

# Targeting millers to improve rice marketing in Uganda

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## Abstract

**Purpose** – Improving milling quality is expected to improve the quality of domestic rice and hence the competitiveness of Uganda's rice industry. Therefore, this study aims to assess the determinants of four aspects of milling, namely, choice of milling technology, millers' perceptions of the importance of paddy quality attributes, milling return and milling capacity.

**Design/methodology/approach** – Multinomial logit, semi-nonparametric extended ordered probit, linear regression and additive nonparametric models are applied to cross-sectional data obtained from a sample of 196 rice millers.

**Findings** – Physical, economic, institutional, technological and sociodemographic factors are found to be important determinants of the four aspects of milling. Physical factors include the distance of the mill from major town and availability of storage space at the milling premises, while economic factors include milling charge and backward integration of miller into paddy production. Contracting and use of a single-pass mill are important institutional and technological factors, respectively, and miller's household size, age, gender and education are the key sociodemographic variables.

**Originality/value** – The study's originality lies in its scope, especially in terms of its breadth. Without compromising the needed analytical rigor, it focuses on four aspects of milling that are critical to improving the marketing of Uganda's rice. In doing so, it provides a holistic understanding of this segment of the value chain and offers specific recommendations for improving the marketing of Uganda's rice.

**Keywords** Rice marketing, Rice milling technology, Milling return, Milling capacity, Paddy quality attributes, Uganda

**Paper type** Research paper

## 1. Introduction

Rice is considered a priority commodity in Uganda's agricultural sector strategic plan (Republic of Uganda, *undated*). Several interventions have been proposed to increase its production and competitiveness, among which are marketing-related interventions. Like other agricultural commodities, marketing of domestic rice involves several business activities that happen between the farm and final consumer, intended to enhance the



consumer's utility with respect to the form, place and time of consumption. One such activity is milling. It has a huge bearing on the marketed quantity, quality and consequently competitiveness of domestic rice.

Quantitative losses of up to 8% have been observed in milling (Ndindeng *et al.*, 2021), and the relatively poor quality of Uganda's milled rice has been primarily attributed to the milling segment of the value chain (Tokida *et al.*, 2014). Candia and Masette (2012) found milled rice to contain 64.3% broken rice, 0.8% foreign matter and 19.5 ppb of aflatoxin contamination. Most of the country's mills are small, old and of outdated technology that does not have destoning, polishing and grading capabilities, and the few modern medium- and large-scale mills are underutilized. Therefore, interventions aimed at improving the marketing of Uganda's rice must necessarily target this segment. Moreover, improvement in the performance of milling in terms of quality and quantity of milled rice would directly benefit other value chain agents, including farmers who sell their rice either as paddy or milled rice.

Four aspects of rice milling influence the milling quality [1] and the quantity of milled rice: type of mill, installed milling capacity, milling return and the quality of paddy, or more so millers' perceptions of the importance of paddy quality (Gummert *et al.*, 2010). The type of mill and paddy quality affect both the quantity and quality of milled rice. Evidence from Asia shows that modernization of rice milling, which would involve replacing the single-pass mill with a complete mill, would go a long way in improving the competitiveness of the rice industry (Barker *et al.*, 1985). Millers' perceptions of the importance of paddy quality determine the governance of rice value chains. Spot markets for paddy will likely exist where millers are indifferent about the quality of paddy (Soullier *et al.*, 2020). Otherwise, organizational arrangements such as formal and informal contracts (Gummert *et al.*, 2010), vertical integration and strategic alliances will ensue to enforce millers' quality control strategies. These arrangements influence the choice of rice varieties to grow, timing of rice cultivation, choice of agronomic and post-harvest practices, and consequently, the quantity and quality of milled rice on the market. The four paddy quality attributes considered in this study are moisture content, cleanliness, varietal purity and homogeneity, which are considered key to obtaining good-quality polished rice (Soullier *et al.*, 2020).

Installed milling capacity and milling return directly affect the marketed quantity of milled rice. At the industry level, the price of milled rice is the sum of the price of paddy equivalent, cost of milling the paddy equivalent and the value of the quality differential in milling, minus the price of any by-product (Lele, 1970). To put it simply and more generally, the price of a retail food product is the sum of the marketing margin (also known as the farm-to-retail price spread and which includes, among other things, processing and transportation costs) and the price of the farm product equivalent of the retail product (Wohlgenant, 2001). The price of the farm product equivalent is simply the ratio of the industry quantity of farm product to quantity of retail product times the farm price. That is,  $P^R = M + (Q^F/Q^R)P^F$ , where  $P^R$ ,  $Q^R$ ,  $P^F$  and  $Q^F$  are retail price, retail quantity, farm price and farm quantity, respectively, and  $M$  is the marketing margin. The ratio  $(Q^F/Q^R)$  is, in our case, the inverse of the aggregate milling return. Installed milling capacity, therefore, also indirectly affects the quantity marketed through its effect on the cost of milling. Assuming full capacity utilization, higher milling capacity lowers the cost of milling the paddy equivalent (through  $M$ ) and consequently the price of milled rice. This would in turn increase the demand for domestic rice. Likewise, higher milling return translates into a lower price of the paddy equivalent, hence a lower price of milled rice.

What are the determinants of millers' choice of type of mill, the importance of paddy quality attributes to millers, installed milling capacity and milling return? This paper examines the determinants of these four aspects of rice milling in the Ugandan context.

[Bagachwa \(1992\)](#) explains the choice of milling technology in Tanzania in terms of input requirements, technology characteristics, price–quality differences among technologies, factor prices for labor and capital, the miller’s choice of products and the nature of the products’ markets. Although the study is quite illuminating, two weaknesses are apparent: first, it was only qualitative, and therefore, the direction and magnitude of influence of these variables was not ascertained. Second, miller-specific characteristics were not considered. More recently, [Kapalata and Sakurai \(2020\)](#) estimate the determinants of adoption of quality-improving milling technologies in Tanzania. A probit model applied to a sample of 112 millers reveals that millers’ experience in buying and selling rice, the milling fee they charge and land ownership have a positive and significant effect on adoption of the integrated milling machine consisting of a paddy cleaner, destoner and rice grader. Elsewhere, [Noel et al. \(2002\)](#) apply multi-attribute utility analysis to one firm in the California wild rice industry to analyze its choice of two rice processing technologies – a traditional technology that either parboils or patches wild rice after curing and an experimental technology that provides for long-term storage of rice after curing. Six attributes that are thought to influence the choice of technology are considered: product quality, demand flexibility, technological risk, inventory carrying cost, barriers to entry and project costs. Product quality and demand flexibility are found to be the most important attributes in the firm’s choice of technology. [Dandedjrohoun et al. \(2012\)](#) analyze the determinants of adoption of improved rice parboiling technology in Benin using a probit model. They find membership in a parboilers’ association and participation in a video training on the technology to positively influence adoption.

Millers’ perceptions of the importance of paddy quality attributes reflect their quality preferences for paddy. For instance, in Benin, millers desire contracts (with producers) that have an agreement on the quality of paddy ([Codjo et al., 2019](#)). Indeed, the quality of inputs including paddy is perceived to be a significant source of risk in milling ([Ohen and Elemi, 2017](#)). However, where millers simply offer milling services, they are indifferent about the quality ([Department for International Development, undated](#)). Several attributes of paddy affect milling quality. Moisture content, varietal purity and homogeneity affect milling return and head rice yield, albeit to different degrees. For optimum head rice, paddy is milled at a moisture content of 14% wet weight basis ([Badi, 2013](#)). Analyzing perceptions of the relative importance of attributes or practices in production can be undertaken using hierarchical Bayes estimation to calculate utility and importance values (see, e.g. [Phillips et al., 2009](#)). However, it appears no empirical study has gone further to estimate the determinants of processors’ perceptions of the importance of paddy quality attributes.

Milling return is a function of pre-milling factors such as moisture content and maturity, and milling factors such as mill type ([Bonifacio and Duff, 1992](#)). The determinants of milling return have been estimated by [Lyman et al. \(2013\)](#) in a multiple regression model. They find that an increase in surface temperatures and harvest moisture content lead to a reduction in milling return. Regarding milling capacity, [Tokida et al. \(2014\)](#) apply a multiple regression model to data from a sample of 80 millers in Uganda. Only two of their seven explanatory variables are statistically significant; an increase in the milling machine’s horsepower increases the milling capacity, *ceteris paribus*, while use of the Engelberg type of mill is associated with a reduction in the milling capacity. In our study, we apply the same regression approach but with a different set of explanatory variables and a larger sample of millers. Additionally, for both milling return and milling capacity, our study employs parametric and nonparametric regression methods to find the best fit to the data.

The rest of the paper is structured as follows: [Section 2](#) provides an overview of rice milling in Uganda. Much of what is known about this segment has been documented by [Kikuchi et al. \(2013\)](#), and more recently by the [Rice Millers Council of Uganda \(2018\)](#). The reader is advised to refer to the two sources for more information. [Section 3](#) presents the

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analytical approach including the data. [Section 4](#) discusses the results, and [Section 5](#) concludes the study with implications for rice marketing in Uganda. Rice marketing in Uganda

## 2. Rice milling in Uganda

Rice milling has expanded over the past two decades in response to a steady increase in the country's paddy production. This was most notable between 2005 and 2009 when upland New Rice for Africa (NERICA) varieties were introduced and heavily promoted in the country ([Kijima \*et al.\*, 2013](#)). In 2012, there were 645 millers, 74% of whom were standalone, i.e. not integrated backward into rice farming; they provided milling services to farmers and traders in addition to procuring and processing paddy and selling the milled rice ([Tokida \*et al.\*, 2014](#); [Kikuchi \*et al.\*, 2016](#)). As of 2018, the number of millers had grown to 965, the majority of whom (829 or 86%) were small-scale, with installed milling capacity of up to 10 MT of milled rice per day or about one ton per hour ([Rice Millers Council of Uganda, 2018](#)). In a late-2019 meeting of rice industry stakeholders that included members of the Millers Council, the consensus was that the number of millers had since 2018 increased to 1,060, of whom 1,030 (97%) were small-scale. Over 50% of millers are in Eastern Uganda because of the region's relatively long history of rice cultivation ([Kikuchi \*et al.\*, 2013](#)). Small-scale millers, who mill approximately 95% of the paddy produced in the country ([Ministry of Agriculture, Animal Industry and Fisheries, 2012](#)), are mostly found in rural areas close to areas of paddy production, whereas medium- and large-scale millers are mostly located in urban areas ([Kijima \*et al.\*, 2013](#)).

There are three types of mills currently in use in Uganda, namely, single-stage (single pass) mill of the Engelberg type, two-stage mill and multistage (multiple pass) mill ([Tokida \*et al.\*, 2014](#)). The single-pass mill removes the husk and bran from the paddy in one pass to produce polished rice. This mill is common among millers located in smallholder rice farming systems. It is characterized by low milling return, low head rice yield and husk and bran that are mixed. The two-stage mill removes the husk from the paddy in the first stage to produce brown rice and removes the bran from the brown rice (i.e. polishes the brown rice) in the second stage to produce polished rice. This mill is superior in performance to the single-pass mill, and the husk and bran are separated and can be further exploited efficiently. The multistage mill undertakes several tasks in separate stages, including precleaning, destoning, hulling, paddy separation and polishing to produce polished rice. It is mainly used by large commercial millers and results in the highest quality and yield of milled rice.

The rapid expansion of the milling segment of the value chain has led to excess milling capacity as high as 59% of aggregate installed capacity ([Barungi and Odokonyero, 2016](#)). Medium- and large-scale millers operate at only 50% of installed capacity, despite having mills that are technologically superior to those of their small-scale counterparts ([Rice Millers Council of Uganda, 2018](#)). To increase capacity utilization, the Government of Uganda allowed certain millers to import brown rice at a reduced East African Community (EAC) Common External Tariff (CET) of US\$150 per MT (down from US\$345) for two years, starting May 2018, on condition that they boost paddy production by establishing nucleus farms and supporting out-grower schemes ([Muwanga, 2019](#)). But, more than two years later, there are no newly established nucleus farms and out-grower schemes. It is inconceivable that farmers would forgo the large profits from milled rice to supply their paddy to millers. Therefore, medium- and large-scale millers ought to invest in their own paddy farms to increase capacity utilization.

Grading of milled rice is guided by the EAC standards. There are three grades of milled rice for human consumption, with the following requirements, among others ([East African Community, 2011](#)): Grade 1: 5% broken, 13% moisture content, 0.1% foreign organic matter, 0.1% foreign inorganic matter; Grade 2: 7% broken, 13% moisture content, 0.2% foreign organic matter, 0.1% foreign inorganic matter; Grade 3: 15% broken, 13% moisture content,

0.5% foreign organic matter, 0.1% foreign inorganic matter. Most rice on the domestic market is ungraded (Kilimo Trust, 2012) probably because of lack of consumer willingness to pay for grading. However, rice traders looking to compete in the regional export market will have to act to make grading an indispensable part of milling operations.

Institutional support for rice milling is provided through the National Agriculture Policy (Ministry of Agriculture, Animal Industry and Fisheries, 2013), the National Industrial Policy (Ministry of Trade, Industry and Cooperatives, 2020) and the National Rice Development Strategy (Ministry of Agriculture, Animal Industry and Fisheries, 2012). For instance, the government has, through these policies and strategy, procured and distributed rice mills (Daily Monitor, 2020) and enforced tariffs and duties on rice, including the CET, which is by far the most critical policy measure for the industry (Ahmed, 2012). The Agriculture Sector Strategic Plan for 2020/2021–2024/2025 supports the training of millers on proper use of milling technologies, the establishment of a rice mill in a key rice growing area, creating awareness on rice quality standards and undertaking adaptive research on rice varieties with high milling return. One of the objectives of the National Rice Development Strategy is to improve the quality of paddy and milled rice, and to that end, training of millers and other value chain agents on quality issues is deemed a critical intervention.

### 3. Method

#### 3.1 Conceptual framework and empirical estimation

The choice of type of mill can be analyzed using a random utility model (RUM). In this model, an individual is assumed to derive utility by choosing an alternative from a set of discrete alternatives. The individual chooses the alternative that maximizes their utility, and that utility is a function of the attributes of the alternative and the individual's characteristics observed by the researcher, as well as the unobserved attributes and characteristics (Horowitz *et al.*, 1994). The observed factors appear in the deterministic (nonstochastic) component of the utility function as explanatory variables, while the unobserved factors are incorporated in the utility function through a random (stochastic) error term, hence the name random utility model. To empirically estimate the RUM, we assume that the components of the error term are independently and identically distributed across alternatives. This enables us to apply the multinomial logit (MNL) model (Greene, 2008). The determinants of choice of type of mill in our MNL model include miller's gender, education level, household size, whether or not the miller grows rice, distance of the mill from a major town, milling charge and whether or not the miller has a contract (formal or informal) with a paddy trader and with a milled rice buyer. We test three propositions [2]:

- P1. An increase in distance reduces the probability of choosing better milling technology.
- P2. An increase in milling charge increases the probability of choosing better milling technology.
- P3. Having a contract with a milled rice buyer increases the probability of choosing better milling technology.

Regression analysis of millers' perceptions of the importance of paddy quality attributes is undertaken using an extended ordered probit (hereafter, EOP) model, which nests the conventional ordered probit model (Stewart, 2004). A maintained hypothesis of the usual ordered probit model is that the cumulative distribution function of the random error term is the standard normal distribution. However, we find this assumption to be restrictive since its failure to hold would render our maximum likelihood parameter estimates inconsistent. The EOP model relaxes this assumption, and we estimate it using the semi-nonparametric (SNP) estimator derived by Stewart (2004). The estimator comprises a series of polynomial

densities, the relevant pseudo-likelihood functions and model selection tests. A model whose polynomial is of degree zero, one or two is simply the usual ordered probit model and one whose polynomial is of degree three becomes the first EOP model.

The perceived importance of a given paddy quality attribute is hypothesized to be a function of the miller's gender, miller's age as a proxy for milling experience, milling charge, distance to major town, possession of a contract with a farmer, contract with milled rice buyer, miller's level of education, type of mill and whether or not the miller grows paddy. For each paddy quality attribute, we test three propositions:

- P4.* Growing of rice lowers the miller's perception of the importance of the attribute.
- P5.* An increase in milling charge improves the miller's perception of the importance of the attribute.
- P6.* Attainment of tertiary education improves the miller's perception of the importance of the attribute.

Determinants of milling return and milling capacity are estimated using the classical normal linear regression model (Gujarati, 2003, p. 107). But, because we are uncertain about the functional form of their relationships, we also estimate them nonparametrically using the additive nonparametric model, which is not very prone to slow rates of convergence and the curse of dimensionality (Bin, 2000). Determinants of milling return are age, gender, education level of miller, distance of mill from major town, type of mill, if the miller undertakes certain operations such as drying paddy and storage, and the average number of days per week the mill is in operation. Milling capacity is likely a function of the same sociodemographic variables, as well the milling charge, possession of contracts with farmers, paddy traders and milled rice buyers, type of mill and paddy cultivation by the miller. We posit that:

- P7.* Use of a two-stage mill increases milling return.
- P8.* Use of a two-stage mill increases the milling capacity.

### 3.2 Data

Data were obtained from a nationwide survey of millers undertaken in August and September 2020. The survey covered the country's five geographical regions in which rice milling is a major activity: eastern, central, northern, north-western and western Uganda. An up-to-date list of millers in the country was not available to serve as our sampling frame, and the cost of generating one was unaffordable. To overcome this deficiency, we purposively selected districts in each region where rice milling is common. A total of 22 districts were selected, including Bukedea, Bugweri, Iganga, Soroti, Kumi, Butaleja, Namutumba and Mbale in eastern Uganda; Kampala, Luwero and Nakaseke in central; Gulu, Amuru, Nwoya and Lira in northern; Arua and Nebbi in north-western; and Kakumiro, Kasese, Kitagwenda, Rubirizi and Hoima in western. Because rice is mainly a cash crop, millers in the vicinity of the major rice markets in each district were identified, and about eight to nine millers willing to participate in the survey were interviewed. A total of 196 millers were interviewed face-to-face using a structured questionnaire (available from the authors).

Data were collected on several variables related to the millers' socioeconomic and demographic characteristics, mill types and milling operations, and external factors that impact the milling business. The models' dependent variables are measured as follows: type of mill is a dummy variable, where 1 denotes miller has a given type of mill, and 0 otherwise. Milling return is as previously defined (see Footnote 1), while installed milling capacity is the quantity of milled rice output per hour that the mill is supposed to produce. Varietal purity is defined as the proportion of paddy that meets the standards of a given variety

(Mapiemfu *et al.*, 2017), whereas homogeneity is the proportion of paddy that meets a standard sample in terms of grain size, shape, weight and color. Millers' perceptions of the importance of paddy quality attributes are measured on a four-point Likert scale, where 1 = least important, 2 = somewhat important, 3 = important and 4 = very important. A description of the variables used in the regression models and their summary statistics are provided in Table 1.

#### 4. Results and discussion

About 69% of millers have the single-pass Engelberg-type of mill. There has been an increase in the proportion of millers with this type of mill, from 52% found by Tokida *et al.* (2014). We find 25 and 6% of millers to have the two- and multi-stage types of mills, respectively. The average milling return is about 67%, which is consistent with the average rate of 65% observed by Tokida *et al.* (2014). The average milling capacity is 844 kg per hour.

Moisture content and cleanliness were perceived by most millers (73 and 57%, respectively) to be very important paddy quality attributes. Even for millers who only offer milling services and would therefore not be overly concerned about paddy quality, they are likely to be concerned about these attributes insofar as they affect milling quality and consequently the millers' reputation. Also, cleanliness is important because impurities such as stones and sharp objects can damage some parts of the mill. The least important attributes are varietal purity and homogeneity. This explains the rampant commingling of rice varieties on the Ugandan market. Other notable characteristics are that 66% of millers are rice farmers too, and 52% purchase paddy.

Variable	Mean	SD	Min	Max
Miller's age (years)	43.03	12.14	18	75
Miller's gender (0 = female, 1 = male)	0.92	0.27	0	1
Miller's household size	9.21	6.40	1	60
Miller completed tertiary education after senior 6 (0 = no, 1 = yes)	0.16	0.37	0	1
Mill's distance from major town (km)	7.88	9.51	0	50
Miller grows rice (0 = no, 1 = yes)	0.66	0.47	0	1
Miller purchases paddy (0 = no, 1 = yes)	0.52	0.50	0	1
Milling charge (UGX/kg of paddy)	135.20	37.21	80	300
Miller has contract with farmer (0 = no, 1 = yes)	0.41	0.49	0	1
Miller has contract with paddy trader (0 = no, 1 = yes)	0.22	0.42	0	1
Miller has contract with milled rice buyer (0 = no, 1 = yes)	0.25	0.43	0	1
Miller has single-pass mill (0 = no, 1 = yes)	0.69	0.46	0	1
Miller has two-stage mill (0 = no, 1 = yes)	0.25	0.43	0	1
Miller has multi-stage mill (0 = no, 1 = yes)	0.06	0.23	0	1
Mill performs paddy drying (0 = no, 1 = yes)	0.57	0.50	0	1
Mill has storage space (0 = no, 1 = yes)	0.63	0.48	0	1
Days mill is in operation each week	6.44	1.08	2	7
Milling return (%)	66.60	6.80	40	85
Installed milling capacity (kg of milled rice/hour)	843.91	818.26	50	5,000

  

Perceived importance of paddy quality attributes				
	Least important (%)	Somewhat important (%)	Important (%)	Very important (%)
Moisture content	12.50	2.08	11.98	73.44
Cleanliness	6.25	7.81	28.65	57.29
Varietal purity	41.15	13.54	22.40	22.92
Homogeneity	51.34	16.04	19.79	12.83

**Table 1.** Description and summary statistics of variables used in the regression models

The results of the MNL model of choice of type of mill are presented in Table 2. The single-pass type of mill is the base outcome. Although we obtain several null effects, the model is valid, and some key results emerge. The chi-squared ( $\chi^2$ ) statistic of 44.09 from the likelihood ratio test has a  $p$ -value of 0.0002. Thus, we reject, at the 1% level of significance, the null hypothesis that all coefficients across all equations are simultaneously equal to zero. The pseudo  $R$ -squared is not a particularly informative statistic in this type of model. Also, we use the likelihood ratio test to test three null hypotheses: there is no difference between millers with a single-stage mill and those with a two-stage mill; there is no difference between millers with a single-stage mill and those with a multi-stage mill; and there is no difference between millers with a two-stage mill and those with a multi-stage mill. For single-pass versus two-stage millers, we obtain a test statistic of 25.18, with a  $p$ -value of 0.0014, and for single-pass versus multi-stage millers, we get a statistic of 23.57, with a  $p$ -value of 0.0027. Therefore, we reject both null hypotheses at the 1% level of significance, implying that millers with a single-pass mill are different from those with a two-stage mill, and they are also different from those with a multi-stage mill. However, we find that millers with a two-stage mill are not any different from those with a multi-stage mill.

The greater the distance from a major town, the lower the likelihood (log-odds) of preferring a two-stage mill to a single-pass mill, holding other factors constant. The same is true for a multi-stage mill relative to a single pass mill. The two- and multi-stage mills are modern types of mills, which are unlikely to be situated deep in rural areas where there is no electricity or where electricity supply is erratic, and they require relatively skilled labor, which would be easier to find in urban centers. Also, rural areas are characterized by bad roads and road networks, which significantly increase the cost of doing business by reducing access to input and output markets. Investment in feeder roads ranks second in terms of impact on Uganda’s agricultural productivity, with a benefit-cost ratio of 7 (Fan and Zhang, 2008). It is reasonable to expect that an increase in investment in feeder roads would decrease the average distance of a miller to the nearest feeder road and major town. Therefore, it is imperative for the government to invest in road infrastructure to support the adoption of better rice milling technologies.

Variable	Two-stage mill		Multi-stage mill	
	Coefficient	RRR	Coefficient	RRR
Distance from major town	-0.06** (0.02)	0.94	-0.08* (0.05)	0.92
Grow rice	-0.40 (0.40)		-1.14 (0.75)	
Gender	1.31 (0.87)		0.91 (1.38)	
Household size	-0.03 (0.03)		-0.25** (0.11)	0.78
Milling charge	-0.002 (0.005)		0.01 (0.01)	
Contract with paddy trader	0.31 (0.55)		1.32 (1.11)	
Contract with milled rice buyer	1.19** (0.55)	3.27	0.66 (1.11)	
Education	-0.27 (0.55)		-14.24 (664.47)	
Constant	-1.37 (1.18)		-2.94 (2.21)	
$N = 187$				
$LR \chi^2 (16) = 44.09$				
$Prob > \chi^2 = 0.0002$				
Pseudo $R^2 = 0.156$				
Log likelihood = -119.411				

**Note(s):** Dependent variable is mill type, coded 1 = single-pass, 2 = two-stage, 3 = multi-stage. The base outcome is the single-pass mill. Figures in parentheses are standard errors. \*\*\*, \*\* and \* denote significant at 1, 5 and 10%, respectively. RRR denotes relative risk ratio

**Table 2.** Results from the MNL model of choice of type of mill

An increase in household size reduces the likelihood of opting for a multi-stage mill relative to a single-pass mill. Two reasons are plausible: the larger the household size, the greater is the proportion of income spent on consumption, and hence, the less the funds available for investing in better milling technology. Also, single-pass mills tend to be small-scale family-owned mills that serve as a source of milled rice for home consumption. That means they would be more appealing to millers with large households. Household size has been found to have a negative effect on the probability of Ugandan households investing in nonfarm enterprises (Deininger and Okidi, 2001), and a negative effect on rice technology adoption in the Philippines (Mariano *et al.*, 2012).

Lastly, having a formal or informal contract with a milled rice buyer increases the log-odds of a miller choosing a two-stage mill over a single-pass mill. This is unsurprising because a contract would stipulate stringent quality and quantity requirements that would compel a miller to adopt better technology to avoid financial loss and reputational risk. Certainly, the two-stage mill would engender some improvement in milling quality to enable the miller to fulfil their contractual obligations. This result underscores the importance of institutional factors in process and product upgrading of Uganda's rice value chains. However, having a contract with a paddy trader is not important in the choice of milling technology, and the model in which we included possession of a contract with a farmer did not yield meaningful results.

Although the results regarding the role of contracts are generally credible, we acknowledge the potential endogeneity of possession of a contract, including the possibility of reverse causality. That is, the possibility that adoption of better milling technology might influence possession of a contract. Endogeneity in the MNL model can be addressed using generalized structural equation modeling (Drukker, 2014). But, for lack of good instruments, we do not implement it in this study.

We calculate relative risk ratios for variables with statistically significant coefficients to obtain a better understanding of the results. Holding other factors constant, the relative risk of choosing a two-stage mill relative to a single-pass mill would decrease by a factor of 0.94 for a unit increase in the miller's distance from a major town. And, for multi-stage versus single pass, the relative risk decreases by 0.92. The relative risk of preferring a two-stage mill to a single-pass mill increases by a factor of 3.27 for a miller who has a contract with a milled rice buyer compared to one without such a contract.

The results of the EOP model of the determinants of the importance of paddy quality attributes as perceived by millers are presented in Table 3. The order of the polynomial used in all equations is 3, the default. For each equation, a likelihood ratio test of the null hypothesis of the ordered probit model against the alternative of an SNP EOP model produced the following  $\chi^2$  values: 10.36 for moisture content, with a  $p$ -value  $\equiv p[\chi^2(1) > 10.36] = 0.001$ ; 3.02 for cleanliness, with a  $p$ -value  $\equiv p[\chi^2(1) > 3.02] = 0.082$ ; 18.88 for varietal purity, with a  $p$ -value  $\equiv p[\chi^2(1) > 18.88] = 0.000$ ; and 13.42 for homogeneity, with a  $p$ -value  $\equiv p[\chi^2(1) > 13.42] = 0.000$ . Thus, we reject the null hypothesis at the 1% level for moisture content, varietal purity and homogeneity, and at the 10% level for cleanliness.

Certain patterns emerge in the results. Millers' perception of the importance of all the four paddy quality attributes declines from very important to least important if they decide to produce paddy for their mills. We conjecture that millers who produce their own paddy master these quality attributes and consider them in the paddy production process. When it comes to milling, they are more concerned with only those factors relevant to the profitability of the milling process, especially cost factors such as labor, energy, storage and transaction costs.

The importance of moisture content and homogeneity diminishes among female millers, which may be indicative of the presence of significant gender dynamics in rice milling. Barungi and Odokonyero (2016) found that women do not participate equitably in rice milling

Variable	Moisture content Coefficient	Cleanliness Coefficient	Varietal purity Coefficient	Homogeneity Coefficient
Grow rice	-0.43* (0.23)	-0.31* (0.19)	-0.53*** (0.15)	-0.32* (0.17)
Gender	-1.69*** (0.62)	-0.69 (0.43)	0.34 (0.21)	-0.62** (0.27)
Milling charge	0.01*** (0.003)	-0.001 (0.002)	0.01*** (0.001)	0.005*** (0.002)
Contract with farmer	0.36 (0.25)		-0.58*** (0.14)	-0.55*** (0.18)
Contract with milled rice buyer	-0.75*** (0.23)		-0.19 (0.19)	0.72** (0.33)
Contract with paddy trader			0.92*** (0.20)	-0.42 (0.34)
Education	1.10*** (0.28)	-0.66*** (0.25)	0.28* (0.17)	0.17 (0.18)
Miller has single-pass mill	-0.49** (0.23)	-0.27 (0.35)	0.31 (0.21)	0.98** (0.38)
Miller has two-stage mill			-0.16 (0.22)	0.30 (0.45)
Miller's age	0.01 (0.01)	0.02 (0.01)	0.004 (0.005)	0.001 (0.01)
Distance from major town		-0.0002 (0.01)	-0.02** (0.01)	-0.01 (0.01)
<i>N</i>	174	173	173	169
Wald $\chi^2$	66.17	15.07	234.64	106.41
Prob > $\chi^2$	0.0000	0.0351	0.0000	0.0000

**Note(s):** Figures in parentheses are robust standard errors. \*\*\*, \*\*, and \* denote significant at 1, 5 and 10%, respectively. Dependent variables are measured on a Likert scale where 1 = least important, 2 = somewhat important, 3 = important and 4 = very important

**Table 3.**  
Results from the EOP  
model of the  
determinants of the  
importance of paddy  
quality attributes

in Uganda, with their involvement relegated to less economically beneficial roles such as fetching water for the mill, preparing meals for mill workers, cleaning mill premises and winnowing and sorting milled rice. Consequently, women who eventually get to own mills are unlikely to be as knowledgeable about important paddy quality attributes relevant to milling as their male counterparts.

Another interesting pattern is that the higher the milling charge, the more important the attributes become, except cleanliness. A higher milling charge implies greater income for the miller, which they would want to sustain by taking the quality attributes more seriously. Regarding cleanliness, we have observed that millers in Sub-Saharan Africa are generally not concerned about the cleanliness of their paddy because of the wrong perception that rice is automatically cleaned during milling. However, this perception is right only for mills with pre-cleaning systems for paddy. It is important for millers to understand that paddy with a lot of impurities increases the cost of milling and decreases the durability of mills.

The effect of distance from a major town is significant only for varietal purity. That a longer distance lessens the perceived importance of varietal purity is probably because consumers in rural areas are not so picky about the quality of rice that they would reject milled rice of commingled varieties. Moreover, the more remotely located the miller is, the more likely they are to mill mostly for home consumption, thereby significantly lessening the importance of varietal purity. We obtain mixed results regarding the effect of contractual arrangements, education and type of mill. Entering a contract with a farmer diminishes the miller's concern about the importance of varietal purity and homogeneity. Contracts between millers and farmers usually encompass informal credit arrangements in the form of interlinked transactions in which the terms and conditions of credit and the purchase/sale of paddy are determined simultaneously in a single transaction. The miller-cum-lender normally has intimate knowledge of the farmer, and they can observe the latter's production practices, including their choice of rice varieties. This mitigates the potential for moral hazard, hence mitigating the principal-agent problem. However, entering a contract with a paddy trader heightens the miller's concern about varietal purity because they are not able to observe the trader's paddy purchasing behavior. The coefficient on contract with a milled rice

buyer is positive, as expected, for homogeneity but counterintuitively negative for moisture content. Also, the coefficients on education are positive and significant for moisture content and varietal purity, but unexpectedly negative for cleanliness. Lastly, use of a single-pass mill increases the importance of homogeneity. This is expected, considering that grain size and shape may dictate the type of mill to use (Badi, 2013). But, use of this type of mill has the opposite effect on moisture content; although moisture content greatly determines head rice yield, this mill is in any case expected to produce low head rice yield, regardless of the paddy's moisture content.

We now turn to the determinants of milling return and milling capacity, which are reported in Table 4, from linear regression models that have been tested for heteroskedasticity, multicollinearity and normality of residuals. In addition, the additive nonparametric specification of each model is estimated, and the results compared with those from the parametric specification. We find the results from the parametric specification to be only slightly better. Therefore, we eschew implementation of a formal model selection procedure. The results of the nonparametric model as well as those from diagnostic tests on the parametric model are available from the authors on request. The models are statistically significant at 1 and 5% for milling return and milling capacity, respectively.

In the milling return model, three variables are statistically significant, namely, miller's age, education level and availability of a storage facility at the mill. The coefficient on miller's age is negative. Clearly, age in this model is not a proxy for experience in rice milling. Rather, it captures depreciation of knowledge and skills, and changes in physical and mental capabilities (Aiyar *et al.*, 2016). Younger millers are likely to be physically stronger and mentally sharper than older ones, possess newer skill sets and are more adaptable to the rapidly changing information and communication technologies. As expected, milling return is significantly higher for millers that completed tertiary education after secondary school than those that did not. Availability of storage space at the mill is an incentive for the miller to optimize paddy purchases, milled rice output and the provision of milling services, which

Variable	Coefficient	
	Milling return	Milling capacity
Age of miller	-0.07* (0.04)	5.71 (5.71)
Gender of miller	1.45 (1.22)	
Education	2.20* (1.20)	-234.77 (179.46)
Distance from major town	0.06 (0.07)	
Grow rice		195.77 (152.63)
Mill has paddy drying facility	1.32 (1.18)	
Mill has storage facility	2.33** (1.14)	
Average number of days of operation per week	0.90 (0.58)	
Two-stage mill	-0.09 (1.40)	-38.10 (174.98)
Multi-stage mill		484.07 (326.20)
Milling charge		2.62 (1.90)
Contract with farmer		267.89 (170.58)
Contract with milled rice buyer		594.16** (275.07)
Contract with paddy trader		-813.16*** (298.22)
Constant	59.33*** (3.64)	90.86 (371.72)
N	169	151
Prob > F	0.0051	0.0273
R-squared	0.124	0.122
Root MSE	6.396	826.19

**Note(s):** Figures in parentheses are standard errors. \*\*\*, \*\*, and \* denote significant at 1, 5 and 10%, respectively. Dependent variables are milling return and milling capacity

**Table 4.** Regression results of the determinants of milling return and milling capacity

may include storage services. Therefore, millers with storage space are likely to be more efficient and consequently achieve higher milling return than those without storage space.

Milling capacity is positively and significantly influenced by a contractual agreement between a miller and a milled rice buyer. The stability of income that comes from an output supply contract encourages millers to invest in greater milling capacity, holding other factors constant. Paradoxically, an input procurement contract with a paddy trader has the opposite effect. This type of contract implies a commitment to a cash outflow. So, if a miller is risk-averse, they may disinvest in milling capacity to minimize the risk of having excess milling capacity when committed to a payment obligation.

## 5. Conclusion

The study uses primary cross-sectional data to assess different aspects of rice milling in Uganda, including choice of milling technology, millers' perceptions of the importance of paddy quality attributes, milling return and milling capacity. The results reveal the importance of physical, economic, institutional, technological and sociodemographic factors in influencing these aspects. Notable among the physical factors are location of the mill and presence of a storage facility on the milling premises. Millers located in rural areas are less likely to use modern milling technology and do not consider varietal purity to be an important paddy quality attribute. And, having a storage facility is good for milling return, holding other factors constant. Economic factors of importance are the backward integration of a miller into paddy production, which undermines their view of the importance of paddy quality attributes in the milling process, and the milling charge, an increase of which would have the opposite effect. The key institutional factor is contracting. A contract with a milled rice buyer encourages upgrading of milling technology and improves milling capacity, and one with a paddy trader improves the miller's perception of the importance of varietal purity. However, a contract with a farmer weakens the perceived importance of varietal purity and homogeneity, whereas one with a paddy trader reduces milling capacity. Regarding technological factors, we find that the use of a single-pass mill strengthens the miller's view that homogeneity is an important paddy quality attribute. Lastly, a miller's education, age, gender and household size are pertinent sociodemographic variables. Attainment of tertiary education after secondary school leads to higher milling return, but aging has the opposite effect. The larger the miller's household, the less likely they are to use a modern mill, and female millers do not consider moisture content and homogeneity to be important paddy quality attributes.

These findings have important implications for improving marketing of Uganda's rice. At the national level, public investment in hard infrastructure, including roads and electricity in rural areas, would encourage rural-based millers to invest in better milling technology. But, irrespective of their location, support to millers to upgrade their milling facilities should emphasize installation of storage facilities. Also, contractual arrangements between millers and milled rice buyers, and millers and paddy traders should be promoted. Lastly, young people should be encouraged to start rice milling enterprises. This is especially important in view of the high level of youth unemployment in the country. For further research, we recommend more in-depth analysis of the gender dimensions of milling to understand the nature of female millers and their enterprises. We also recommend examining the importance of cooperatives or a millers' membership in associations/groups to the four aspects of rice milling.

## Notes

1. We define milling quality as in [Siebenmorgen et al. \(2021\)](#): the ratio of head rice yield (HRY) to milled rice yield (MRY, also known as milling recovery or milling return). HRY is the proportion of whole grains based on the weight of paddy, while MRY is the proportion of milled rice based on the weight

of paddy. Because millers were unable to precisely determine their HRY, we use milling return as a proxy for milling quality.

2. In the statistical sense, we test, for each hypothesis, the null hypothesis that the association between a given variable and the choice of milling technology is not statistically significantly different from zero.

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