing, and the financial and credit constraints they face to obtaining productivity-enhancing inputs. This kind of service/input provision is also in mills' interest as it helps ensure a reliable supply of smallholder cane over time as it helps registered growers manage to produce a quantity of cane sufficient for the mill's needs and be productive enough over time to want to continue producing cane.

Institutional arrangements between cane growers and millers in Uganda

Farmers engaged in cane production in Uganda can be categorized by the following four types of institutional arrangements with large and/or small sugarcane mills (Mbowa et al., 2023, Martiniello, et al., 2021; Martiniello 2017; Hall, 2017):

1) Registered
    a. A formal or informal agreement in which a mill commits to buying all cane harvested from a specific cane parcel or plot of a grower, once the cane is mature (usually 17-18 months after planting or ratooning).
    b. The farmer commits to sell all cane harvested from that parcel to the mill. The mill sends a representative to register a plot in person, typically after planting.
2) Registered and Aided

[6] These agreements are sometimes made via written and signed contracts and sometimes via a verbal agreement. In practice, registration by some mills has involved long, written, multi-year, signed contracts that the mill has managed to enforce (the case with Kinyara & Hoima Sugar in Bunyoro) (Mbowa et al, 2023). By contrast, registration by mills in Busoga (Kakira) and Center (Scoul-Lugazi) appears to have been less formal and were not technically legally binding, though were respected by most farmers and those mills prior to 2012 or so as many new, small-scale mills entered the cane milling industry in Busoga and Buganda (ibid, 2023).

a. A formal or informal agreement in which a mill provides a registered grower with inputs and/or extension services, either on credit or for purchase up front. Inputs may include cane seedling material, inorganic fertilizer, pesticides, insecticides and/or herbicides, though what is offered may vary by mill, farmer characteristics, and the farmer's history with the mill. Provision of input on credit is especially helpful for smallholders, who are unlikely to able to access inputs due to credit and/or input market failures (Little and Watts, 1994; Simmons, 2002; Adams et.al, 2018).
b. If inputs are provided on credit, the farmer and miller agree that the mill will recover the value of the input loan made to the farmer by deducting it from the gross value of harvested cane that the farmer later delivers to the mill at harvest.

3) Spot sellers
   a. A farmer who foregoes any offer of registration and/or aid from a mill and waits until cane is mature to decide on which mill to which he will sell his cane prior to harvesting. Presumably, the farmer's decision is based on which mill offers the highest cane price at that time, though he has no guarantee that a mill will buy his cane. In addition, in a situation of oversupply of cane, a spot seller may lose considerable leverage in price negotiation with a mill with which it is not already registered.[7]
4) Mixed arrangement
   a. Case where a farmer has more than one parcel of cane and chooses to use IA-1, IA-2, or IA-3 for one parcel, and a different IA with another one.

Theoretically, aid should improve farmer productivity through better access to yield-enhancing inputs and quality extension, while registration should provide the farmer with market assurance that may incentive him to increase his investment in inputs and/or plot investments to improve soil fertility and/or water management (Tschirley et al, 2010; Poulton, Kydd, & Dorward, 2004).

History of structural and institutional change in Uganda's cane milling industry

Between privatization and liberalization of the sugarcane milling sector in 1986 and 2005, Uganda had only three large-scale mills, which were located in three different regions of the country: Kakira in the East, Kinyara in the West, and Scoul-Lugazi in central-Uganda (Okumu 2015; Mubiru 2015). During that time period, the majority of farmers were registered or registered-aided, as farmers in each region had only one mill to which they could sell. This provided an environment in which the large cane mills were willing to provide inputs and assistance, often on credit, in the knowledge that the physical nature of harvested cane made it cost-prohibitive for a farmer to try to side-sell their cane to a large mill in another region.

[7] This is due to the fact that unharvested cane loses its sugar content and thus value the more months pass beyond maturity (17-18 months for the varieties grown by Ugandan farmers). The situation described would be an example of "hold up" that can be created by transaction cost and information asymmetry (Rogerson, 1992).

However, this situation changed beginning in 2006, as the Ministry of Trade, industry, and Cooperatives (MTIC) began to sell licenses for new cane mills (Mbowa et al, 2023). By 2018, 11 new small-scale mills had entered the cane milling industry, which had only 3 large mills between liberalization of the industry in 1986 and 2005 – Kakira in Busoga, Scoul-Lugazi in Buganda, and Kinyara in Bunyoro. These large mills each had a nucleus estate, though also relied upon arrangements with outgrower farmers to obtain adequate quantities of cane input for the mill throughout the year (Okumu, 2015). However, when the Ministry of Trade Industry and Cooperatives (MTIC) inadvertently provided licenses to new mills without any location restrictions or nucleus estate requirements, this enabled the new mills to locate themselves near the original 3 large ones, with the goal of recruiting some of the large mill's farmers to sell to them instead while trying to attract new farmers to the industry.

In order to entice existing growers away from the large mills, small mills offered higher prices relative to the large mills. Large mills eventually had to match these, which benefited farmers in the short term. However, the new mills did not provide inputs on credit, extension services, or market assurance prior to the harvest period as large mills had historically done. As some former large mill outgrowers began to side-sell their cane to the small mills and in some cases, not repay inputs loaned to them on credit, the large mill Kakira in Busoga, and to a lesser extent Scoul-Lugazi in Buganda, began to offer inputs such as fertilizer on credit only to their most trusted, long-term outgrowers, and growers that were selling to small millers were not receiving much extension advice, as most cane-specific extension is provided by large mills (Mbowa et al, 2023). It is important to note that the number of new, small mills that entered Busoga was considerably higher and earlier than small mills that entered Buganda. Bunyoro has two small mills but the two large-scale mills (Kinyara and Hoima, a factory owned and managed by the same company) buy nearly all the cane in the region and essentially do not have competition.

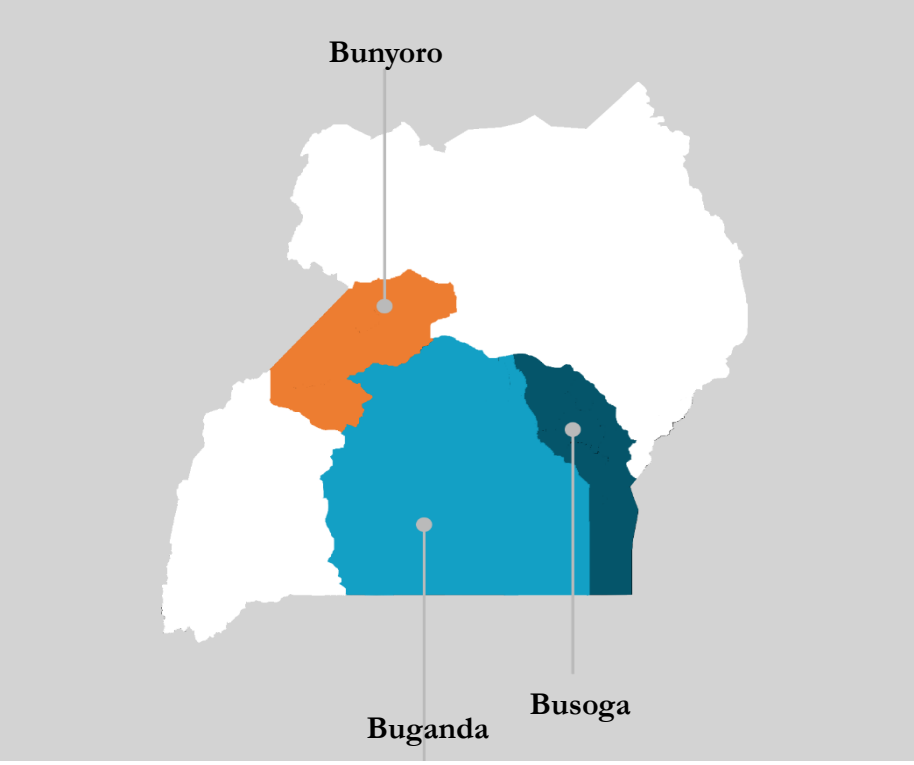
Eventually, overexpansion of cane area resulted in an oversupply of cane from 2018 to 2021, by which point market assurance coordination had nearly broken down in Busoga and became a problem even for registered farmers in Buganda and Bunyoro, who had mature cane that was months beyond optimal harvest timing but no buyer for it. Mbowa et al (2023) provides a more in-depth discussion of this historical context, the main coordination challenges in 2021, and policy implications for the industry. This paper's objective is to use these differences in the strength of grower-miller coordination between the three regions in 2021 to assess whether the strength and nature of this coordination influences grower access to yield-enhancing inputs and extension, and if and how such inputs and extension advice are associated with improved yields.

III. Methodology

Study area and sources of data

The study uses primary data collected in a household and community survey conducted concurrently in November and December 2021 in 12 districts within the three main cane growing regions of Uganda (Buganda, Busoga, and Bunyoro) as illustrated by Figure 1. In the household survey, data were collected from 1,800 randomly selected households (150 in each district)[8] using a structured questionnaire stratified along the three known sugarcane production institutional arrangements i.e., *registered, and aided outgrowers*; *registered and unaided outgrowers*, and *spot sellers (neither registered nor aided)*.

Figure 1. Map of Uganda's regions and the study areas



The study area was stratified into the three sub-regions according to intensity in sugarcane economic activities i.e., six districts (Luuka, Mayuge, Kaliro, Kamuli, Jinja and Iganga) in Busoga sub-region with the largest number of sugar mills; three districts in Buganda (Buikwe, Mukono and Kayunga); and three districts in Bunyoro (Hoima, Kikuube and Masindi). Busoga sub-region had an influx of more small new mills and hence with relatively high competition between mills for cane. The Bunyoro sub-region is dominated by two large mills (Kinyara, and Hoima sugar factory); the one small mill (Bwendero) provides minimal competition for cane competition for growers. While the

[8] The survey included 1,771 households in these 3 sub-regions, of which 931 were cane growers, and 72 community interviews. This data was complemented by qualitative information collected through focus group discussions (FGDs) with farmers and key informant interviews (KII) within these same communities.

Central region (Buganda) lies between Eastern and Western regions in terms of the number of processing mills. Primary data on resource availability and use, input-output levels, prices of farm produce and inputs and some other relevant information was collected by interviewing the farmers using a well-structured questionnaire. Data was also collected regarding the socioeconomic factors of sugarcane farmers such as level of education, age, farming experience, credit availability, access to mill development activities and extension services. The study is quantitative by nature and descriptive in design. Analysis of this primary data was supplemented by secondary data collected through desk reviews of various reports from administrative sources (FAOSTAT, MTIC, MAAIF), and review of relevant reports and journals.

Conceptual Framework

The conceptual framework used to address the first research question (RQ-1) regarding the determinants of farmer cane productivity is derived from well-known results of the microeconomic theory of production. The production function of a farm household is represented as:

$$(1) \quad h(q, x, z) = 0$$

where q is a vector of output quantities, x is a vector of variable input quantities, and z is a vector of fixed factor quantities. Using p and w to represent the prices of outputs and inputs, respectively, a producer's restricted profit function can be represented by $p'q - w'x$. This is a producer's gross revenue (price * output quantity) less variable costs (input prices * variable input quantities). The producer is then assumed to choose the combination of variable inputs and outputs that will maximize his profit subject to the production technology constraint:

$$(2) \quad Max\ p'q - w'x, \quad s.t. \quad h(q, x, z) = 0$$

The solution to this maximization problem is a set of input demand and output supply functions that can be written as:

$$(3) \quad x = x(p, w, z) \quad and \quad q = q(p, w, z)$$

where input demand (the quantity of a variable input used) is a function of the output price (p), the price of a specific input, prices of other inputs, and fixed factor quantities. Likewise, output supply is a function the output price, prices of variable inputs, and fixed factor quantities. Substituting the expressions in (3) for x and q results in a profit function represented as:

$$(4) \quad \pi = \pi(p, w, z)$$

We assume a normalized Cobb-Douglas production function with a single output (q), which results in a log-linear production function (Yotopoulos and Lau, 1979). The conventional Cobb-Douglas production and profit functions have also been used by several prior studies of factors that influence

outgrower cane productivity and profitability (Munir et al., 2015; Reza et al., 2016; Olukunle, 2016; Haider, Ahmed & Mallick, 2010; Dlamini & Masuku,2012).

To address the second research question, regarding the potential influence of grower-miller institutional arrangements on farmer input use and access to quality extension services, we rely upon principles from New Institutional Economics (see section 2.2), which condition a farmer's incentives and disincentives associated with each of the four IA categories (section 2.2). The grower-miller institutional arrangements of registration and registration-with-aid are theoretically expected to influence cane yield thru two main pathways, each of which leads to separate hypotheses (H) regarding the association between IAs and farmer behavior and outcomes, as follows:

1) IMPROVED ACCESS TO INPUTS and TECHNICAL KNOWLEDGE -- Farmers who are aided should:
   a) HI-1.1: Have better access to inputs, be more likely to use them and at higher application rates.
   b) HI-1.2: Have better access to quality extension.
   c) In turn, extension messages can lead to (HI-1.3): Higher probability of farmer adoption of better crop and soil management practices in cane production.

2) IMPROVED MARKET ASSURANCE -- Farmers who are registered should have more reliable market access/assurance, and thus:
   a) (HM-1): Be more likely to sell cane once it is mature.
   b) This should, in turn, provide an incentive for growers to: (HM-2) Invest more in their cane in terms of variable inputs (fertilizer, seedling quality, use of family and hired labor, etc); (HM-3) Paying for quality extension (if need be), and (HM-4) Higher probability of making longer-term plot-level investments in water conservation, tillage, etc.

Note that farmer use of inputs and improved management practices may increase through pathway (1) and/or (2). Additional hypotheses related to cane productivity are derived from agronomic research and empirical findings of the relationship between input use and cane productivity: (HP-1) use of inputs such as inorganic fertilizer, quality seedling material, appropriately applied chemicals (pesticides, insecticides) should increase cane productivity; as should (HP-2) application of good management practices.

Results from existing empirical studies of cane grower productivity and profitability provide support to these hypotheses. For example, using multivariate regression analysis and farm-level cost-benefit analysis, Dlamini and Masuku (2012) found that timely weeding, fertilization, irrigation, and inter-cropping of cane each had a statistically significant positive association with cane productivity and profitability. Other studies have also found evidence of a positive association between farmer experience – and credit availability and cane productivity and profitability (Haider, Ahmed and

Mallick, 2010). Likewise, analysis by Nazir et al (2013) and Dlamini and Masuku (2012) finds that the prices of fertilizer (urea), land preparation, seed, weeding, and irrigation all have a negative association with cane profitability – implying that those inputs have a positive association with cane profitability.

Empirical strategy

Descriptive analysis

To address RQ1 (What are the key factors associated with variation in farmer cane yield, under farmer conditions?), our empirical strategy is to being with descriptive analysis focused primarily on factors within a farmers' control, such as use yield-enhancing inputs, use of good complementary crop and soil management practices, use of hired and family labour, and access to quality extension (at least partially). This helps to inform the specification of ensuing econometric analysis of factors associated with variation in farmer cane yield, as well as the interpretation of their partial effects on cane yield. To address RQ2 (To what extent are IA associated with farmer access to inputs, extension, and adoption of good management practices?), we add descriptive analysis of farmer input use by grower-miller IA and region to that on the factors associated with improved farmer cane yield. To address RQ3 (Was cane profitable for farmers in Uganda in 2021, for whom, and what factors condition profitability or unprofitability?), we use descriptive analysis of farmer cane profitability as well as the four main components of profitability, by region and IA.

The ensuring descriptive and econometric productivity analysis is conducted at plot level, the lowest level at which the EPRC Sugarcane Household Survey collected information on input use, management practices, and yields. The analysis uses a subsample of n=537 cane plots on which cane was harvested by growers and sold in 2021. Descriptive analysis of profitability of cane production is conducted at both the plot and household-level. The general approach to the descriptive analysis is adapted from the approach used by Tschirley et all (2010) to study how institutional arrangements influence productivity, profitability, and performance in cotton subsectors across Africa.

Econometric Analysis

An econometric model for cane grower yield at the plot-level is given by:

$$(1) \qquad Y_{ij} = \alpha + \beta P_{ij} + \gamma X_i + \delta M_c + \varepsilon_{ij}$$

Equation (1) represents the general specification used in this study for an OLS regression of farmer cane yield (Y_{ij}). The dependent variable cane grower yield is the quantity of cane harvested per acre by a household i on parcel number j. P_{ij} is a vector of plot-level explanatory variables, including number of working age adults in household age 15-64 per acre, travel time from house to plot (minutes), and dummy variables that are farmer reported, including: =1 if the cane seedling source was from a large mill (=0 otherwise); 1=plot is sloped (=0 otherwise); 1=plot has sandy soil (=0 otherwise); 1=plot has clay soil (=0 otherwise); 1=plot is titled (=0 otherwise), and 1=plot is rented in (=0 otherwise). Another plot-level dummy variable is included that =1 if a plot is currently

ratooning cane (=0 otherwise) is included because yield of a ratoon crop is typically somewhat lower than yield from a first harvest of cane – particularly if it is a second, third or fourth ratoon. On the other hand, a cane grower is typically only able to produce a ratoon crop after his/her first harvest (or a second ratoon after a first ratoon, etc) if he/she had used recommended inputs and good complementary crop and soil management practices (called good management practices, hereafter) during the initial period from planting cane to the first harvest of it (Ali and Chaudhry, 1990). Given that the survey instrument inadvertently collected information from cane growers on their cane-related plot and soil management practices from only a subset of growers (those that ratooned), the ratoon crop dummy could be expected to capture at least part of any association between a farmer's plot and soil management practices (and possibly other aspects of farm management skill) and cane yield.

X_i is a vector of household-level explanatory variables, including household demographic, socio-economic characteristics, and shocks, as follows: total landholding (acres), the natural log (ln) of total household asset value (includes livestock, domestic and transport assets), age of the household head, the head's number of years growing cane, farmer distance to the main mill he sells to currently; and dummy variables that =1 if the head completed primary school (=0 otherwise); =1 if head completed secondary school or higher; X_i also includes dummies for respondent reported shocks, including: 1=weather shock (drought, flooding) (=0 otherwise); 1=crop disease (=0 otherwise); and 1=household experienced death or illness of a household member in 2021 (=0 otherwise).

M_c is a vector of community-level variables from the 75 communities in the sample, including input prices: the log of the price of herbicide (Ush/litre), and the log of the local farm wage (Ush/day); and market access variables, including: community distance to the nearest district town; a dummy that =1 if community has access to two or more mills. Theoretically, a farmer that has a potential option to sell to more than one mill may be able to negotiate a higher sale price, which could improve their profits per acre, yet competition between mills can also potentially diminish grower-miller coordination, which could limit farmer access to inputs. Finally, spatial dummies are included, either for 2 of the 3 subregions, or 9 of the 10[9] districts- depending on the specification.

The plot-level yield equation is estimated using OLS with population sampling weights applied. Standard errors are clustered at the household level given that some households harvested more than one cane field. Partial effects estimated from the regression are considered to be associations with log of yield rather than causal effects given that the data is cross-sectional and that some of the technology-related variables could potentially be correlated with unobserved heterogeneity of time varying or time constant household or plot-level factors.

[9] Due to limited case numbers of harvest plots in some districts, those from Iganga district are combined with the adjacent Jinja district, and likewise, those in Hoima are combined with Kikube.

Additional yield regressions will be estimated to assess the potential association between cane yield and recommended ratoon management practices including: (i) dismantling of ridges; (ii) stubble shaving (root pruning) at initiation of ratoon; (iii) gap filling when there is more than 45 cm distance (gap) between clumps; (iv) paired-row system of planting to optimize plant population; (v) trash mulching in alternate rows so as to conserve soil moisture; and (vi) managing weeds. For cane plots that were currently being ratooned, the EPRC Sugarcane Grower Household survey asked growers whether they had applied any of the management these management practices.

IV. DESCRIPTIVE ANALYSIS OF CANE PRODUCTIVITY AND INPUT USE

Institutional arrangements between sugarcane growers and millers and market access

The high level of miller competition for growers in Busoga eventually led to a breakdown in grower-miller coordination of cane supply and demand provided by registration, and decreased willingness of Busoga's large mill (Kakira) to offer inputs on credit to all but their most trusted outgrowers. This also occurred in Buganda (Scoul-Lugazi), though the relatively smaller number of new mills entering the region resulted in a decline but not breakdown in grower-miller coordination in cane supply/demand and aid. Only one small mill entered Bunyoro, which had virtually no effect on Kinyara and Hoima's monopsony[10] control of growers' access to inputs on credit and a buyer. The trade-off (inverse relationship) between the level of miller *competition* and the level grower-miller *coordination* is demonstrated by the fact that the region with the highest competition between mills (Busoga) had the lowest grower-miller coordination (only 8 percent of growers registered-aided and 21 percent registered), the region with more moderate miller competition (Buganda) had better coordination (57 percent of growers registered-aided; 8 percent registered), while the region with virtually no miller competition (Bunyoro) had much higher grower-miller coordination (86 percent of growers registered-aided; 1 percent registered) (Table 1). Likewise, the share of spot sellers – growers with no coordination with large or small mills prior to cane maturity for market assurance or input access -- is highest in the region with most competition (Busoga, 65 percent) and lowest in the region with virtually no competition (Bunyoro, 11 percent).

The share of growers by intentions to sell in 2021 by mill, mill size, and region show that the large mill in Busoga (Kakira) only accounted for 38 percent of such grower intentions Busoga in 2021, while the large mill in Buganda (Scoul-Lugazi) accounted for 88 percent of grower intentions in

[10] A monopsony is a market in which there exists only one buyer of a commodity; a monopoly is a market in which there is only one seller. Kinyara and Hoima Sugar factories are owned by the same company and coordinate their management of contracted growers, thus are essentially one monopsony buyer of cane in Bunyoro.

Buganda, and the 2 large mills in Bunyoro accounted for 97 percent in Bunyoro (Appendix Table A1). This demonstrates just how much more competition for growers that Kakira faces from small mills in Busoga compared with Scoul-Lugazi in Buganda, while Kinyara/Hoima have virtually no competition in Bunyoro.

Table 1. Share of cane growing households in 2021

Institutional arrangement	Busoga	Buganda	Bunyoro	Total	n	Region	% HHs	n
	---------- % HHs ----------							
Register/aid	8.0	57.0	86.3	25.7	308	Busoga	72.4	322
Registered	20.9	7.7	0.9	16.3	85	Buganda	13.6	161
Spot seller	65.3	25.2	11.7	52.3	251	Bunyoro	14.0	210
Mixed	5.8	10.1	1.1	5.7	49	Total	100.0	693
Total	100.0	100.0	100.0	100.0	693			

Source: Authors' computations from EPRC sugarcane household survey (2021).

Weak coordination of cane supply and demand in Busoga is also demonstrated by the fact that, among all cane plots that matured[11] in 2021, the region with the highest level of miller competition (Busoga) had the lowest share of plots that farmers managed to harvest and sell that year (35 percent), compared with 48 percent in Buganda and 59 percent in Bunyoro (Table 2). Likewise, Busoga had the highest share of mature cane plots (21 percent) that were sold by a cane grower unharvested (at a very low price, as discussed in section 6), compared with 10 percent in Buganda and only 0.2 percent in Bunyoro. In all three regions, around 41 to 44 percent of plots had mature cane that farmers were not able to harvest and sell given lack of a buyer.

Table 2. Share of cane farmer plots by cane harvest-sale status in 2021

2021 Farmer cane harvest-sale status for plots with mature cane in 2021[1]	Busoga	Buganda	Bunyoro	Total	n
	---------- % plots ----------				
Harvested & sold to mill or trader	35.5	48.1	58.6	39.0	537
Sold cane in field unharvested	20.9	10.0	0.2	17.8	193
Had mature cane but no cane harvest or sale	43.6	41.9	41.2	43.2	575
Total	100.0	100.0	100.0	100.0	1,305

Source: Authors' computations from EPRC sugarcane household survey (2021).

The financial implication of unharvested cane at or past maturity is that its owner has been waiting for 18 or more months to obtain revenue from his/her investment of land, labor, inputs, and capital into the crop, yet that investment and any potential returns are inaccessible until the farmer is able to obtain a buyer for it at a reasonable price. At the same time, any field tied up with unharvested mature cane translates to foregone future income from whatever crop the farmer expected to plant

[11] For the cane varieties grown by farmers in Uganda, sugarcane reaches maturity – the point of maximum extractable sugar content and thus value -- at 17-18 months.

as soon as the cane was harvested (which could include initiating a ratoon cane crop). In addition, the longer a farmer has to wait to harvest cane after it reaches maturity, the lower the extractable sucrose remains and thus the lower the revenue per acre that he can earn once it is harvested and sold.

Fortunately, by mid-2022, the oversupply of cane eventually fell back to below the level typically demanded, millers subsequently began to raise their purchase prices and buy cane again, and growers with old cane were eventually able to sell it (reportedly). Yet, we began discussion of the study findings with this context to highlight the extreme difficulty that many cane growers had with finding a buyer for their mature cane in 2021, as this provides important context to the ensuing productivity and profitability analyses in this paper.

Cane grower productivity

Before considering input use, we first consider one of the study's two main outcomes of interest – farmer cane yield (tons/acre). Productivity analysis in this section is based only on the 39 percent of mature cane plots that were harvested by growers in 2021, as farmer yield could not be recorded for fields that a farmer sold unharvested (i.e. the buyer arranged and paid for the harvesting of them). At the sample level, it is clear that there are large differences in mean and median cane grower yield across regions, as Bunyoro mean cane yield of 50 tons/acre is 31 percent higher than Buganda's mean of 38 tons/acre, while Bunyoro's median cane yield is 21 percent higher than in Buganda (Table 3). Bunyoro's mean and median yields were 84 percent higher than those in Busoga. Likewise, Buganda's mean cane yield of 38 tons/acre is 56% higher than Busoga's 27 tons/acre, and Bunyoro's median yield is 60 percent higher (mean differences for both comparisons are statistically significant at the 0.05 level).

Table 3. Plot-level mean/median cane yield by region and grower-miller institutional arrangement, 2021

	Yield (tons/acre)			Institutional	Yield (tons/acre)		
Region	mean	median	N	arrangement	mean	median	N
Busoga	27.0	23.3	256	Register/aid	38.5	32.8	235
Buganda	38.9	36.0	119	Registered	28.0	30.0	100
Bunyoro	49.9	43.6	162	Spot seller	30.3	23.3	154
Total	31.8	26.7	537	Mixed	28.4	26.7	48
				Total	31.8	26.7	537

Source: Authors' computations from EPRC sugarcane household survey (2021).

The sample level mean yield of registered-aided growers (38.5 tons/acre) was 45 percent higher than that of registered growers (28 tons/acre) and 24 percent higher than those of spot sellers (30 tons/acre) (Table 3). However, mean/median cane yields of registered-aided farmers in Busoga and Buganda are not higher than those or registered farmers and are slightly lower than those of spot sellers (Table 4). Thus, the yield advantage of registered-aided growers at the total sample level

appears to be driven the very large share of registered-aided and harvested plots in Bunyoro and the fact that Bunyoro's mean and median yields are considerably higher than those in Buganda and Busoga (Table 4). This suggests that registration with aid from the two large mills in Bunyoro provides more benefits for registered-aided growers in Bunyoro than for those in the other regions.

Table 4. Plot-level mean/median cane yield by region and grower-miller institutional arrangement, 2021

Institut. arrange-ment	------ Busoga ------				------ Buganda ------				------ Bunyoro ------				Total sample			
	% of plots	cane yield (t/ac) mean	median	N	% of plots	cane yield (t/ac) mean	median	N	% of plots	cane yield (t/ac) mean	median	N	% of plots	cane yield (t/ac) mean	median	N
Regist/aid	14	22.3	18	35	64	37.1	30	66	88	49.7	44	134	30	38.5	33	235
Registered	51	27.1	30	83	9	38.3	37	14	1	63.7	88	3	39	28.0	30	100
Spot seller	29	28.3	23	106	16	42.0	40	26	10	51.3	33	22	25	30.3	23	154
Mixed	6	24.4	25	32	11	42.0	37	13	1	36.1	30	3	6	28.4	27	48
Total	100	27.0	23	256	100	38.9	36	119	100	49.9	44	162	100	31.8	27	537

Source: Authors' computations from EPRC sugarcane household survey (2021).

Given our expectation and hypothesis that yields are positively correlated with input use and that farmers in regions with higher grower-miller coordination will have higher levels of input use, the descriptive analysis continues by investigating potential variation in factors known to influence yield – such as input use and good management practices – by both region and institutional arrangement. Mean and median yields of plots that have used inorganic fertilizer, used cane seedling from a mill, are currently in ratoon (proxy for farmer use of good management practices) or managed by a farmer that has received any cane extension visit from a large mill in the past are higher than yields on plots without those inputs, applied management practices, or information access (Table 5). By contrast, use of cane seedling from a neighbor, farm group, NGO, or other organization (other than a large mill or own seedling) is associated with slightly lower mean and median yields, while a plot managed by a farmer who has received cane extension from a source other than a large mill has only slightly higher mean and median yield. It is important to note that these are just bivariate relationships, and multivariate regression analysis is needed to control for the many other factors known to influence cane yield besides any one of these inputs. Nevertheless, the four factors in Table 5 that one would expect to have a positive association with yield – and larger than the other type of the same input – are associated with higher yields.

Table 5. Farmer cane yield by use or not of inputs or access to extension, plot-level

Input type	Yield (tons/acre)			Input type	Yield (tons/acre)		
1=Fertilizer use	mean	median	N	*1=Ratoon crop*	mean	median	N
No	30.4	24.0	400	No	27.8	22.0	156
Yes	36.6	30.0	137	Yes	33.9	30.0	381
1=Seedling from mill				*1=received cane extension from large mill*			
No	29.6	24.8	423	No	31.1	24.0	289
Yes	48.4	40.0	114	Yes	33.1	30.0	248
1=Seedling from neighbor, farm group, etc				*1=received cane extension from other source*			
No	32.5	27.8	403	No	31.3	25.0	416
Yes	30.4	23.3	134	Yes	33.0	27.0	121

Source: Authors' computations from EPRC sugarcane household survey (2021).

Cane grower access to inputs

If obtaining registration with aid from a mill improves a grower's access to yield-enhancing input and registration provides them with market assurance that may incentivize them to invest in such inputs (and perhaps more), one would expect to see a lower share of growers in Busoga use inputs relative to other regions. From farmer cane plots harvested in 2021, it is apparent that better coordination between millers and growers (registration with aid or registration) is associated with higher shares of farmers using fertilizer, receiving an extension visit (at any time), currently ratooning, and sourcing cane seedlings from a large mill. For example, nearly half the plots in Bunyoro received inorganic fertilizer, compared with 28 percent in Buganda and 16 percent in Busoga (Table 6).

Table 6. Share of farmers' plots to which inputs were applied, by input or management practice type and region

							-------- Source of seed ---------			
Region	Inorganic fertilizer	Pesti-cides, herbi-cides	Exten-sion visit, mill	Exten-sion visit, other	Hired labor	Ratoon crop	Large mill	Others	Own seed	"ratoon crop" (no source)
	---------- share of plots with input applied or info obtained (%) ----------									
Busoga	16	33	25	29	89	64	1	44	18	37
Buganda	28	74	64	35	94	66	45	15	9	31
Bunyoro	47	21	68	19	95	72	34	4	0	62
Total	22	37	36	29	91	65	12	34	14	40

Source: Authors' computations from EPRC sugarcane household survey (2021).

Because most cane-specific extension reported by sample farmers was from large mills, it is not surprising that regions with a considerably higher share of plots controlled by registered-aided farmers (64 and 68 percent of plots in Buganda and Bunyoro, respectively) report having ever received a cane-specific extension visit, compared with only 25 percent in Busoga. Likewise, 45 and

34 percent of growers in those two regions, respectively, used cane seedling from a large mill – compared to only 1 percent of plots in Busoga (Table 6). Forty-four percent of plots in Busoga used seed obtained from other farmers, farmer groups or traders – implying that such seed was not recently propagated under ideal management conditions, as is done by large mills. Like other crop seed or planting material, cane seedling material becomes less productive the more times that it is grown and recycled. The share of plots in ratoon – likely a proxy for good crop management – is a bit higher in Bunyoro (72 percent) relative to Buganda and Busoga (66 and 64 percent, respectively).

Our interpretations of regional differences in access to inputs and information above were based on the assumption that regional differences in input use could likely be explained by differences in the shares of farmer-plots by type of farmer's IA. The prevalence of farmer input use by both IA and by region is addressed more directly by Table 7, for which there are four main findings[12]. It is important to note that in Bunyoro, the only IAs that can be meaningfully compared are registered-aided and spot sellers, given that other two categories are represented by only a single plot each. First, registration with aid is not as strongly associated with fertilizer use as might have been expected, as spot sellers are as likely to have used inorganic fertilizer as registered-aided growers (Table 7). This is perhaps not surprising given the context of the significant breakdown in coordination in Busoga – and to a lesser extent in Buganda – as it led large mills in Busoga to stop providing fertilizer on credit to nearly all aided growers a few years before 2021 and to only provide seedling material and extension. Declining grower-miller coordination and increasing failures by growers and millers to honor registration commitments also led Buganda's large mill to significantly reduce the number of farmers who received inputs on credit in recent years. Nevertheless, this does not imply that better coordination to enable farmers to access inorganic fertilizer on credit (via registration with aid) is thus not needed in these regions and that enough growers are able to self-finance fertilizer -- as only 16 and 28 percent of plots in Busoga and Buganda had inorganic fertilizer applied to them (Table 7).

[12] While the regional focus of Table 5 used only the n=537 plots that were harvested, to investigate patterns in institutional arrangements and input use by region, we use a larger sample of plots that includes those harvested in 2021, sold unharvested, or remained unharvested with mature cane.

Table 7. Share of farmers' plots to which inputs were applied, by input or technology type, institutional arrangement, and region

Institutional arrangement	% of plots	Inorgan. fertilizer	Pesti-cides, herbi-cides	Exten-sion visit, mill	Exten-sion visit, other	Hired labor	Ratoon crop	Source of seed: Large mill	Source of seed: Others	Source of seed: Own seed	Source of seed: "ratoon crop" (no source)	n
Busoga	share of plots with input applied											
Register/aid	7	8	17	52	37	89	82	8	29	5	59	63
Registered	28	12	44	23	33	96	73	1	33	26	40	153
Spot seller	61	22	34	19	25	83	56	0	60	11	29	315
Mixed	3	8	9	37	28	98	61	1	1	50	48	42
Total	100	16	33	25	29	89	64	1	44	18	37	573
Buganda												
Register/aid	47	27	78	78	36	100	70	48	7	12	33	88
Registered	6	38	58	59	42	100	67	30	33	8	29	9
Spot seller	38	30	62	19	23	85	66	29	34	0	37	75
Mixed	9	22	94	85	47	79	48	71	6	15	9	24
Total	100	28	74	64	35	94	66	45	15	9	31	196
Bunyoro												
Register/aid	79	47	20	69	23	97	71	35	0	0	65	99
Registered	0.8	58	58	73	0	100	85	27	15	0	58	1
Spot seller	19	48	27	62	2	85	76	31	24	0	45	24
Mixed	0.8	45	0	100	0	91	91	0	9	0	91	1
Total	100	47	21	68	19	95	72	34	4	0	62	125

Source: Authors' computations from EPRC sugarcane household survey (2021).

Second, access to large mill extension – none if provided by small mills -- is considerably more frequent for plots managed by registered-aided or mixed arrangement farmers (Table 7). Third, use of cane seedling from a large mill was more prevalent among registered-aided farmers in each region. Fourth, most cane-specific extension visits in 2021 in these regions were from large mills staff, and thus it is not surprising that farmers that are registered-aided by a large mill are more likely to receive extension from them.

Prevalence of input use at the sample level (using the n=537 harvested plots) shows more clearly that while registration with aid is not associated with a higher likelihood of inorganic fertilizer use, this IA is associated with higher access to other inputs and services. For example, the shares of plots that had a ratoon crop (74 percent), use of cane seedling from a large mill (32 percent), and received extension visit from a mill (67 percent of plots) for plots of registered-aided farmers are all considerably higher than those of plots managed by spot sellers, which has input use shares of 57 percent, 3 percent, and 21 percent, respectively (Table 8).

Table 8. Share of farmers' plots to which inputs were applied, by input or technology type, institutional arrangement

Institutional arrangement	% of plots	Inorgan. fertilizer	Pesti-cides, herbi-cides	Exten-sion visit, mill	Exten-sion visit, other	Hired labor	Ratoon crop	Source of seed: Large mill	Source of seed: Others	Source of seed: Own seed	Source of seed: "ratoon crop" (no source)	n
Register/aid	15	31	36	67	31	96	74	31	10	5	54	238
Registered	25	14	45	26	34	96	73	3	33	25	39	104
Spot seller	57	24	36	21	24	84	57	3	56	9	31	154
Mixed	4	12	27	49	32	94	59	16	2	41	41	41
Total	100	22	37	36	29	91	65	12	34	14	40	537

Source: Authors' computations from EPRC sugarcane household survey (2021).

V. ECONOMETRIC ANALYSIS OF FARMER CANE PRODUCTIVITY

Introduction

Descriptive statistics of the dependent and explanatory variables used in the econometric analysis of farmer cane yield are provided in Table 9. A test of the joint significance of both the regional and district dummies indicates that both sets are jointly significant, though use of the district dummies improves the adjusted R-squared, indicating that inclusion of district dummies in the model explains more variation in yield than regional dummies. The following discussion refers to the specification (2) using district dummies, unless otherwise specified.

Key factors associated with improvements in farmer cane productivity

There are four explanatory variables that have a statistically significant positive association with cane grower yield that are within a farmer's control, including: use of cane seedling from a large mill, having a cane crop in ratoon, application rate of inorganic fertilizer, and total labor days used per acre. First, use of cane seedling from a mill has a statistically significant association with yield and indicates 25 percent higher yield, on average, than use of seedling from another source – such as own seedlings or those purchased from a neighbour, farmer group, or trader (Table 10) – while controlling for other factors, such as use of other inputs. This result is consistent with key informant reports that fresh, quality seedlings provide better cane yield than seedlings that have been recycled for many harvests, and that they had anecdotal evidence that many farmers recycled their own seed for too many years or obtained seedlings that had been recycled by other farmers. In addition, key

informants noted that large mills are essentially the only source of source of fresh, quality seedlings, which was corroborated by the household survey data[13].

Second, a plot that is currently in ratoon has a statistically significant and positive association with yield, indicating 31 percent higher yields on average compared with farmers that are not ratooning (Table 10). Because cane yield from a ratoon crop is expected to be no larger than a farmer's first harvest and is typically somewhat lower, it appears that the large positive association between the ratoon crop dummy and cane yield is capturing the effect of good plot and soil management (and probably farm management skill in general) on cane yield, as noted in the Econometric Analysis section above. The survey data provides support for the use of the ratoon crop dummy as a proxy for use of recommended cane crop, plot, and soil management practices, as ratoon crop farmers practice an average of 4 out of the 6 practices, and none of the practices are implemented by fewer than 53 percent of ratoon crop farmers (Table 11).

A common concern in econometric analysis of farmers' crop productivity using cross-sectional data is that factors that are typically unobserved by a household survey such as farm management skill and good crop/plot/soil management practices are known to have a positive effect on crop yield yet are essentially in the error term of a regression. Because these management practices are also usually positively correlated with farmer technology choice – such as using quality, fresh cane seedlings, available only from a large mill – it is possible that the coefficient on use of quality cane seedlings will capture not only any positive effect of this input on cane yield but also capture at least part of the positive effect of the unobserved good management practices on yield. In this situation, the coefficient on use of large mill seedlings would suffer from omitted variable bias (Wooldridge, 2002) – a form of endogeneity – and the bias would be positive. The implication is that the partial effect of large mill seedlings on cane yield that is estimated would be positive and larger in magnitude than the true effect that can be attributed to yield gains from large mill seedlings alone.

However, because the explanatory variables include a proxy control for use of good management practices (1=ratoon crop) and a dummy that =1 if the household received extension from a large mill at some time in the past as well as a separate dummy that =1 if the household received extension from another source – from which the farmer likely learned the good management practices, this suggest that the statistically significant positive association between use of large mill seedling and cane yield actually reflects a yield gain attributable to the seedling and not just positive bias from an omitted variable. Yet, because potential endogeneity of the use of large mill seedlings dummy is not tested and controlled for using a 2SLS or control function approach, the possibility that the magnitude of this positive association may be overstated cannot be dismissed.

[13] While some small mills provide seedling material to farmers, the survey data indicates that this accounts for at most 0.5 percent of farmers indicating that their seedling source for 2021 was from a mill. It is not surprising that small mills would not produce much seedling material given that the land and capital requirements to produce it is far beyond what most small mills could manage given their lack of a nucleus estate, not to mention the technical expertise. The government agricultural research system has reportedly not done any varietal breeding or agronomic research on sugarcane for many years.

Table 9. Descriptive statistics of dependent and explanatory variables used for regression analysis

	---------- Sample statistics ----------				--- Population sampling weighted means ---			
Dependent and explanatory variables	mean	SD	Min	Max	Total	Busoga	Buganda	Bunyoro
cane yield (tons/ac)	36.578	25.534	0.5	154	31.780	27.064	38.177	49.865
ln(cane yield, tons/ac)	3.318	0.861	-0.693	5.037	3.206	3.078	3.338	3.740
1=HH applied fertilizer to cane	0.255	0.436	0	1	0.223	0.163	0.283	0.475
quantity fertilizer, kg/ac)	11.276	25.391	0	100	8.855	5.716	12.965	21.046
ln(quantity fertilizer, kg/ac)	0.841	1.578	0	4.615	0.711	0.495	0.962	1.582
price urea (Ush/kg)	3,343.7	2,697.3	1,000	20,000	3,729	4,031	3,038	2,860
price of herbicide, Ush/litre	19,685.9	6,658.2	8,000	40,000	19,294	18,960	17,168	23,249
farm wage, Ush/day	7,905.5	5,631.6	741	26,667	8,615	9,783	5,721	5,498
ln(price urea (Ush/kg))	8.006	0.372	6.908	9.903	8.107	8.157	8.006	7.948
ln(price of herbicide, Ush/litre)	9.830	0.347	8.987	10.597	9.828	9.821	9.691	10.006
ln(farm wage, Ush/day)	8.684	0.851	6.608	10.191	8.871	9.067	8.309	8.425
HH total labor days used per acre (hired + family)	61.752	65.161	8	240	59.368	58.811	62.817	58.711
ln(HH total labor days used per acre (hired + family))	3.664	0.980	2.197	5.485	3.699	3.729	3.576	3.673
HH no. of working-age adults (age 15-64) per acre	1.393	1.628	0	16	1.394	1.519	1.268	0.867
1= planting material source is miller	0.212	0.409	0	1	0.118	0.012	0.438	0.338
1= ratoon crop	0.709	0.454	0	1	0.654	0.641	0.655	0.722
1= received cane extension from mill (any year)	0.462	0.499	0	1	0.363	0.248	0.637	0.684
1= received cane extension, other source (any year)	0.043	0.203	0	1	0.082	0.093	0.087	0.015
1= plot is sloped	0.423	0.494	0	1	0.365	0.320	0.512	0.448
1= plot is titled	0.240	0.428	0	1	0.225	0.192	0.576	0.037
1= plot is rented in	0.091	0.288	0	1	0.082	0.083	0.147	0.013
Travel time to plot (minutes)	35.932	58.095	0	300	42.857	49.941	30.807	18.225
Altitude (m)	1,118	41	1,019	1,245	1,113	1,107	1,135	1,118
HH total landholding (acres)	23.285	92.529	1	2,017	22.561	24.798	17.536	16.050
ln(HH total household asset value)	14.630	1.598	0	19.170	14.718	14.646	15.118	14.677
1= HH head completed primary school	0.216	0.412	0	1	0.205	0.203	0.198	0.225
1= HH head completed secondary school or more	0.410	0.492	0	1	0.496	0.541	0.428	0.330

Table 9. Continued

	---------- Sample statistics ----------				--- Population sampling weighted means ---			
Dependent and explanatory variables	mean	SD	Min	Max	Total	Busoga	Buganda	Bunyoro
1=HH head is female	0.123	0.329	0	1	0.140	0.151	0.099	0.125
HH head's age (years)	48.678	13.510	16	85	46.983	46.194	47.478	50.604
Farmer's no. years growing cane (years)	10.434	7.914	1	44	10.998	11.732	9.549	8.657
1= HH reported weather shock	0.665	0.472	0	1	0.583	0.562	0.448	0.833
1= % of community with weather shock	0.614	0.238	0.083	1	0.523	0.483	0.419	0.842
1= HH reported crop disease	0.354	0.479	0	1	0.316	0.296	0.411	0.326
1= % of community with crop disease	0.306	0.155	0.000	0.68	0.307	0.309	0.419	0.185
1= HH suffered member death or illness	0.225	0.418	0	1	0.221	0.211	0.165	0.328
distance from community to district headquarters (mi)	12.119	8.911	1	42	10.467	8.658	12.656	17.683
distance from community to nearest market (miles)	3.435	5.573	0	23	3.228	2.701	6.406	2.689
cane farmer distance to his main mill (km)	24.000	19.235	1	164	20.604	18.472	32.649	19.281
Community no. years growing cane (years)	18.592	12.464	3	61	16.353	15.902	20.501	14.413
1=community has access to 2+ cane mills	0.635	0.482	0	1	0.824	0.922	0.825	0.307
1=farmer has sold to large mill previously	0.620	0.486	0	1	0.419	0.256	0.824	0.856
1=Busoga	0.464	0.499	0	1	0.720			
1=Buganda	0.235	0.424	0	1	0.143			
1=Bunyoro	0.302	0.459	0	1	0.137			
Observations (n)	537				537	249	126	162

Source: Authors' computations from EPRC sugarcane household survey (2021). Notes: SD = standard deviation

Table 10. OLS regression of ln (farmer cane yield, tons/acre), plot-level, 2021

	Dependent variable = farmer cane yield	
Explanatory VARIABLES	(1)	(2)
Input prices, inputs, management practices, extension		
ln(quantity fertilizer, kg/ac)	0.0555+	0.0807**
	(0.0901)	(0.0059)
ln(price of herbicide, Ush/litre)	-0.0257	-0.1624
	(0.8935)	(0.4501)
Total labor days used (hired + family) per acre	0.2359**	0.2066**
	(0.0002)	(0.0003)
1= seedling source is miller	0.2602*	0.2525*
	(0.0422)	(0.0486)
1= ratoon crop	0.3092*	0.3134*
	(0.0256)	(0.0230)
1= received mill extension (any year)	-0.0196	-0.0558
	(0.8655)	(0.6359)
1= received extens any other source (any yr)	-0.0820	-0.1424
	(0.7701)	(0.6010)
Plot characteristics		
1= plot is sloped	0.0774	0.0669
	(0.3905)	(0.4744)
1=plot has sandy soil	-0.1266	-0.0820
	(0.2729)	(0.4712)
1=plot has clay soil	-0.1413	-0.0294
	(0.3695)	(0.8556)
1= plot is titled	0.1476	0.1535
	(0.3023)	(0.2822)
1= plot is rented in	-0.2308	-0.2618
	(0.2103)	(0.1422)
Altitude (m)	-0.0025	-0.0029+
	(0.1025)	(0.0956)
Travel time to plot (minutes), with squared term	0.0026*	0.0027*
	(0.0483)	(0.0370)
Household farm assets and human capital		
Total landholding (acres)	-0.0002	-0.0003
	(0.4665)	(0.2128)
ln(total household asset value)	-0.0239	-0.0143
	(0.4059)	(0.6447)
1= HH head completed primary school	0.4054**	0.4040**
	(0.0067)	(0.0067)
1= HH head completed second or better	0.1443	0.1155
	(0.2800)	(0.4020)
1=HH head is female	0.0229	-0.0507
	(0.8523)	(0.6796)

Table 10. Continued

HH head's age (years)	-0.0016	-0.0014
	(0.7075)	(0.7374)
Farmer's no. years growing cane (yrs)	-0.0087	-0.0115
	(0.4171)	(0.2975)
Shocks		
1= HH reported weather shock	0.0921	0.1518
	(0.4165)	(0.1954)
1= HH reported crop diseases	-0.0887	-0.0904
	(0.4342)	(0.4361)
1= HH suffered member death-illness	-0.0907	-0.1017
	(0.4820)	(0.4355)
Community and regional variables		
community distance to nearest town (mi)	-0.0053	-0.0039
	(0.3458)	(0.5161)
farmer distance to his main mill (mi)	0.0021	0.0027
	(0.5789)	(0.4636)
1=community has access to 2+ cane mills	0.1571	0.1900
	(0.2174)	(0.1805)
1= Buganda subregion	0.1993	
	(0.2954)	
1=Bunyoro subregion	0.6907**	
	(0.0000)	
1= Kamuli district		-0.7058*
		(0.0216)
1=Kaliro district		-0.1526
		(0.4070)
1= Luuka district		-0.3624
		(0.1549)
1= Mayuge district		-0.3743+
		(0.0579)
1= Buikwe district		-0.0374
		(0.9038)
1= Kaynga district		-0.0781
		(0.7815)
1= Mukono district		0.0579
		(0.8118)
1= Kikube district		0.7239*
		(0.0119)
1=Masind district		0.2541
		(0.2246)
Observations	537	537
Adjusted R-squared	0.240	0.262
Spatial dummies jointly significant (p=0.01)	Yes	Yes

Notes: statistical significance level indicators ** p<0.01, * p<0.05, + p<0.1; population-based sampling weights applied, and standard errors are clustered at household level. Source: Authors' computations from EPRC sugarcane household survey (2021).

Table 11. Mean values of recommended ratoon management practices

Recommended ratoon management practices	Busoga	Buganda	Bunyoro	Total
1= dismantling of ridges	0.632	0.755	0.880	0.676
1= shaving stubble (pruning root) at ratoon initiation	0.445	0.695	0.890	0.528
1= gap filling if > 45 cm gap between clumps	0.657	0.783	0.779	0.687
1= paired row planting system (optimize plant density)	0.560	0.640	0.661	0.582
1= trash mulching in alternate rows to conserve soil moisture	0.778	0.894	0.899	0.807
1= managing weeds	0.692	0.938	0.972	0.755
Number of practices 1 to 6 used on plot	3.764	4.705	5.081	4.035
1= ridges + stubble + paired row planting	0.325	0.420	0.578	0.366
No. of observations (n)	191	79	111	381

Source: Authors' computations from EPRC sugarcane household survey (2021).

The third main finding is that inorganic fertilizer use has a statistically significant and positive association with yield, though the magnitude is small – a 1% increase in the fertilizer rate is associated with only a 0.08 percentage point increase in yield (Table 10). Thus, a 10 percent increase in the fertilizer rate is associated with a 0.8 percentage point increase in yield. This is a rather low cane-fertilizer response rate, though if the dummy for seedling-from-mill is interacted with the fertilizer rate, the fertilizer response rate nearly doubles to 0.14 percent for a 1 percent increase in the fertilizer rate.

Fourth, quantity of labour used per acre also has a statistically significant and positive association with yield, indicating that 1% increase in labour use is associated with a 0.21 percentage point increase in yield. Thus, 10 percent increase in labour is associated with a 2.1 percent increase in yield. This may be related to yield gain from timely weeding and/or the ability to harvest quickly, both of which are labour-intensive activities. Fifth, households with a head who completed primary school have 40 percent higher yields on average than those with a head that has not completed primary (the base group). Higher head's education is typically positively correlated with household asset wealth, yet because input use and the ratooning dummy are separately included, it is not clear what education-yield relationship this education dummy is capturing. It may be serving as a separate proxy for better management skills and knowledge.

The price of herbicide does not have a significant association with yield, but its sign is negative as expected. Receipt of an extension visit in a prior year does not have a statistically significant association with yield, though it is positively correlated with ratooning and using seedling from a mill, which are. The sign on the titled plot dummy is positive as expected, as a more secure tenure provides the owner with an incentive to make investments he might now make otherwise. The sign on rented-in plot is negative, also as expected, though both are statistically insignificant. The household reported shocks related to weather, crop disease, or death/illness of a household member do not have a statistically significant association with yield, though the latter two have negative signs as expected.

The statistically significant spatial dummy for the Kikube district (that includes Hoima district) means that farmers in these two districts obtain 72 percent higher yield, on average, than those in Jinja & Iganga, the base group (Table 10). Farmers in Kaliro and Mayuge districts (Busoga) have 71 percent and 37 percent lower yield on average. Likewise, the statistically significant association between the subregional dummy for Bunyoro in the first column implies farmers in Bunyoro have 69 percent higher yields, on average, relative to those in the Busoga, the base category. A spatial dummy is an intercept shifter, and like the intercept, it captures the average effect of unobserved factors on the dependent variable cane yield. In other words, even after controlling for input use and a range of other factors known to influence cane yield at the plot, household, and community level, Bunyoro cane growers still obtain 69 percent higher cane yields on average than those in Busoga – and the factors behind that additional yield difference are not observed (i.e. not included as explanatory variables) and are thus unknown.

There are two most likely explanations for this 69 percent yield advantage of Bunyoro farmers – above and beyond the yield advantage they enjoy due to more prevalent use of improved inputs – are more consistent and better application of recommended crop, plot, and soil management practices and use of higher quality seedling material and inorganic fertilizer. Most farmers in Bunyoro are contracted with the large mills Kinyara and Hoima, and under their contractual agreements, employees of the large mills perform land preparation, planting, input application, weeding, and harvest on contracted farmer cane fields – not the farmers themselves. This could result in good management practices being implemented more consistently and properly in Bunyoro. Another potential source of yield gain could be use of higher quality inputs, as most are sourced by Kinyara and Hoima themselves. Further research is warranted to better understand this large yield gap between cane growers in Bunyoro region relative to Busoga and Buganda.

It should also be noted that the study team learned through qualitative focus group discussions and key informant interviews in Bunyoro that the contractual agreements between the Bunyoro farmers and Kinyara/Hoima were 24-page complicated contract documents that the farmers were required to sign, which at the time they did not understand (Mbowa et al, 2023). While grower associations could theoretically assist individual growers with understanding such contracts and agreements with the mills, cane grower associations in these regions are quite weak and have limited capacity (ibid, 2023). In addition, there has effectively been no public sector oversight of grower-miller institutional arrangements for many years. These issues all warrant consideration by the government and industry stakeholders as the existing cane industry policy and enabling environment framework is being reviewed.

The dummy variable indicating that a community two or more mills does not have a statistically significant association with yield, though the sign is positive. This is perhaps not surprising as the benefit to growers of miller competition – higher cane purchase prices – would be seen in profits per acre, not necessarily yield. Second, the level of competition in Busoga became so strong that coordination on both input access and cane supply and demand in the region declined so far by

2021 that it would appear to be a factor in the region's lower input use on average. A discussion of the role of institutional arrangements within the cane industry between 2012 and 2021 (Mbowa et al, 2023) notes that there is an inherent trade-off between the benefits for growers of increased competition between mills (higher cane prices) and the benefits of tighter grower-miller coordination (better grower access to quality inputs and extension, and strong market assurance) (Poulton, Kydd, & Dorward, 2004).

Additional specifications are estimated that include dummies for the upper for quintiles of household landholding in place of the landholding variable and a separate regression using quintiles of total cane acreage instead. The results indicate that there is an inverse relationship between farm size and cane yield (and total cane area and cane yield), which is a common finding across many crops in a context where farm labor is the main power source for input application, weeding, and harvesting.

Ratoon management practices and cane productivity

To assess the potential for associations between recommended ratoon management practices and cane productivity, dummy variable indicators of each of the 6 ratoon management practices described in section 4.2 are included in an OLS regression of cane yield using a specification nearly identical to that shown in Table 10.[14] Table 10 Specifications estimated included: each individually to begin; then two at a time, then up to five at a time; second combinations of practices without high correlation between them; and finally, the management practices were combined into a single count variable of the number of practices implemented on a given cane plot, and this was included within the specification (and not the separate management dummies). It is important to note that as these practices were only recorded for plots that had been ratooned in 2021, which represents 65 percent of the n=537 farmer plots that were harvested in 2021, the following results are only representative of farmers who were able to harvest and sell that year.

All the practices except for shaving stubble at root initiation in Busoga are used by more than half of the growers in any given region that are currently ratooning, and the most frequently used practice is trash mulching in alternate rows to conserve soil moisture and managing weeds, which were used by 81 and 76 percent of growers, respectively (Table 11). We find that the count variable "number of practices used on the plot" has a statistically significant and positive association with cane yield, indicating that adopting an additional ratoon management practice is associated with 4 percent higher cane yield. None of the ratoon management practice dummies had a statistically significant association with cane yield (of ratooned plots) on their own, though the combination of (i)

[14] Explanatory variables used to investigate potential association between ratoon management practices and cane yield include those shown in Table 10, though total labor days/acre variables are dropped and replaced by the log of farm wage in the community and the household number of working-age adults per acre. The reason for this is that actual labor days could be higher due to implementation of the practices, though use of total labor days/acre results in the same findings. The ratoon dummy is also dropped because it =1 for all cases for which management practices are observed.

dismantling of ridges; (ii) shaving stubble at ratoon initiation; and (iv) paired row planting system to optimize plant density is associated with a 15 percent increase in cane yield.

To better understand what farmer characteristics might be associated with use of ratoon management practices, we estimate a Poisson regression of the number of ratoon management practices using the controls for the OLS regression. We find that a farmer-plot that has received a cane-specific extension visit in 2021 or before from a mill is associated with an additional 0.8 management practices adopted, on average, holding other factors constant. Likewise, receipt of a cane-specific extension visit from another source (NGO, government, farmer group) is associated with an additional 1 management practice adopted, on average. However, it should be noted that most cane-specific extension has been provided by mills, as 36 percent of cane growers that harvested in 2021 reported receipt of cane-specific extension from a mill in 2021 or a prior year, compared with only 9.8 percent that received cane-specific extension from another source. Results for several control variables are consistent with expectation, as a farmer-plot that is rented-in is associated with -0.6 fewer management practices used, a death or illness in the households is associated with -0.5 fewer practices used, and the sign for the indicator of a titled plot is positive.

Caution should be taken from these findings related to extension access, as household receipt of extension can be correlated with unobserved farmer characteristics and potentially lead to coefficient bias. Given that farmer management skill and knowledge would likely have a positive association with both cane yield and adoption of recommended management practices, our inability to adequately control for a farmer's management skill and knowledge would likely result in any coefficient bias being upward.

Analysis in this section found that some ratoon management practices are associated with higher cane yields. It seems clear from results of Table 10 that adoption of good crop and soil management practices can pay off with in the form of higher yields, though for farmers to be convinced to make the kinds of labor investments needed to implement them, they ideally could view local demonstration plots and/or attend field days focused on practices. Many farmers that are ratooning are already using these practices, which in part is why they are able to ratoon in the first place. Future research on cane crop and soil management practices could collect plot-level input-output data on cane yields an ask both ratoon and non-ratoon crop producers more specific question about whether they have heard of some specific crop and soil management practices, where did they hear or see the practice implemented, have they ever tried it (why or why not), and do they still use it.

VI. DESCRIPTIVE ANALYSIS OF CANE GROWER COSTS OF PRODUCTION AND PROFITABILITY

Institutional arrangements, market access, and profitability

Profitability of cane production in Uganda varied considerably by region and type of buyer in 2021. In the context of an oversupply of cane in 2021 relative to demand, cane profitability also depended on whether a farmer with mature cane was able to find a buyer to which he could harvest and deliver his cane or resort to selling unharvested cane from a plot for a considerably lower price. In In addition, institutional arrangements between growers and millers had a strong influence on the buyer options that farmers had to choose from – their level of market access – which in turn influenced the profitability of their cane production. This section begins by looking at how cane profits per acre vary by a farmer's access to a willing buyer.

It should be noted that profitability analysis is not feasible for the 43 percent of mature cane plots that remained unharvested at the time of the household survey (Table 2) due to data limitations[15]. Fortunately, the oversupply of cane observed in 2021 eventually fell back to (and below) the level demanded in 2022, millers subsequently began to raise their purchase prices and buy cane again, and growers with mature, unharvested (old) cane in 2021 were eventually able to sell it in 2022 (reportedly). It is also important to note that results for Bunyoro need to be taken with significant caution as production costs reported by Bunyoro farmers as the field work team felt that many Bunyoro farmers had underreported their production cost[16]. While the computations in the tables in this section only include plots from Bunyoro where the farmer had reported an input cost for each input that had been used on his plot (including draft power and hired labor), more work is needed to investigate and verify that these cases do not exhibit underreporting of input costs. Nevertheless, this subset of Bunyoro cases is included in the analysis in this section because profitability is a function of several components, only one of which is total costs of production per acre. We have confidence in the information provided by Bunyoro farmers on other components, such as Bunyoro cane yield (quantity harvested per acre), the quantity sold per acre, cane sale price per ton, and whether a given input was used or not on a farmer's plot.

The first main finding is that there was a considerable difference in mean and median cane profits per acre by region in 2021. For example, cane profit per acre in Buganda (1,241,772 Ush/acre) is nearly double the mean from Busoga (683,668 Ush/acre), and profit per acre in Bunyoro (2,410,564

[15] The main data limitation for constructing a rough estimate of the profitability of unharvested plots is the lack of recall information on the farmer's typical yield on the plot or the yield the prior year (2020).

[16] This was primarily due to the fact that farmers contracted with the two large millers there (Kinyara and Hoima) did not engage in land preparation, input application, or harvesting of their cane plots – employees of the millers did this, as per the arrangement stipulated by the grower-miller contracts in that region.

Ush/acre) is double that of Buganda (Table 12). The regional difference in median profits per acre followed the same regional pattern but were even larger. There is an even larger difference in mean and median cane profits per acre between plots of farmers that harvested and sold cane to a mill or another buyer, at 1,423,440 and 1,195,000 Ush/acre, respectively, compared with those of farmers who sold unharvested cane in their field to a buyer, where both the mean and median were negative at -296,662 and -163,333 Ush/acre, respectively.

Table 12. Mean and median profit/acre by region and level of market access, plot-level, 2021

All farmer plots				*Farmer harvested & sold*			*Farmer sold crop unharvested*		
Region	mean	median	n	mean	median	n	mean	median	n
Busoga	683,668	100,000	339	1,201,256	1,044,000	216	(261,127)	(150,000)	123
Buganda	1,241,772	800,000	145	1,692,738	1,230,000	104	(734,558)	(525,000)	41
Bunyoro	2,410,564	1,920,956	125	2,417,458	1,920,956	124	495,957	495,957	1
Total	902,965	254,286	609	1,423,440	1,195,000	444	(296,662)	(163,333)	165

Source: Authors' computations from EPRC sugarcane household survey (2021).

The gross revenue earned by farmers selling unharvested cane was so low that such sales appear to have been made in financial desperation. It may be that these were farmers with mature cane but who could not find a buyer with a reasonable price for it, but also could no longer afford to wait for one, and they decided to cut their losses and sell the cane for whatever they could get, if only to free up the land for a different crop. This form of cane sale accounted for 31 percent of plots that were harvested in 2021, and the negative average profits per acre highlight just how vital reliable market assurance is for growers. Because some households have multiple cane plots, we next aggregate gross revenue and total costs per acre to the household level and recompute profits per acre at the household level. This does not change the pattern of significant regional differences in profitability, though mean and median profitability per acre is somewhat lower at the household relative to plot level (Table 13, left columns).

Table 13. Mean and median cane profit/acre by region and level of market access, household level, 2021

All farmers				*Farmer harvested & sold*			*Farmer sold crop unharvested*		
Region	mean	median	n	mean	median	n	mean	median	n
Busoga	703,639	122,222	245	992,265	605,474	147	(187,735)	(95,000)	98
Buganda	1,329,562	766,400	109	1,363,334	830,000	80	(296,292)	(198,810)	29
Bunyoro	2,309,114	1,880,281	112	2,068,744	1,803,129	111	495,957	495,957	1
Total	946,841	262,000	466	1,213,717	848,111	338	(194,723)	(95,000)	128

Notes: farmers that harvested at least one plot are included in the columns of table; those who had only sales of unharvested cane are in the columns to the right.

The second main finding is that regions with stronger grower-miller coordination (higher shares of farmers that are registered or registered-aided) have a lower share of plots that were sold unharvested in desperation. For example, only 31 percent of Busoga's plots that were harvested or sold unharvested in 2021 were controlled by farmers that were registered or registered-aided – i.e. relatively low coordination – and the region had the highest share of plots that ended up being sold unharvested (35 percent) (Table 14). Buganda had significantly better coordination, with 57 percent of plots managed by registered or registered-aided farmers, and the second lowest share of plots sold unharvested (18 percent). Bunyoro had the highest level of coordination, with 84 percent of plots managed by registered/registered-aided farmers and had less than one percent of their plots sold unharvested.

Table 14. Share of households that harvested/sold cane and those that sold cane unharvested (%), by region, 2021

Institutional Arrangement	Busoga	Buganda	Bunyoro	Total	Region	Harvested & sold cane	Sold cane unharvested	Subsample total
	--- share of plots (column %) ---					--- share of plots (row %) ---		
Registered-aid	7	50	83	19	Busoga	65	35	100
Registered	24	7	1	20	Buganda	82	18	100
Spot seller	60	31	15	53	Bunyoro	99.6	0.4	100
Mixed	9	12	1	9	Total	70	30	100
Total	100	100	100	100				

Source: Authors' computations from EPRC sugarcane household survey (2021).

Third, while both large and small mills failed to fully honor their commitment to buy mature cane from all their registered and registered-aided growers in 2021, market assurance from large mills was somewhat stronger compared with small mills. For example, only one percent of plots of registered-aided farmers and zero percent of plot of registered farmers with a large mill ended up sold unharvested in 2021, compared with 10 percent and 16 percent for plots registered-aided and registered with a small mill, respectively (Table 15). The same pattern is seen with farmers engaged in a mixed arrangement. For example, only 16 percent of plots managed by farmers using a mixed arrangement (spot selling and registration/registration-aid) with large mill registration sold unharvested plots, compared with 50 percent of those with the mixed strategy and registered with a small mill.

Table 15. Share of households that harvested/sold cane and those that sold cane unharvested (%), by institutional arrangement, 2021

Institutional Arrangement	Harvested & sold cane	Sold cane unharvested	Subsample total	Did HH sell cane unharvested? No	Yes	Subsample total
	--- share of plots (column %) ---			--- share of plots (row %) ---		
Registered-aided, large	18	1	13	99	1	100
Registered-aided, small	8	2	6	90	10	100
Registered, large mill	9	0	6	100	0	100
Registered, small mill	16	7	14	84	16	100
Spot seller	41	81	53	54	46	100
Mixed - large mill	6	2	5	84	16	100
Mixed - small mill	3	6	4	50	50	100
Total	100	100	100	70	30	100

Source: Authors' computations from EPRC sugarcane household survey (2021).

Fourth, both mean and median household-level cane profitability is higher for farmers that are registered-aided compared with those that are registered, while those that are registered have higher mean/median profitability than spot sellers or using a mixed arrangement (Table 16, left columns). This difference is seen whether plots sold unharvested at lower prices are included in household cane profitability in 2021 (Table 16) or if they are not (Table 17). In addition, mean and median profitability in 2021 was higher for farmers that were registered-aided, registered, or in a mixed arrangement with a large mill relative to a small mill (Table 16, right columns).

Table 16. Mean and median cane profit per acre by institutional arrangement and large/small mill, 2021

Institutional Arrangement	Profit/acre mean	median	% hhs	N	Institutional Arrangement	Profit/acre mean	median	% hhs	N
Registered-aid	1,440,629	912,333	20	162	Registered-aid, large	1,483,308	1,033,699	13	91
					Registered-aid, small	1,350,306	766,400	6	71
Registered	801,589	513,818	19	58	Registered, large mill	1,398,830	769,765	6	25
					Registered, small mill	514,092	254,286	13	33
Spot seller	501,965	33,333	55	214	Spot seller	501,965	33,333	55	214
Mixed	518,583	250,000	6	32	Mixed - large mill	1,078,630	968,750	3	23
					Mixed - small mill	(156,535)	(58,649)	3	9
Total	743,088	254,286	100	466	Total	743,088	254,286	100	466

Source: Authors' computations from EPRC sugarcane household survey (2021).

Table 17. Mean and median cane profit per acre by institutional arrangement and large/small mill, 2021

Institutional Arrangement	Profit/acre mean	median	% hhs	N	Institutional Arrangement	Profit/acre mean	median	% hhs	N
Registered-aid	890,774	588,571	12	70	Registered-aid, large	1,123,409	710,000	9	54
					Registered-aid, small	271,219	76,000	3	16
Registered	797,975	513,818	21	56	Registered, large mill	1,399,221	725,000	7	23
					Registered, small mill	514,092	254,286	14	33
Spot seller	474,077	33,333	60	197	Spot seller	474,077	33,333	60	197
Mixed	489,557	166,765	7	31	Mixed - large mill	1,040,394	664,667	4	22
					Mixed - small mill	(156,535)	(58,649)	3	9
Total	594,187	133,333	100	354	Total	594,187	133,333	100	354

Source: Authors' computations from EPRC sugarcane household survey (2021).

Given Bunyoro's significant profitability advantage over Busoga and Buganda regions, we re-estimate profitability by institutional arrangement and mill size using just Busoga and Buganda households, to avoid having Bunyoro's high profits obscure the situation in the other two regions. In Busoga and Buganda, farmers with registration-aid or registration do not have higher mean or median profitability when considering the four IA categories (Table 18, left columns). However, when mill size is also considered, the farmers registered-aided/registered with a large mill have higher mean and median profits per acre compared with farmers that are registered-aided/registered with a small mill, as well as spot sellers (Table 18, right columns).

Table 18. Mean and median cane profit per acre by institutional arrangement and large/small mill, Busoga, and Buganda, 2021

Institutional Arrangement	Profit/acre mean	median	% hhs	N	Institutional Arrangement	Profit/acre mean	median	% hhs	N
Registered-aid	890,774	588,571	12	70	Registered-aid, large	1,123,409	710,000	9	54
					Registered-aid, small	271,219	76,000	3	16
Registered	797,975	513,818	21	56	Registered, large mill	1,399,221	725,000	7	23
					Registered, small mill	514,092	254,286	14	33
Spot seller	474,077	33,333	60	197	Spot seller	474,077	33,333	60	197
Mixed	489,557	166,765	7	31	Mixed - large mill	1,040,394	664,667	4	22
					Mixed - small mill	(156,535)	(58,649)	3	9
Total	594,187	133,333	100	354	Total	594,187	133,333	100	354

Source: Authors' computations from EPRC sugarcane household survey (2021).

Table 19. Mean and median cane profit per acre by institutional arrangement and large/small mill, Busoga, and Buganda, 2021

Institutional Arrangement	Profit/acre mean	median	% hhs	N	Institutional Arrangement	Profit/acre mean	median	% hhs	N
Registered-aid	973,663	696,182	17	63	Registered-aid, large	1,158,337	710,000	13	53
					Registered-aid, small	342,126	76,000	4	10
Registered	1,020,816	605,474	27	49	Registered, large mill	1,399,221	725,000	10	23
					Registered, small mill	794,037	605,474	17	26
Spot seller	1,113,670	715,000	47	99	Spot seller	1,113,670	715,000	47	99
Mixed	524,527	250,000	9	26	Mixed - large mill	1,058,675	968,750	6	21
					Mixed - small mill	(228,706)	(58,649)	4	5
Total	1,009,294	605,474	100	237	Total	1,009,294	605,474	100	237

Source: Authors' computations from EPRC sugarcane household survey (2021).

Components of cane profitability

To better understand differences in cane profitability by region and institutional arrangement, we next consider the three components of the crop profits per acre – the quantity sold (tons/acre), the crop price per unit (Ush/ton), and total costs/acre. While Bunyoro growers enjoyed 44 percent higher mean yields than Buganda growers (54 percent higher median yields), the mean and median quantities per acre that they were able to sell were only slightly higher than those in Buganda (Table 18). This is because about 17 percent of plots in Bunyoro have sale quantities that are 25 percent lower than harvested quantities, on average. About 15 percent of Buganda plots also had the same phenomenon, with average sale quantities 25 percent lower than harvested, on average. More research is needed to understand why this occurred, and why Busoga plots avoided these losses in potential sales. Nevertheless, Buganda and Busoga maintain higher average and median sale quantities per acre relative to Busoga.

Table 20. Quantity sold (tons/acre), gross cane price (Ush/ton), gross revenue/ac, total costs/acre and profit per acre: for farmers that harvested, plot-level 2021

	Quantity sold t/ac		Gross cane price/t		Gross revenue/acre		Total costs/acre		Profit/acre	
Region	mean	median	mean	median	mean	median	mean	median	mean	median
Busoga	25.3	21.0	80,126	95,000	2,154,222	1,810,667	1,062,506	730,000	1,201,256	1,044,000
Buganda	33.8	28.0	95,431	97,000	3,252,875	2,688,000	1,630,694	1,333,333	1,692,738	1,230,000
Bunyoro	34.9	30.0	92,426	91,500	3,199,822	2,771,874	945,665	757,895	2,417,458	1,920,956
Total	27.8	23.3	83,880	95,000	2,443,842	1,923,833	1,130,909	819,000	1,423,440	1,195,000

Source: Authors' computations from EPRC sugarcane household survey (2021).

Second, the median cane price paid in regions with competition from smaller mills (Busoga and Buganda) are 95,000 and 97,000 Ush/ton, higher on average than those in Bunyoro at 91,500 Ush/ton, a region without cane milling competition (Table 20). Yet, while the large mill in Busoga pays an average of 95,702 Ush/ton for cane, 30 percent of Busoga growers sold their cane to a trader (Table 21), whose average cane price 75,113 Ush/ton (Table 22), and 12 percent of Busoga growers sold to a transporter, whose average price was even lower at 25,420. By contrast, 12 percent

of Buganda growers sold to a trader, and none sold to a transporter. This explains in large part why the mean cane price in Busoga is 18 percent lower that of Buganda. Busoga's lower mean/median yields and lower mean prices explain why gross revenue/acre in Busoga is 17 percent lower, on average, than in Buganda. Buganda and Bunyoro have similar gross revenue because Bunyoro's yield advantage is tempered by somewhat lower cane prices.

Table 21. Share of plots by type of cane buyer and region (%), 2021

	Busoga	Buganda	Bunyoro	Total	Busoga	Buganda	Bunyoro	Total
Cane buyer	--- share of plots (column %) ---				--- share of plots (row %) ---			
Large mill	20	74	95	38	39	30	31	100
Small mill	25	6	1	19	95	4	0.5	100
Agent	6	2	3	5	87	6	7	100
Trader	30	12	1	24	92	8	0.4	100
Transporter	15	0	0	11	100	0	0.0	100
Farmer, farm group, etc	3	6	1	3	64	32	4	100
Total	100	100	100	100				

Source: Authors' computations from EPRC sugarcane household survey (2021).

Given the caveat noted above about the potential underreporting of cost of production data in Bunyoro, we compare total variable production costs per acre between Buganda and Busoga only. The mean of Buganda's total variable costs per acre is 60 percent higher than that of Busoga, while its median is 82 percent (Table 21). To better understand why Buganda's total costs are so much higher, we break down production costs by the share using each type of input and median input costs per acre

Table 22. Mean, median, and minimum prices by type of cane buyer (Ush/ton), 2021

Cane buyer	mean	median	min	n
Large mill (Busoga, Buganda)	95,614	96,000	70,000	128
Large mill (Bunyoro)	91,874	91,500	68,436	107
Small mill	94,417	97,000	78,000	51
Agent	70,442	90,000	30,000	24
Trader	75,113	90,000	12,500	79
Transporter	25,420	20,000	20,000	9
Farmer, farm group, other	93,213	96,000	20,000	18
Total	81,018	95,000	12,500	416

Source: Authors' computations from EPRC sugarcane household survey (2021).

Cane growers in Buganda were much more likely to use many types of inputs, such as pesticides, insecticides, or herbicides (chemicals, 77% of growers) compared with the 38% using chemicals in

Busoga (Table 23). They were also more likely to buy fertilizer (23% of plots compared to 13% in Busoga), cane seedling from a large mill (36 percent to 1 percent) and to hire labour (94 percent to 88 percent). Among farmers using the following inputs, Bugandan farmers also spent double the median amount per acre of Busoga growers on chemicals, 75 percent more on seedlings, and three times the amount on hired labour. Average expenditure shares of each input type in total variable costs of cane production show that expenditure on hired labour was easily the largest cost component for both regions, accounting for an average of 52 and 56 percent of total variable costs for Busoga and Buganda, respectively (Table 24). This is followed by 20 and 18 percent, respectively for seedlings. It appears that higher costs of hired labour and seedling material are the main reasons explaining why Bugandan costs of production are considerably higher than in Busoga. Although the average farm wage in Busoga of 9,727 Ush/day is higher than that in Buganda (5,876 Ush/day) (Table 25), Bugandan cane growers hire an average of 58 labor days per acre compared with 51 in Busoga (Table 26).

Table 23. Share of plots with expenditure and median cost per acre by input type and region, 2021

Region	Inorganic fertilizer	Pest/insect herbicide	Seedlings mill	Seedlings other	Draft power	Extension	Hired labor	Land rental
% of farmer-plots with expenditure on this input								
Busoga	9	32	1	46	47	2.3	88	45
Buganda	23	77	36	19	56	4.3	94	33
Bunyoro	35	22	19	3	45	2.3	100	7
Total	13	37	7	39	48	2.5	90	40
median cost per acre, among users								
Busoga	86,667	34,286		266,667	100,000	36,364	238,571	175,000
Buganda	100,000	66,667	500,000	466,667	120,000	66,667	740,000	200,000
Bunyoro	75,000	16,155	216,811	114,286	75,000	30,769	417,500	200,000
Total	86,517	42,857	429,594	266,667	100,000	36,364	266,667	175,000

Source: Authors' computations from EPRC sugarcane household survey (2021).

Table 24. Mean cost shares of variable inputs in total variable input costs for cane production, by region, 2021

Region	Inorganic fertilizer	Pest/insect herbicide	Seedlings	Draft power	Extension	Hired labor	Land rental
Mean shares of each input in total costs of production per acre							
Busoga	1.7	2.5	20.0	9.4	0.4	51.7	14.2
Buganda	2.7	8.1	18.3	7.9	0.2	56.0	6.9
Bunyoro	5.2	1.0	6.3	5.9	0.1	79.9	1.6
Total	2.2	3.1	18.6	8.9	0.3	54.8	12.1

Source: Authors' computations from EPRC sugarcane household survey (2021).

Table 25. Unit prices of inputs

Region	Price of urea (Ush/kg)		Price of DAP (Ush/kg)		Price herbicide (Ush/litre)		Farm wage (Ush/day)		Land rental rate (Ush/acre, annual)	
	mean	median	mean	median	mean	median	mean	median	mean	median
Busoga	4,021	3,500	3,017	3,000	18,928	19,977	9,727	10,000	137,652	125,000
Buganda	3,056	3,000	3,213	3,250	17,278	20,000	5,876	6,667	159,138	122,500
Bunyoro	2,860	3,000	2,840	2,800	23,249	20,000	5,498	3,887	167,992	160,000
Total	3,729	3,500	3,020	3,000	19,294	19,977	8,615	10,000	144,780	125,000

Source: Authors' computations from EPRC sugarcane household and community surveys (2021).

Table 26. Labor use per acre

Region	No. days total labor per acre		No. days hired labor per acre		No. days family labor use per acre		Share of hired labor in total labor (%)	
	mean	median	mean	median	mean	median	mean	median
Busoga	60	38	52	26	8	0	78	100
Buganda	66	28	58	21	10	1	76	97
Bunyoro	47	35	40	28	7	2	79	93
Total	59	34	51	26	8	0	78	100

Source: Authors' computations from EPRC sugarcane household survey (2021).

VII. Conclusions

This paper uses descriptive and econometric analysis of household survey data from the three main cane-growing regions of Uganda to provide empirical evidence of the key factors associated with improvements in grower cane productivity, the extent to which institutional arrangements between growers and millers influence growers' access to inputs and market assurance, and whether and how these institutional arrangements influence cane growers' productivity and profitability.

Cane productivity and input use

There are large differences in average and median farmer cane yield across the three regions. For example, the average cane yield of 50 tons/acre in Bunyoro is 31 percent higher than Buganda's mean of 38 tons/acre, and 84 percent higher than Busoga's mean of 27 tons/acre. There are also significant regional differences in input use, with Buganda and Bunyoro typically having more prevalent use of inputs and access to extension. For example, 45 and 34 percent of growers in Buganda and Bunyoro, respectively, used cane seedling from a large mill – compared to only 1 percent of plots in Busoga. Likewise, nearly half the plots in Bunyoro received inorganic fertilizer, compared with 28 percent in Buganda and 16 percent in Busoga. Finally, 64 and 68 percent of plots

in Buganda and Bunyoro, respectively, were owned by farmers that had received a cane-specific extension visit in 2021 or prior, compared with 25 percent in Busoga.

Econometric analysis of cane yield finds four explanatory variables that have a statistically significant positive association with cane grower yield that are also within a farmer's control, including: use of cane seedling from a large mill, having a cane crop in ratoon, application rate of inorganic fertilizer, and total labor days used per acre. First, use of cane seedling from a mill is associated with 25 percent higher yield, on average, than use of seedling from another source – such as own seedlings or those purchased from a neighbour, farmer group, or trader. This result is consistent with key informant reports that fresh, quality seedlings provide better cane yield than seedlings that have been recycled for many harvests, and that many farmers have been recycling their seed for too long or buying over-recycled seedlings from others.

Second, a cane plot that is currently in ratoon has a 31 percent higher yield on average compared with plots not being ratooned. However, because ratooning is not expected to improve cane yield compared with a first cane harvest, it appears that the dummy variable used to indicate that a plot is ratooned is functioning as a proxy measure of farmer use of good crop, plot, and soil management practices. The survey data provides support for this interpretation as farmers with a cane plot in ratoon used an average of 4 of the 6 most recommended management practices for cane production. In addition, separate regression analysis of ratooned plots that includes a count variable "number of practices used on the plot" finds that adopting an additional ratoon management practice is associated with 4 percent higher cane yield. That said, the magnitude of the positive yield gain from use of good management practices may be overstated to some degree due to the study's inability to fully observe and thus control for use of good management practices and farm management skill.

Third, inorganic fertilizer has a statistically significant and positive association with yield, though the magnitude is small – as a 10% increase in the fertilizer rate is associated with only a 0.8 percentage point increase in yield. While this cane-fertilizer response rate doubles for farmers that also use quality seedlings from a mill, the magnitude of this association is still relatively small. Fourth, a 10 percent increase in labour is associated with a 2.1 percent increase in yield. This may be related to yield gain from implementing labor-intensive plot management practices, timely weeding, or the ability to harvest quickly.

Fifth, even after controlling for input use and a range of other factors known to influence cane yield at the plot, household, and community level, Bunyoro cane growers still obtain 69 percent higher cane yields on average than those in Busoga and Buganda -- and the factors behind this additional yield difference are not observed. However, the two most likely explanations are that Bunyoro farmers have more consistent and better application of recommended crop, plot, and soil management practices and use of higher quality seedling material and inorganic fertilizer. This explanation is due to the fact that most farmers in Bunyoro are contracted with Kinyara and Hoima large mills, and under their contractual agreements, employees of the large mills perform land

preparation, planting, input application, weeding, and harvest on contracted farmer cane fields – not the farmers themselves. Such employees and their supervisors would likely have better knowledge of good management practices and the equipment to implement them. Further research is warranted to better understand and explain why the yield gap between the Bunyoro region and Busoga and Buganda regions is so large, even after controlling for input use.

Sixth, access to quality extension can facilitate farmer adoption of good management practices. For example, a farmer-plot that has received a cane-specific extension visit in 2021 or before from a mill is associated with an additional 0.8 management practices adopted, on average, holding other factors constant, while a cane-specific extension visit from another source is associated with an additional 0.9 practices adopted.

Institutional arrangements, market access, and access to inputs and extension

In Uganda, there is a clear trade-off (an inverse relationship) between the level of competition between large and small mills in a region and the level of grower-miller coordination of market assurance and input access. Market assurance is a joint grower-miller commitment to the sale/purchase of a grower's cane as indicated by the "registration" of a grower's cane plot by a mill, while input access consists of "aid", such as quality inputs and/or extension, possibly on credit, that is offered by mills to select registered growers. For example, the region with the highest competition between mills (Busoga) had the lowest grower-miller coordination, as only 8 percent of growers were registered-aided and 21 percent were registered. The region with more moderate miller competition (Buganda) had better coordination (57 percent of growers registered-aided and 8 percent registered), while the region with virtually no miller competition (Bunyoro) had much higher grower-miller coordination (86 percent of growers registered-aided and 1 percent registered). Likewise, the share of spot sellers – growers with no coordination with large or small mills for market assurance of input access prior to cane maturity -- is highest in the region with most competition (Busoga, at 65 percent) and lowest in the region with minimal competition (Bunyoro, at 11 percent).

Second, better grower-miller coordination was associated with better grower access to key inputs and services and with a higher likelihood of having a ratooned plot in 2021. For example, among plots managed by registered-aided farmers, 32 percent used cane seedling from a large mill, 67 percent received an extension visit from a large mill in 2021 or before, and 74 percent had a ratoon crop. By contrast, among plots managed by spot seller farmers, only 3 percent used cane seedlings from a mill, 21 percent received an extension visit from a large mill, and 57 percent had a ratoon crop.

Third, better grower-miller coordination was also associated with much better market access for mature cane in 2021. For example, the region with the highest coordination, Bunyoro, had the highest share of mature plots that were harvested and sold (59 percent) in 2021 and the lowest share of plots that were sold unharvested (i.e. at a very low price) at only 0.2 percent. By contrast, the

region with the lowest level of coordination, Busoga, had the lowest share of mature plots that were harvested and sold (36 percent) and the highest share of plots that were sold unharvested (21 percent). Nevertheless, farmers in all three regions were adversely affected by the significant oversupply of cane in 2021 as demonstrated by the fact that 41 to 44 percent of plots at or beyond maturity in 2021, depending on region, were not harvested due to lack of a buyer and/or a reasonable cane price offer. This oversupply represented a failure of adequate coordination by the public sector and the industry of the supply of and demand for cane at both region and national levels.

Profitability of cane production

There was a considerable difference in mean and median cane profits per acre by region in 2021, as cane profit per acre in Buganda (1,241,772 Ush/acre) was nearly double the mean from Busoga (683,668 Ush/acre). Profit per acre in Bunyoro was even higher than that of Buganda, though it is not cited here given uncertainty regarding the likely underreporting of costs of production in Bunyoro.

These regional differences in profitability were driven primarily by differences in levels of grower-miller coordination, as better coordination was associated with better market access and input access. For example, plots of farmers that harvested and sold cane to a mill or another buyer – i.e. good market access -- earned an average profit of 1,423,440 Ush/acre compared with an average profit/acre of -296,662 Ush/acre (a loss) for farmers who were forced to sell unharvested cane in their field to a buyer – i.e. poor market access. The gross revenue earned by farmers selling unharvested cane was so low that such sales appear to have been made in financial desperation. These were likely farmers with cane many months beyond maturity who could not afford to wait any longer for a buyer, so they decided to cut their losses and sell the cane for whatever they could get, if only to free up the land for a different crop. This highlights just how important market access is to growers, particularly during a period when cane supply significantly exceeds demand.

Differences in coordination by region also influenced the average cane prices received by growers received who were able to harvest and sell to a mill or other buyer. For example, while the large mills in Busoga and Buganda paid similar cane prices on average of 95,614 Ush/ton, the mean cane price in Busoga (80,126 Ush/ton) was about 18 percent lower than in Buganda (95,421 Ush/ton). The reason is that 30 percent of Busoga growers sold their cane to a trader, whose average cane price was 75,113 Ush/ton, and 12 percent sold to a transporter, whose average price was even lower at 25,420 Ush/ton. By contrast, 12 percent of Buganda growers sold to a trader, and none sold to a transporter. Higher average cane prices and cane yields resulted in significantly higher gross revenue per acre for Buganda growers compared with Busoga, though Buganda's higher costs of production per acre tempered this advantage to some extent.

Policy Implications

The evidence in this study shows how important strong coordination between growers and millers are for market assurance and grower access to quality inputs and extension. It also demonstrates that better access to and use of quality inputs and crop, plot, and soil management practices are associated with higher cane yield, and that better market access for growers is associated with higher farmer cane profits/acre. Fortunately, the oversupply of cane in 2021 eventually fell back to the level demanded in 2022, millers subsequently began to raise their purchase prices and buy cane again, and growers with old cane were eventually able to sell it (reportedly). Yet, the policy and enabling environment framework that enabled such an imbalance in grower-miller coordination of cane supply and demand to occur between 2018 and 2021 – along with significant financial losses for many growers – is still in place. That framework also enabled a near collapse of large mill provision of quality seedlings, inorganic fertilizer, and extension on credit to registered-aided growers in Busoga, and this appears to explain in part why their yields are considerably lower than those of Buganda and Bunyoro.

In response to the unprecedented financial and coordination challenges faced by the industry in the past few years (Mbowa et al, 2023), government and industry stakeholders are reviewing that framework with the recognition that it needs to be updated to reflect structural and institutional changes in the industry since the adoption of the 2010 National Sugar Policy and The Sugar Act of 2020 (Mbowa et al., 2023). The revised policy framework and enabling environment will require not only resolution and clarification of several contentious policy issues but also public sector oversight of grower-miller relations and better coordination of the national supply of and demand for cane (ibid, 2023). The success of this policy reform and implementation process in improving grower-miller relations and coordination is paramount if the industry is going to remain both financially sustainable and inclusive, as the outgrower scheme is the predominant way in which growth of the sugar industry can promote rural transformation and improve rural household incomes.

While farmer use of fresh, quality seedlings is vital to improving their cane productivity, a minority of plots (30 to 40 percent) used them in Buganda and Bunyoro in 2021 and only 3 percent in Busoga. Nearly all seedlings provided by a mill are from the large mills, which is likely because propagation of quality seedlings entails an upfront investment that is far too large for small mills given their lack of a nucleus estate. However, not all growers would or could obtain such seedlings via registration and aid with a large mill, and small mills are not able to provide this input. Because cane seedlings can be recycled by growers, agricultural research to develop and extension services to disseminate and promote them have characteristics of a public good. Given significant funding challenges faced by the National Agricultural Research Organization (NARO) of Uganda and the relatively small number of cane growers relative to those producing food crops, is it probably not realistic to expect the public sector to do much varietal work on cane. However, there are institutional modalities that have worked for other cash crops where a small levy (tax) on growers and millers is collected by the industry or government and reinvested back into development programs for the industry. Assuming an organization could be staffed and government by

representatives of growers, millers, and government, it could potentially contract out varietal development and propagation to large millers and even large cane growers and be funded by the industry levy. Another reason that varietal development beyond that controlled by large mills is needed is because, in recent years, the large mills have adapted some 12-month cane varieties for use on their nucleus estates, but they have not shared any of this material with growers. Grower access to a shorter duration variety could theoretically improve their incomes and income stability over time by enabling them to harvest cane more frequently.

Second, better coordination between farmers and quality, cane-specific extension services are vital for improving farmer cane productivity over time. The public agricultural extension system in Uganda is woefully underfunded for its existing crop mandate, and training public extensionists in cane productivity issues would not likely make sense anyway from a cost-benefit perspective, given how few cane growers there are compared with growers of food crops. Most cane-specific extension comes from large mills. This implies that a policy environment that improves coordination between farmers and large mills is a cost-effective way for cane growers to receive quality, cane-specific extension advice. However, because not all growers would or could be registered-aided with a large mill, a cane industry development fund could provide financing to grower associations, who could in turn hire private sector extensionists and coordinate provision of extension to farmers not registered-aided by a large mill. That said, this would be a significant challenge in practice as cane grower associations in these regions are quite weak currently, and the history of public sector interventions to build the capacity of grower associations has generally not been positive, though Tanzania has one cane grower association that manages to provide transportation services for grower delivery of harvested cane to mills.

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APPENDIX A.

Appendix Table A1. Approximate share of growers[1] by mill they report "still selling to in 2021".

Mill Name	Mill Category	Location	Busoga	Buganda	Bunyoro	All growers
Kakira	Large	Busoga	37.9			18.7
Mayuge	Small	Busoga	19.4	0.3		9.6
Kaliro	Small	Busoga	19.5			9.7
Kamuli	Small	Busoga	20.2			10.0
Scoul-Lugazi	Large	Buganda	2.1	88.6		21.2
GM	Small	Buganda	0.9	3.8		1.3
Ssezibwa	Small	Buganda		3.0		0.7
Victoria	Small	Buganda		4.3		1.0
Kinyara	Large	Bunyoro			64.7	18.0
Hoima	Large	Bunyoro			34.7	9.7
Kyenjojo	Small	Bunyoro			0.6	0.2
Bwendero	Small	Bunyoro			0.1	0.0
Total			100.0	100.0	100.0	100.0

Source: Authors' computations from EPRC Sugarcane Household Survey data. Notes: 1) Share computed across household-mill level cases, and some households sell to more than one mill, thus this is an approximate share of growers