

Quality determinates of rice price in open bag markets in Sub-Saharan Africa

Quality determinates of rice price

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Received 4 February 2021

Revised 29 June 2021

2 September 2021

Accepted 3 September 2021

Abstract

Purpose – Weaknesses in the grades and standards system in low-income countries across Sub-Saharan Africa undermine the transparency of agricultural markets. In the Democratic Republic of the Congo (DRC), Ghana and Mozambique rice is predominately sold in open bags and if rice price does not reflect its quality, then inefficiencies may lead to consumer welfare losses. Importantly, it is possible that impoverished communities are priced out of the market due to inflated and inefficient prices. The objective of this study is to examine determinates of rice price by estimating the impact of selected rice quality attributes on rice prices in Democratic Republic of the Congo, Ghana and Mozambique.

Design/methodology/approach – We collected 363 rice samples from open air markets in Bukavu (DRC), Nampula (Mozambique) and across Ghana in 2019. Each rice sample was analyzed in a food science lab for the quality attributes: percentage of chalk and broken, chalk impact, length and length-to-width ratio. We used multiple regression analysis to estimate if and to what extent quality attributes were the drivers of price.

Findings – Findings suggest that there are irregularities in the Ghanaian market for broken rice and that regardless of quality, imported rice is priced higher than domestic rice. In the DRC and Mozambique, our results indicate price is driven by length and length-to-width ratio in the former and length-to-width ratio in the latter.

Research limitations/implications – Rice samples were purchased from market vendors and thus consumer preferences for attributes were not revealed.

Originality/value – These results provide valuable insight to policymakers regarding the need for proper labeling and regulation of open bag rice sales in an effort to increase consumer welfare and improve food security.

Keywords Broken rice, Mozambique, Democratic Republic of the Congo, Ghana, Open air markets

Paper type Research paper

1. Introduction

In Sub-Saharan Africa, rice is increasingly becoming an important food crop (Kihoro *et al.*, 2013; Muthayya *et al.*, 2014). Unlike in Asia where the growing middle class is reducing its rice

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The findings and conclusions in this manuscript are ours and should not be construed to represent any official USDA or US government determination or policy. All errors are our own.

Funding: Funding provided by the University of Arkansas Chancellor's Innovation and Collaboration Fund.



Journal of Agribusiness in
Developing and Emerging
Economies

Vol. 13 No. 3, 2023

pp. 361-378

Emerald Publishing Limited

2044-0839

DOI 10.1108/JADEE-02-2021-0038

consumption, increased rice consumption is linked to economic development and urbanization across Africa (Nasrin *et al.*, 2015). Although rice is the most important staple in the world, in terms of caloric intake, it is thinly traded on global markets. Only 7% of total rice production is traded globally ("PS&D", 2020). This is largely due to the fact that rice is mainly consumed where it is produced, and that rice is still a highly protected commodity. Strict import standards, including limits on the allowable percentage of broken kernels, standards on rice length and percentage of chalky kernels, can also limit trade if they do not closely reflect consumer preferences (Muthayya *et al.*, 2014). High-quality importation standards often drive up the price of rice and leave the poorest of the poor vulnerable to food insecurity.

Our study considers the functionality of the open bag rice markets of the Democratic Republic of the Congo (DRC), Ghana and Mozambique. For this study, a market is considered functioning efficiently when rice price (1) is a function of its quality attributes and (2) has the expected relationship with the quality attributes (e.g. negative relationship between price and percentage of broken kernels, etc.). We aim to estimate which, if any, quality attributes drive market pricing in open air markets. This study provides a unique perspective on rice in Sub-Saharan Africa because these three countries represent distinct rice policies, socio-political contexts and rice cultural heritage. All three countries are quickly growing in both population and rice consumption. Sparse literature documents how quality affects rice price in Ghana, and no studies have been conducted for Mozambique and DRC to our knowledge. Rice preferences in Africa are still evolving and remain heavily dependent on proximity to a port and indigenous rice consumption (Demont *et al.*, 2017; Demont, 2013). Historic urban bias, even in countries with rice heritage, has allowed higher quality, imported rice to flood the continent, which continues to shift consumer preferences. Thus, understanding what consumers value is of importance for plant breeders, food security experts, governments and food importers. Rice traders and governments that impose strict import standards on broken rice percentage, as in Nigeria and Haiti, only limits rice consumption to the upper class because such high-quality rice is expensive. This study investigates how markets in three African countries are pricing lower quality (higher chalk and broken percentages (Fitzgerald and Resurreccion, 2009) rice based on its attributes (see Appendix for rice quality details). If low-quality rice is priced accordingly this could signal that consumers can differentiate quality attributes and import standards could be lowered.

Beyond market motivations, this study also has environmental implications. Irrigated paddy rice is a water-intensive crop, accounting for approximately 25% of total global annual freshwater usage (Dobermann, 2012). Growing 1 kg of rice, on average, takes two to three times more water than other cereal grain crops (Tuong *et al.*, 2005; Grassi *et al.*, 2009). Given that two-thirds of the global population are now confronting water scarcity (Mekonnen and Hoekstra, 2016), and the fact that rice uses such large amounts of water, it is environmentally important that all rice goes to human consumption and not to an alternative use. In the United States for instance, it is common to use lower quality rice for pet food, thus the water-intensive rice crop does not make it to its intended market. Market pricing and consumer preferences across Africa need further examination to prevent "sub-quality" rice from entering the non-human food chain if low-income countries globally are willing to consume it. A large concern across Africa is the lack of standards and monitoring of open bag markets where there could be incentives for wholesalers and merchants to mix high- and low-quality rice and sell it at high-quality prices. If markets do not work efficiently, the presence of low quality rice could erode the market value for high-quality rice and cause market failure.

This study addresses several important questions related to rice markets in the DRC, Ghana and Mozambique. First, this study examines the efficiency of rice markets. Efficient rice markets are those where quality attributes are reflected properly in rice prices. A functioning market matches the preferences of consumers with the quality and price of

products; therefore, quality attributes consumers' desire, such as lower levels of brokenness and shape (e.g. length and width) should drive price in a functioning rice market. The open-air bag style markets across Africa make it difficult to visually differentiate the levels of quality characteristics. For example, an untrained eye would struggle to differentiate between 10 and 15% broken; however, there would likely be a difference in price. Regardless of packaging, without an enforceable system of certification for credence attributes, consumers have no guarantee that rice is being sold at the price that matches its quality. Thus, the first goal is to assess whether prices reflect actual quality. The innate difficulty for consumers to visually assess the specific level of a quality attribute of the rice in open bags, which are not labeled at a market, can lead to market failures. Inefficient markets can lead to inflated rice prices because the discounts for lower quality are most likely not being accounted for correctly. The inflated prices push the poor out of the market, making them unable to express their demand and participate in the market. In Ghana a survey of market shoppers found that low-, middle- and high-income consumers spent on average the same monthly budget on starches (characterized by rice, cassava and maize), yet that budget represented a much larger portion of low-income households monthly income (Amfo *et al.*, 2019). This has obvious food insecurity implications as the urban rich often drive rice markets in many low-income countries (Demont *et al.*, 2013).

If markets are working efficiently, consumer's preferences can be efficiently expressed. Thus, the second goal of this study is to determine which quality attributes are the major drivers of price in each country. This study uses the proxy of availability of various qualities of rice in markets as a signal that demand exists. By assuming in a functioning market that quality and price will match consumers' preference, we can determine which quality attributes are valued by consumers based on availability and price in the open bag market.

Our primary attribute of interest is the percentage of broken rice. If consumers indicate indifference to broken (proxied by insignificant or minimal price impacts), then there is an opportunity to segment the market accordingly. Offering more choices for percentage of broken rice allows consumers to purchase the rice that best meets their preferences and as importantly for food security in Africa – their budgets. Segmenting the market allows consumers to spend what they are willing and able to, to cover their rice demand. Nutritionally speaking, broken and whole kernels are nearly identical and have the same starch and protein content (Wang *et al.*, 2002). If it is found that broken play no role in rice price then it provides important evidence that broken should not be a constraint to importation.

Rice exporting countries will benefit from this study in three aspects. First, knowing the quality attributes that drive price across the three countries allows exporters to send the rice with specific attributes to specific countries. Secondly, broken rice can be sold at a higher price if consumers are indifferent to percent broken, which can increase the revenue exporters get from broken rice that would otherwise be sold as 100% broken rice for human consumption, or for non-human or indirect-human consumption uses (e.g. pet food or brewing). Increasing the percent of broken rice (harmonized system (HS) code 100640) exported as milled rice (HS 100630) could be particularly helpful for large Asian rice exporters, such as Thailand and India, with a significant presence in these African markets and large volumes of broken rice available. To illustrate, India and Thailand exported an average of 11 and 9 million metric tons of broken rice (HS 100640) a year in the period 2015–2019 (“UN COMTRADE”, 2003), some of which could be diverted into the production of milled rice (HS 100630) catered to specific markets where consumers are indifferent about percent broken. Lastly, rice demand can increase as the market matches more closely the preferences of consumers, including those potentially priced out of the market due to inefficient pricing.

Prior studies conducted in the Philippines (Unnevehr, 1986; Cuevas *et al.*, 2016) have regressed quality attributes, which are measured in a lab setting, on rice price to identify

consumer preferences. Our study adds to existing literature by using the similar methodology to analyze largely unexplored African rice markets. We specifically consider quality attributes that can be seen visually (search variables: broken, chalkiness, length and width) rather than physicochemical (amylose, texture, stickiness, etc.) attributes that cannot be determined without advanced analysis. This research gives insight into a rapidly growing staple crop in three rapidly growing countries. There is little in the way of previous rice attribute studies in Mozambique and DRC and while literature does exist for the Ghanaian market it does not specifically address the drivers of rice price (see [Appendix](#) for country details). This study can benefit rice exporters, rice policy makers, food security advocates, rice scientists and rice consumers by exploring what attributes drive rice price in each respective country.

2. Hedonic price model

Hedonic pricing assumes that the demand for goods is derived from the demand for specific attributes, or similarly, that a product is a basket of attributes, each contributing to the product's market price. Hedonic price models are rooted in Lancaster's theory of demand that states that a product can be described as a bundle of characteristics or attributes ([Lancaster, 1971](#)). Consumers choose which product to buy based on the bundle of attributes embedded in the product, and the price they pay is considered the revealed WTP for a product ([Lusk and Shogren, 2007](#)). Formally, we define the hedonic price model as:

$$P_i = \sum_k \alpha_k X_{k,i} + \varepsilon_i \quad (1)$$

where P_i is the market price for rice type i , $X_{k,i}$ is vector of selected quality variables k for rice type i , α_k is a vector of parameters and ε_i is the error term.

3. Data

Long grain non-fragrant rice samples were collected from ten markets across Bukavu, DRC (the sixth largest city in DRC and the capital of South Kivu province) in the summer of 2019. A total of 101 samples (each roughly 100 g) were purchased in open-air markets by the same participant who purchased the rice at all the markets in Swahili. At the point of purchase the price of the rice, in Congolese Franc (CDF), was recorded along with the weight of the rice (so we could standardize price per kg, as rice in DRC is sold in open bags and distributed by scooping cups of various sizes into a bag). All the collected samples were imported to DRC and non-parboiled. As an inland city, the dominance of imported rice in the Bukavu market is surprising; however, without having historic rice heritage ([Demont, 2013](#)), urban bias is likely driving the presence of imported rice.

Long grain non-fragrant rice samples were collected from nine markets across Nampula, Mozambique (the third largest city in Mozambique and capital of the Nampula province) in the summer of 2019. 112 samples (roughly 100 g) were purchased in open-air markets by the same participant who purchased the rice at all markets in either Portuguese or Makua (the local tribal language). Prices per kg were labeled on/in each bag in Mozambican metical (MZN) which the data collector noted with each sample. Like the DRC samples, all the collected samples were imported and non-parboiled. Mozambique falls into the category of coastal countries with a historic preference for local rice ([Arouna et al., 2021](#)), due to proximity to rice cultural heritage, as defined by [Demont \(2013\)](#). Despite the classification as a coastal country with a historic preference for domestic rice and increasing yields ([Arouna et al., 2021](#)), imported rice was the dominant presence in open air markets. The presence of imported rice could be attributed to a lack of supply of the preferred domestic

rice or could point to a change in rice preference due to large amounts of imported rice, as seen in Senegal by Britwum and Demont (2021). Future research is needed to further explore the influence of imported rice in Mozambique.

Long grain non-fragrant rice samples were collected from 14 markets across Ghana (10 clustered around Accra and four in northern Ghana) between July and August of 2019. A total of 150 samples were collected. The majority of the transactions were done in the Akan dialect, with a few in English. Local units such as “olonka”, “American tin cup” or “margarine tin” were used in purchasing each sample. These local units consist of empty cans or plastic containers with varying sizes that reflect the price, which was known prior to the purchase through signage. Similar to the DRC samples, in Ghana prices were determined by container size. Subsequently, the per kg price at which the samples were bought were calculated into an average score of its purchase price divided by its kg equivalence determined with an electronic weighing scale. Each sample was also labeled as imported or domestic and parboiled or non-parboiled.

In each of the three countries there was no negotiation in price, as the price for each type of rice in each location was delineated with signage. Prices in Mozambique were labeled per kg, in DRC and Ghana they were labeled by scoop (of various sizes which necessitated weighing each sample to get its per kg price). As is common in many African open markets, some vendors may put more rice to the top of the premeasured cup (mitigated by the weighing and standardizing of each sample) but this was not negotiated and each sample was purchased at its per scoop value. While bargaining is common in many African markets, it is less prevalent when prices are labeled. While not attempted for the reasons listed above, if bargaining did take place it was our *a priori* expectation that the relative difference in “bargained” prices would be equivalent to the labeled prices.

A potential criticism of the sampling by convenience method employed in this study is that the samples collected may not represent what consumers are actually buying and the price they pay since prices and quantities purchased by consumers were not observed. In an attempt to mitigate this, we purchased rice from multiple vendors in each market and went to several markets in each of the focus areas. Further, given that rice price was labeled and negotiation not common, we approximately know what consumers would pay if they purchased each type of rice which gives us a metric for revealed WTP.

All rice samples were analyzed in the Rice Processing Lab at the University of Arkansas. The SeedCount Image Analysis System, which is manufactured by Next Instruments (“Next Instruments”, 2020), was used to analyze each of the individual samples. From each sample, we used a random 20 grams to estimate various quality attributes. The SeedCount method used this 20-g sample to create a sub-sample for processing a 500-kernel sample and employed a flatbed scanner to create a digital image of each individual rice kernel. Kernel-by-kernel data was taken for each of the 500-kernel samples and then aggregated for an average score per sample. The SeedCount terminal setup uses a tray with individual slots for each of the 500-kernel sample with half of the kernels laying horizontally, allowing for a width measurement, and the other half laying vertically to measure length.

The SeedCount image analysis software uses a comparison of each kernels’ length with the average sample length to determine broken percentage (defined as less than three-fourths the sample average length). Broken and head (whole kernel) rice are the result of milling the hull and bran from the rough rice. Percentage broken is thus measured as the percent weight of a rice sample less than three-fourths the average sample length relative to the original rough, unmilled rice weight (see Appendix for further details on rice quality measurements). Chalky areas in rice grains, the opaque white parts of the grains, are deemed, generally, to represent poor quality in many rice market segments and thus can result in lower prices and demand (Fitzgerald and Resurreccion, 2009). Chalky areas in rice grains are caused by loose packing or incomplete filling of starch granules (Singh *et al.*, 2003). SeedCount further

quantifies rice chalkiness for each sample as chalk impact (rated from 0 to 100). Thus, from the SeedCount results we could quantify many of the search attributes deemed important for consumers in the three target countries; length, length-to-width ratio (LWR), percent broken and chalkiness for each of the 363 total rice samples. Although cleanliness has been cited as a relevant search attribute in Ghana (Sedem Ehiakpor *et al.*, 2017), and may likely be a relevant attribute in DRC and Mozambique, the overwhelming majority of the rice samples collected in the three countries were clean, which led us to exclude cleanliness from the model due to lack of data.

4. Empirical model

The variables included in all three datasets were identified as: length (mm), width (mm), length-to-width ratio, percent broken, percent chalky and chalk impact (ranging from 0 to 100). Using available variables, multiple regression analysis was used to estimate the impact of each quality attribute on the observed price. We used a log-log model so that the coefficients could be interpreted as elasticities to determine relative importance of quality attributes for determining rice prices. Eight models, consisting of different combinations of the independent variables, were estimated for each of the five scenarios: (1) Ghana total, (2) Ghana imported, (3) Ghana domestic, (4) DRC total and (5) Mozambique total, giving a total of 40 models estimated which are available in [Appendix](#). The same models were run for each country to allow for comparison. The models estimated for each country show the consistency in significance level of relevant variables along with limited variability in significant coefficients. The models included variations of all available quality characteristics. The quality characteristics' specifications and justifications are described below.

The human eye most realistically looks at rice kernels as a length-to-width ratio, giving a measurement for shape referred to as slenderness. The use of length-to-width ratio in combination with length is consistent with prior literature (Custodio *et al.*, 2019). By using length and the length-to-width ratio we account for both length, which is often used in export standards, and the shape of kernels, which consumers can visually identify.

Chalk has several definitions in the international market. There are differences between percent chalky kernels (which is used as the metric of grading in the United States) and chalk impact (which we use in this study). The US rice quality standard defines a chalk kernel as one with one-half or more of its area chalky. The percentage of chalk rice in a sample is the percentage weight of chalk kernels over the total weight of the sample. Chalkiness as we define it in this study, using the chalk impact measure, is the total area of a sample which is chalky. Chalk impact usually, though not always, gives a larger value of chalkiness. Regardless of which measure of chalkiness was used the results were similar. The zero values of chalk impact were replaced with a near zero number (1.0×10^{-35}) to allow for taking logs. The nature of our study requires analyzing a sample of a purchased sample, meaning a zero value of chalkiness from the lab analysis likely translates to a very low level of chalkiness in the open bag of rice available to consumers, that is not exactly zero. For this reason, we feel the replacement of zeros with an near zero number in the data is a reasonable assumption.

In Ghana, where parboiled rice is prevalent and has been shown to affect price, a dummy variable for parboiled observations was included. Previous research (Piao *et al.*, 2020; Tomlins *et al.*, 2005) found that in Ghana consumers, specifically in the south (Ayeduvor, 2018), prefer non-parboiled rice. Parboiling can strengthen rice kernels and therefore reduce brokenness. If a strong relationship exists between parboiling and quality characteristics, including a parboiled dummy variable would introduce multicollinearity in the model. For our sample of Ghana parboiled observations there is weak correlation (-0.313) between parboiled and brokenness. Given the previous literature which showed a preference for non-parboiled rice, we included a parboiled dummy. Further, unlike in DRC and Mozambique

where all samples were imported, Ghana had imported and domestic samples that were disaggregated into their own regression. Because previous literature has found that Ghanaians prefer imported to domestic rice, *ceteris paribus*, we wanted to test this hypothesis by estimating domestic and imported rice separately. By running three separate models by country (and two for domestic and imported rice in Ghana), rather than including fixed effects dummies, we allow flexibility of each quality attribute to vary by country.

Fixed effects for markets were tested in each country (shown in [Appendix](#)). The significance of the market binary variables varied by country, but the coefficients of the quality attributes remained largely unchanged after the inclusion of market fixed effects. Including the market fixed effects, ranging from 9 to 14 markets, decreased degrees of freedom without providing any new insights. It would stand to reason that rice is more homogeneous in quality attributes within a market as opposed to across markets, as vendors in a market may purchase from the same wholesalers. If this is the case then the market fixed effects could be capturing some of the explanatory power of the rice quality variables. As such, we pooled all markets together, by country, in the preferred model. Unlike the DRC and Mozambique, where samples were collected within the same city, in Ghana samples were collected in and around Accra as well as the North of the country. To account for spatial preferences or transportation cost differences, each model for Ghana included a locational fixed effect for Accra or “other”.

The preferred model was selected based on existing literature, while also considering adjusted R^2 and AIC comparisons. The consistency in our preferred model across the countries in this study allows for comparison of elasticities. The preferred model for DRC and Mozambique is as follows:

$$\log(\text{Price}) = \beta_0 + \beta_1 \log(\text{Broken}) + \beta_2 \log(\text{Length}) + \beta_3 \log(\text{LWR}) + \beta_4 \log(\text{Chalk Impact}) + \varepsilon \quad (2)$$

And the following equation for Ghana:

$$\log(\text{Price}) = \beta_0 + \beta_1 \log(\text{Broken}) + \beta_2 \log(\text{Length}) + \beta_3 \log(\text{LWR}) + \beta_4 \log(\text{Chalk Impact}) + \beta_5 \text{Parboiled} + \varepsilon \quad (3)$$

After the preferred model was estimated, the results for each country were tested for homoscedasticity using the Breusch–Pagan test. If the model was found to be heteroscedastic, the heteroscedasticity consistent covariance matrix was estimated using HC3 as in [Long and Ervin \(2000\)](#) due to our small sample size. Robust standard errors from HC3 correction were obtained using *R* version 4.0.2 and the Sandwich package and the *lmtest* package ([Zeileis, 2004](#); [Zeileis and Hothorn, 2002](#)). Models were also checked for multicollinearity, given the relationship between brokenness and chalkiness, using the variance inflation factor (VIF) function in the *car* package in *R*. None of our models indicated multicollinearity, defined as having a VIF above a threshold of ten. Additionally, the data was examined for breakpoints in the brokenness variable slope using piecewise linear regression and breakpoint analysis. This would reveal any thresholds of significance in brokenness, for example revealing that broken are only significant above 15%. The analysis was done using the segmented function in the segmented package in *R*. However, no significant breakpoints or thresholds were identified indicating that rice price and broken percentage had a linear relationship.

5. Results

Summary statistics for the quality attributes found through the SeedCount analysis are presented in [Table 1](#). The absolute differences in maximums and minimums for length and

	DRC	Mozambique	Ghana (Total)	Ghana (Domestic)	Ghana (Imported)
Price (USD)*					
Min	0.59	0.49	0.37	0.37	0.56
Mean	0.79 ^a	0.67 ^b	1.03 ^c	0.97 ^d	1.06 ^{cd}
Max	1.34	0.98	2.04	1.91	2.04
Std. Dev.	0.13	0.13	0.30	0.30	0.30
Length (mm)					
Min	5.88	5.77	5.69	6.08	5.69
Mean	6.87 ^a	7.01 ^b	6.86 ^a	6.71 ^c	6.94 ^{ab}
Max	7.56	7.6	7.73	7.36	7.73
Std. Dev.	0.30	0.25	0.33	0.27	0.34
LW ratio					
Min	2.48	2.27	2.30	2.44	2.30
Mean	3.00 ^a	3.02 ^a	2.91 ^b	2.69 ^c	3.03 ^a
Max	3.34	3.33	3.35	3.11	3.35
Std. Dev.	0.16	0.15	0.22	0.14	0.16
Broken (%)					
Min	0.5	1.5	0.3	0	0.3
Mean	8.77 ^a	7.3 ^b	8.81 ^{ab}	13.31 ^{ab}	9.05 ^{ab}
Max	19.2	22.5	40.4	26.9	40.4
Std. Dev.	2.76	4.20	9.87	5.76	11.58
Chalk impact (0–100)					
Min	0.49	0.18	0	0	0
Mean	3.7 ^a	3.5 ^a	6.98 ^b	15.25 ^c	2.32 ^d
Max	10.1	27.83	85.48	85.48	15.1
Std. Dev.	1.80	3.24	16.78	25.86	2.79
Observations	101	112	150	54	96
2018 per capita rice consumption (kg)	29.7 ^{**}	31.5 ^{***}	47.8 ^{***}	–	–

Table 1. Summary statistics for quality attributes

Note(s): *Exchange rate as of June 2, 2020; **Helgi Library (2020); ***Durand-Morat and Chavez (2021) Variables with different letters (a, b, c, d) indicate statistical difference at the 5% level

LWR appear to be relatively small, but this is due to the physiological properties of long grain rice, a kernel can only get so long and so wide. That being said, the relative differences between the maximum and minimums ranged from 12 to 35%. On average, the Mozambican sample had the largest kernel length at 7.01 mm and imported Ghanaian samples had the largest LWR at 3.03, indicating the most slender kernels. There is greater variation in both the measure of chalkiness and percent broken kernels. The lowest broken percentage was zero from a domestic Ghanaian sample and the highest was 40.4% from an imported Ghanaian sample. Chalkiness ranged from zero in both a Ghanaian domestic and imported sample to 85.48 in a domestic Ghanaian sample. On average the Ghanaian domestic rice was of lower quality in all categories (shorter, more chalky and with more broken). This result is consistent with previous studies (Ayeduvor, 2018; Alhassan *et al.*, 2016), which found that Ghanaian rice was of lower quality relative to imported rice.

6. Quality impacts

6.1 Percentage of broken

We find that in Ghana (both in domestic and in imported rice) and Mozambique increased broken reduce rice price. In Mozambique a 1% increase in broken would reduce price by 0.095% ($p < 0.01$) (Table 2). To put this in perspective, the difference between the maximum and minimum percentage of broken rice in the Mozambique rice samples was 21% (Table 1). This difference coupled with the estimated impact of broken on price would suggest that

Variable	DRC	Mozambique	Ghana (Total)	Ghana (Domestic)	Ghana (Imported)
Constant	4.626*** [0.837]	4.320*** [0.874]	-0.708 [1.129]	-0.597 [2.505]	-0.692 (1.219)
Log(Broken)	-0.006 [0.028]	-0.095*** [0.034]	-0.082*** [0.022]	-0.139* [0.074]	-0.076** (0.030)
Log(Length)	2.166*** [0.582]	0.920 [0.521]	1.644*** [0.627]	1.875 [1.463]	1.391* (0.778)
Log(LWR)	-0.677*** [0.250]	-0.874*** [0.259]	-0.210 [0.159]	-0.408 [0.475]	-0.016 (0.316)
Log(Chalk)	0.050*** [0.017]	-0.064** [0.026]	0.002 [0.001]	0.002 [0.003]	0.001 (0.001)
Parboiled	-	-	-0.301*** [0.076]	-0.355** [0.140]	-0.277*** (0.096)
R ²	0.277	0.411	0.303	0.362	0.233
VIF min	1.009	1.810	1.345	1.169	1.651
VIF mean	1.611	2.116	1.549	1.654	1.946
VIF max	2.187	2.414	1.757	2.003	2.376
Observations	101	112	150	54	96

Note(s): ***, **, * denote $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively; [] denote, robust standard errors and () represent non-robust standard errors

Table 2. Impact of rice quality variables on price

there would be a price difference of 2.00%, a small difference both in price difference and in range of brokenness. For reference, Cuevas *et al.* (2016) found a 9.7% price difference in the Philippines given the larger brokenness range of 2.4–66.4%. This would suggest that consumers care less about broken, and as such vendors do not adjust price for broken quantity. Alternatively, there is a market failure and because consumers cannot differentiate between samples with different percentages of broken, rice vendors take advantage of this. This result could suggest that rice may not be priced according to its percent broken, considering the Mozambican government stated the grading and standardization system in Mozambique for rice is weak (“Republic of Mozambique”, 2009). Further research is warranted in Mozambique to determine if consumers really do not discount broken rice (at a high percentage) or vendors are not pricing rice according to the broken percentage it contains. In the current markets, there appears to be little incentive for the rice supply chain to improve rice quality by reducing broken rice because either consumers are insensitive to percentage broken or the market is not providing a premium.

A similar story unfolds in Ghana (total sample) where the difference between maximum and minimum percentage of broken is 40.1% (Table 1) and the estimated coefficient on broken rice is -0.082 ($p < 0.01$) resulting in a difference in rice price of only 3.28%. Unlike Mozambique, there is existing literature on Ghanaian consumer preferences and broken rice has been found to be discounted (Sedem Ehiakpor *et al.*, 2017; Asante, 2013). Our results suggest that vendors are either (1) not pricing rice according to the percentage broken or (2) they simply do not know the percentage broken and thus price all visually similar rice equally. Asante (2013) interviewed 206 Ghanaian consumers about rice preference and 20 and 39% listed percentage of broken grains as either very important or important, respectively (out of four Likert categories, only 14% said it was not important). This seems to indicate the existence of some market inefficiencies, either from a rent seeking standpoint or simply from the supply chain not preserving the milling information.

The DRC estimates indicate that price was not a function ($p > 0.1$) of broken rice. Like Mozambique this warrants further research on consumer preferences as there has not been a consumer preference study on rice quality attributes in DRC. Our results indicate that either consumers are indifferent to broken rice percentage or markets are simply not pricing rice accordingly. It would seem unlikely that consumers would be indifferent given the high difference in maximum and minimum of broken in our sample period with the lack of market standards. If consumers were truly indifferent, it would be more profitable for vendors to sell higher amounts of broken, *ceteris paribus*, as they cost less to source.

6.2 Grain chalkiness

Chalk was not found to affect price ($p > 0.1$) in Ghana for all samples (domestic, imported and the pooled sample). This is an interesting result as Ghana had the highest average and largest standard deviation of chalk (Table 1). Diving deeper however, imported rice in Ghana had the lowest average chalk impact and a lower variance, indicating that given the low amount of chalk in imported rice and the fact that chalk values are consistently low and homogeneous across samples, the variation in chalk is not enough to warrant price changes. Conversely, domestic rice in Ghana had the highest chalk possibly indicating that domestic rice is simply priced as such, where imported rice may have differentiating price impacts (broken and length). Still, in Benin Ndindeng *et al.* (2021) found that reducing brokenness could increase consumer surplus more than reducing chalkiness. Our findings indicate that the same could be true in Ghana.

In Mozambique chalk was found to negatively affect rice price, with a 1% increase in chalk resulting in a 0.064% decrease (Table 2) in price ($p < 0.05$). The difference between the chalkiest average sample and the least in Mozambique was 27.65%, which would result in a price difference of 1.77%. While seemingly small, it is often difficult for consumers to assess chalkiness. Both chalk definitions (percent chalky and chalkiness) were modeled and chalkiness as we define it produced more robust results, having more statistical power with similar coefficients. Regardless of definition, it appears that chalk, while significant, is either not being priced correctly or is simply not a large factor in rice price in Mozambique.

Chalk in the DRC samples had the lowest variance, lowest maximum and relatively small mean. That being said, chalk was found statistically significant ($p < 0.01$) with a 1% increase in chalk resulting in an increase in price of 0.05%. While this result is counterintuitive the difference between the largest and smallest average chalk sample in DRC was 9.61% resulting in a price difference of 0.48% in price. Given the low variance and low mean chalk value it is likely that rice vendors simply cannot visually differentiate the “best” from the “worst” sample with regards to chalk. More research is warranted based on this result to see if vendors would price accordingly when the variance increases.

6.3 Kernel length and shape

When the Ghanaian samples are disaggregated, it was found that neither length nor slenderness (LWR) affected the price of domestic rice, and only length affected the price of imported rice, with longer kernels being priced at a premium (Table 2). One hypothesis on why domestic rice price is not a function of length or width while imported rice price is could be that imported rice is seen as superior to domestic rice and consumers are more selective when purchasing. The difference between the longest and shortest average sample grain length for imported rice in Ghana was 35.85% (Table 1) which would result in a price difference of 49.87% ($p < 0.05$).

Interestingly, in Mozambique slenderness was found to affect price with a 1% increase leading to a 0.874% decrease in price ($p < 0.01$) but price was not found to be a function of length. The difference between the largest average and the smallest average LWR sample collected in Mozambique was 37.86%. Using the estimated coefficient from Table 2 would result in a price difference of 33.09%, *ceteris paribus*. The negative relationship between price and slenderness could indicate a preference for bold grain types, especially when considering the insignificance to length in determining price.

In DRC, it was found that rice price is both a function of length and LWR with longer kernels being priced at a premium and more slender kernels being discounted. The difference between the average longest and shortest kernel length samples from DRC was 28.5% (7.56 and 5.88 mm, respectively). Given this and the length coefficient of 2.166 ($p < 0.01$) the difference in the price of the above samples is estimated to be 61.73%, *ceteris paribus*. A similar story is found for the effects of LWR on rice price in DRC where the difference between the largest and

smallest average ratio sample was found to be 29.55% (2.48 and 3.34, respectively), which would result in an estimated price difference of 20.0%, using the LWR coefficient of -0.677 ($p < 0.01$). With more slender kernels being discounted, there could be a preference for more bold grain shapes in DRC even with a premium being placed on kernel length.

7. Value heterogeneity across African countries

Having looked at differences between the three countries on an attribute level, we also considered the absolute difference in price on a holistic level for a rice sample sold in each of the three countries. Figure 1 shows the percent difference in price if the average sample of rice in one country was sold in another. The average sample is defined as the mean of the quality attributes from each country. The preferred model for each country, in Table 2, was used to calculate the average log price. The parboiled data in Ghana was not used in the percent difference calculation in DRC and Mozambique. Zero was used as the average of the parboiled quality attribute for DRC and Mozambique in Ghana. By showing the percent difference in price of the average sample compared to the base countries, Figure 1 visually depicts the unique preferences of each country.

Considering most of the rice imported to DRC, Mozambique and Ghana is of similar quality (Table 1), the statistical difference in price can largely be attributed to difference in preferences in each country. This highlights how rice is not a homogeneous commodity in that countries value the same sample differently. We should note these differences in price do not include any transportations costs. Therefore the difference in price should not be viewed as an opportunity for arbitrage, but instead as an illustration of the contribution of each quality attribute to the price in different markets.

7.1 Democratic Republic of the Congo

In DRC, the average sample of Mozambique rice would be valued 0.31% higher than the average sample of DRC rice. The rice from Mozambique has higher average length and LWR than the rice from DRC, so the higher valuation is congruent with the previously discussed

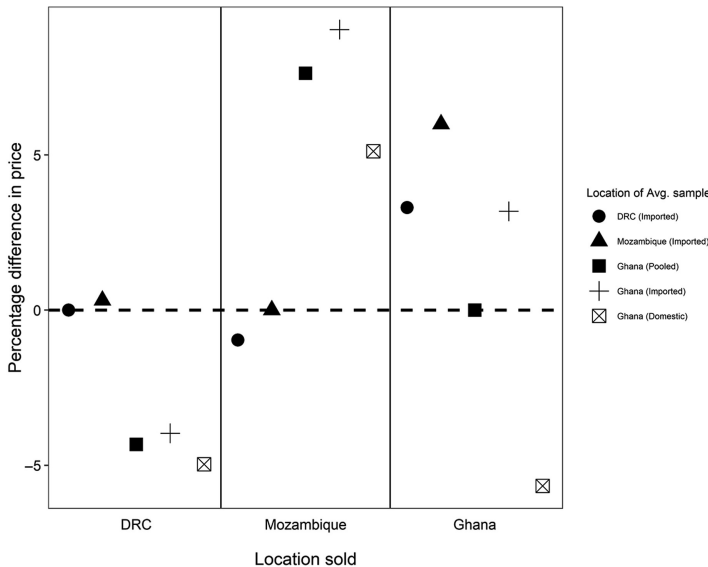


Figure 1.
Percentage difference
in value of average
quality rice sold in
alternative countries

results. The average of all rice, domestic and imported, from Ghana is valued 4.33% less than average DRC rice in a DRC market. The average of rice imported to Ghana is valued at 3.97% less than the average sample of DRC rice. While the average sample of domestic Ghanaian rice is valued at 4.97% less than the DRC average sample. In DRC, domestic Ghanaian rice would be valued less than rice imported to Ghana, which is consistent with Ghanaian preferences.

7.2 Mozambique

In Mozambique, the average sample of rice from DRC would be worth 0.96% less than the average sample of rice from Mozambique. DRC rice is valued lower than the Mozambican rice in Mozambique for the same reason Mozambican rice was valued higher in DRC. Both countries have similar levels of chalkiness while Mozambique has the higher average LWR. The average sample of all rice from Ghana would be worth 7.63% more than the average sample of Mozambican rice. The average rice sample imported to Ghana would be worth 9.04% more than the average of Mozambican rice. The average sample of domestic Ghanaian rice would be worth 5.12% more than the average Mozambican rice sample sold in Mozambique. Again, the domestic rice from Ghana is valued less than rice that is imported to Ghana.

7.3 Ghana

For Ghana the baseline is the average sample of all rice in Ghana, including both domestic and imported rice. The average sample of DRC rice sold in Ghana would be worth 3.31% more than average sample of Ghanaian rice. The average Mozambican sample of rice would be worth 5.99% more than the average sample of total rice in Ghana. The average sample of rice imported to Ghana would be worth 3.19% more than the average sample of total rice in Ghana. Compared to the average domestic rice sample which is valued at 5.66% less than the average sample of total rice in Ghana. As seen in DRC and Mozambique, the rice imported into Ghana is valued higher than domestic rice, which is congruent with previous findings as Ghana is a coastal country, distant from rice cultural heritage (Demont, 2013). Among the three countries involved in this study, the preference for the rice imported to Ghana over domestic Ghanaian rice, when considering the average sample, is consistent.

Although parboiled rice is a value-added attribute, it was found to decrease price for both imported ($p < 0.01$) and domestic ($p < 0.05$) rice. Parboiled rice is also discounted in nearby Benin, as found by Ndindeng *et al.* (2021). Results from Table 2 indicate that, ceteris paribus, domestic parboiled rice sells for 35.6% less than non-parboiled and imported parboiled sells for 27.7% less than non-parboiled imported rice. These results are consistent with previous literature (Taylor and Archibald, 2019; Tomlins *et al.*, 2005) on Ghanaian consumer demand where it was found that although consumers perceived parboiled rice to have higher nutritional qualities (and thus often preferred by local governments), it is less preferred by most consumers due to perceived poor quality of domestic parboiled rice.

For every specification, the directional fixed effect for Ghanaian markets was insignificant (Table 3). The robust insignificance, across seven model specifications, would seem to indicate that the region of purchase in Ghana does not significantly influence price.

8. Discussion

Rice is an important staple food globally and is increasingly important across Sub-Saharan Africa. Functioning markets and pricing of commodities are key tools for promoting food security for the most vulnerable populations. Our study provides critical insights into how quality affects rice prices in DRC, Mozambique and Ghana as well as revealed areas for future analysis. One of the main findings of this study is that each country seems to have distinctive

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-2.426 ^{***} [1.200]	-2.828 ^{**} [1.192]	-1.286 [1.210]	1.824 ^{***} [0.371]	1.884 ^{***} [0.371]	-1.261 [1.223]	-1.366 [1.238]
Broken	1.799 [0.596]	2.057 ^{***} [0.585]	-0.078 [0.022]	-0.109 ^{***} [0.022]	-0.099 ^{***} [0.025]	-0.073 ^{***} [0.025]	-0.080 ^{***} [0.022]
Length	0.758 [*] [0.400]	0.670 [*] [0.403]	1.365 [0.574]	—	—	1.336 [0.588]	1.446 [0.588]
Width	—	—	0.635 [0.410]	—	—	0.651 [0.415]	0.561 [0.410]
Length to width ratio	—	—	—	0.060 [0.153]	0.017 [0.157]	—	—
Chalk impact	—	0.001 [0.001]	—	0.001 [0.002]	—	—	0.002 [0.001]
Chalky (%)	-0.001 [0.001]	—	—	—	-0.0005 [0.001]	-0.0004 [0.001]	—
Parboiled	-0.314 ^{***} [0.068]	-0.243 ^{***} [0.074]	-0.340 ^{***} [0.067]	-0.297 ^{***} [0.077]	-0.345 ^{***} [0.072]	-0.349 ^{***} [0.070]	-0.299 ^{***} [0.077]
Accra	0.127 [0.087]	0.127 [0.099]	0.095 [0.065]	0.071 [0.086]	0.080 [0.088]	0.095 [0.066]	0.085 [0.067]
R ²	0.262	0.257	0.296	0.260	0.255	0.298	0.307
Observations	150	150	150	150	150	150	150

Note(s): ^{***}, ^{**}, ^{*} denote $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively; [] denote, robust standard errors, and 0 represent non-robust standard errors; Variance inflation factors (VIF-s) ranged from 1.010 to 1.468 and mean of 1.172, suggesting very little multicollinearity

Table 3.
Ghanaian locational
(Accra and outside of
Accra) models

pricing differences for quality attributes. Even if countries price certain quality attributes positively the magnitude can be drastically different. This highlights the fact that rice price can vary greatly based on small quality differences and should be priced based on specific quality attributes. The results of broken rice impacts on prices are thought-provoking because they demonstrate the likelihood of market failures in Ghana, and simultaneously generate deeper questions about consumer preferences in Mozambique and DRC. There is extensive, non-hypothetical literature on Ghanaian consumer preference for non-broken rice yet there the estimated discount for brokenness is minimal. Our study would seem to suggest that vendors in Ghana are not pricing rice based on the preferences previously discovered. The range of percent broken in Ghanaian samples (40.1%) and the estimated small impact (3.28%) suggests one of two market failures.

First, vendors simply may not be aware of the percentage of broken in the rice they are selling. While initial importers would have to be aware of this percentage because they pay exporters based on this, the supply chain may be breaking down prior to the final sale to consumers. This could be due to mixing of open bags or mixing of different rice types. The second potential market failure may be the fact that vendors are aware of broken percentages but are aware that consumers cannot visually assess differences and thus do not discount rice prices accordingly. A recent study done by [Rahman et al. \(2021\)](#) found evidence millers and wholesalers were using market power combined with lack of government intervention to make large price increases in Bangladesh rice markets. With similar market conditions, there is potential for similar market failures in African rice markets. Regardless of the type of market failure illustrated in our results (reinforced by previous literature on Ghanaian rice preferences), the findings indicate a compelling need for increased grading and standards at the final point of sale. Further segmentation of rice by percent broken could increase total welfare, if consumer welfare increases more than vendor welfare decreases, and specifically improve the purchasing ability of lower income people. Still, it should be noted that the cost of implementing regulated standards could lead to increased price of all rice, regardless of quality. Even if regulated standards reduce the price of low-quality rice, the cost of implementation and monitoring could again increase the price of the low-quality rice leading to ambiguous impacts on welfare. In the case of inefficient markets, standards should be introduced with continual monitoring to avoid unintended decreases in welfare among the low-income group. Further research is warranted to see if consumer WTP would warrant standards for open bag rice markets and what, if any, of the additional regulation costs would be split between consumers and vendors. Future research is also needed to help understand these results better, such as conducting consumer preference studies that would allow for comparison of the pricing behavior by vendors with what consumers' revealed preferences for selected rice quality attributes are.

We provide a first empirical examination of rice price response to quality attributes, finding relatively small impacts of broken on rice price. Given the fact that the Mozambican government stated the grading and standardization system in Mozambique for rice is weak and is yet to become an important tool for both domestic rice production and consumption, one of two things become apparent. Our results indicate either consumers do not value whole rice and are not willing-to-pay a premium (we find a premium but it is not a large factor), or the lack of standards and grading has led to a market failure. Given the large range of broken rice in the Mozambican sample (21%) and its small estimated impact, our results would at the least suggest a market failure in labeling and pricing to some degree. If consumers did not care about broken rice, then the mean of all samples should be higher than 3.5%, which is low by international standards as broken rice is sustainably cheaper to purchase on the international market. In a relative context, [Lyman et al. \(2013\)](#) found that broken rice is priced at 40% below head rice (whole kernels) and as such we should see a 9.2% (40% multiplied by 21%) difference between the max and the min broken in Mozambique.

One potential argument for the small, relative price differences among quality attributes is that consumers cannot visually differentiate marginal differences (say the difference between 15 and 25% broken). One explanation is simply that consumers do not demand higher quality rice and that sellers thus do not take these characteristics into pricing. That being said, all the quality attributes in this study directly affect the cooking and texture of rice once prepared. Thus, another possible scenario is that consumers cannot visually differentiate marginal differences in quality but value them after preparation is complete. All this being said, if consumers truly did not value quality attributes such as broken and chalky rice we should have seen a much higher volume of broken and chalky rice in the samples since rice vendors can source this much cheaper on the international market. This would seem to imply that consumers do value these quality attributes but have a difficult time delineating them in an open bag setting.

The results of this study are important on two distinct fronts. First, because the rice culture (preferences) is still evolving, market preferences are still developing. In some countries, such as Nigeria, rice traders/importers have proactively set high barriers to entry for rice quality which results in the urban middle and high classes to benefit from rice imports while the poor are priced out of the market (Lancon and Benz, 2007). Other countries, such as the DRC, Mozambique and Ghana, do not have quality import regulations yet and as such, consumers and not policymakers are driving the market prices and their regulations (or lack of quality regulations). The potential for indifference, based on insignificance in DRC and minimal price discount in Mozambique, to broken rice in Mozambique and DRC has important food security and importation implications. Since many countries where rice is embedded into their culture discount broken rice, there is often an excess supply of broken rice which leads it to be used in the pet food or brewing industries. If more markets accept broken (or at least a higher percentage of broken) rice, then a possibility exists to increase food security and input-use efficiency in a food security context (as rice uses a high volume of water). The results of this study can be used by rice importers and exporters who are trying to best segment the rice market in DRC, Mozambique and Ghana, and perhaps more broadly throughout Sub-Saharan Africa. Most importantly, this study should be used as a spring board for future research focused on the potential of rice importers/exporters to segment rice with high percentage of broken rice when serving the DRC and Mozambican markets. From a food security perspective, future research should use non-hypothetical experiments to determine what, if any, thresholds consumers would value for broken rice in Mozambique and DRC, two of Africa's fastest growing countries.

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Appendix

The Appendixes are available online for this article.

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