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RESEARCH ARTICLE

Does Rice Quality Matter? Understanding Consumer Preferences for Rice in Nigeria

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Abstract
Rice is a staple crop in Nigeria. Even with a push to increase domestic production, little is known about the functionality of Nigeria's open bag markets and the preferences of consumers for specific rice attributes. Our study uses a hedonic price model to identify quality attribute preferences of consumers and potential market failures. Our results indicate that Nigerian consumers prefer rice with homogenous long slender kernels and a low presence of broken rice and are indifferent to chalkiness. The findings are useful as they can inform future strategies for rice breeders, domestic policy makers, and rice exporters.

Keywords: Consumer preference; Nigeria; quality attributes; rice

JEL classifications: Q10; O13; Q13

Introduction

Rice consumption in sub-Saharan Africa has grown significantly in the last decade at a rate of 5.57% a year compared to the global rate of 1.22% (USDA, 2022), based on growth in both per-capita consumption and population (Durand-Morat and Chavez, 2020). Rice is now the second most important source of calories across many sub-Saharan countries, behind maize (Ajala and Gana, 2015; Nigatu et al., 2017). In many parts of Nigeria, rice has overtaken traditional staples, like cassava, in terms of daily caloric importance, changing from a luxury to a staple good (Nigatu et al., 2017). Since 1990, per capita rice consumption has increased 143% in Nigeria (Nigatu et al., 2017). Despite the large quantities of rice produced in Nigeria, domestic production has not kept up with increased consumption. Rice production in Nigeria has grown at a rate of 4.27% annually between 1990 and 2019, based almost exclusively on an increase in area harvested, which grew 3.74% a year on average over the same period. Nigeria expanded rice acreage from 1.21 million hectares in 1990 to 3.35 million hectares in 2019, the largest expansion worldwide (USDA, 2022). However, rice yields have remained stagnant consistently below two metric tons per hectare (Takeshima and Maji, 2016).

Despite the efforts to achieve rice self-sufficiency, primarily after the rice price spike during the 2007–2008 rice crisis, Nigeria continues to import large amounts of rice (1.94 million metric tons a year in the last 5 years) and remains one of the largest rice importers worldwide (USDA, 2022). Thailand and India are the main suppliers of imports to Nigeria, accounting for 67.6% and 22.7% of imports in the last 5 years, respectively (United Nations, 2022), most of which is parboiled long-grain rice (Ministry of Commerce and Industry of India, 2022; Ministry of Commerce of Thailand, 2022). Market projections for the coming decade suggest that rice imports in Nigeria will continue growing, driven primarily by population growth, which will increase demand by 3.1% per year

(Durand-Morat and Chavez, 2020). To slow the import of rice and improve self-sufficiency, the Nigerian government has implemented rice tariffs, levies, and quantity controls (Hoffmann and Melly, 2018). To avoid the added cost, rice is smuggled into Nigeria through tariff evasion at ports, like Lagos, and from Benin and Niger through eastern and northern land borders, effecting cities like Kano (Dorosh and Malek, 2016; Hoffmann and Melly, 2018; M. E. Johnson and Dorosh, 2017). Because this rice is smuggled, it presents issues with quality regulation and thus a potential for asymmetric information between vendors and consumers.

Unlike Asia, where rice has been engrained in culture for centuries, rice preferences in Nigeria are still evolving. Higher quality imported rice is prominent in urban markets in Nigeria, which has led to continual shifts in consumer preferences. For instance, urban preferences in Nigeria for rice have become biased toward Asian export quality standards, against which African-produced lower quality rice has difficulty competing (Coulibaly, Tebila, and Diagne, 2015; Demont and Ndour, 2015; Fiamohe et al., 2018). There is a well-documented preference for imported rice relative to domestic Nigerian rice (Emodi and Dimelu, 2012; Futakuchi, Manful, and Sakurai, 2013; Ogundele, 2014; Onya, Okezie, and Ejiba, 2019; Tiamiyu et al., 2010). Previous research found that consumers prefer imported rice based on their perceptions that imported rice has better quality attributes (Obih and Baiyegunhi, 2017). It has been found that consumers perceive higher prices of imported rice as a reflection of better-quality attributes, and this perception reinforces their preference and willingness-to-pay (WTP) for imported rice (Akaeze, 2010). Obih and Baiyegunhi (2017) considered how variation in price and quality of rice, both domestic and imported, influence consumers' willingness-to-change existing purchase habits and preferences. They find that households with higher incomes use rice price as a heuristic for quality, assuming that higher priced rice must be of better quality (Obih and Baiyegunhi, 2017), which leads to a consistent preference for imported rice regardless of increased cost and/or quality.

Domestically produced rice is typically consumed in rural areas where the quality of domestic rice is heterogenous and is considered inferior to imported rice. As such, domestic rice production is not linked directly to consumer rice preferences (Johnson et al., 2013). Domestic Nigerian rice, when milled properly, could meet or even exceed the quality of imported rice (Ogunbiyi, 2011); however, poor milling technologies degrade the quality of domestically produced rice. Poor milling technologies are found specifically in small- and medium-scale millers that handle 80% of domestic rice milling (Gyimah-Brempong, Johnson, and Takeshima, 2016). The large-scale rice millers, which can produce quality equivalent to imported rice, face inconsistent supply and higher production costs. As a result, domestic large-scale millers struggle to compete with imported rice without government intervention, such as the recurrent restrictions on rice imports (Gyimah-Brempong, Johnson, and Takeshima, 2016).

In addition to milling quality challenges, there is limited progress in terms of rice varieties adapted to the growing conditions of Nigeria, in part due to limited governmental investment in research and development of rice varieties (Takeshima and Maji, 2016). Although some domestic rice is of similar quality to imported rice (Futakuchi, Manful, and Sakurai, 2013; Tiamiyu et al., 2010), studies have shown that consumers still indicate a preference for imported rice. Fiamohe et al. (2018) found that imported rice demanded a 20% premium to local rice. Thus, it is important to better understand if the preference is simply due to the perception that imported rice is of better quality, or if consumers value quality attributes that domestically produced rice lacks. Nasrin et al. (2015) found that commercialization is one of the key drivers explaining the recent increase in rice production in Nigeria and concluded that policies should focus on improving the performance of rice markets in Nigeria and facilitating market access and participation. Johnson et al. (2013) found that most rice traders in Nigeria invest little to upgrade the product to meet consumer demands. Additionally, small-scale millers rarely upgrade to better paddy varieties and processing technologies and thus are only weakly linked to retail markets.

Studies of rice consumer preferences in Nigeria are primarily informed by sensory evaluation studies and consumer surveys, which are hypothetical in nature. Adeyeye et al. (2010) found in a

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sensory evaluation survey of Nigerian rice consumers that participants showed a strong preference for parboiled rice and long slender kernels. When consumers were asked the most important quality they considered when making rice purchases, the most important was being stone free, followed by taste and aroma of cooked rice, and finally a consistent shape with the percentage of broken rice being the least important consideration to consumers (Adeyeye et al., 2010). Previous research in Nigeria (Ogunleke and Baiyegunhi, 2019) found that higher rates of broken grains of Nigeria's local rice caused consumers to discount price. The level of broken grains is importantly used by consumers in grading domestic rice (Diako et al., 2010).

Twine et al. (2022) published a nonhypothetical hedonic study of rice in sub-Saharan Africa. The authors analyzed five sub-Saharan countries in Africa, including Nigeria. The study provides an empirically robust analysis of quality attributes, both physical and chemical, contribution to rice price for sub-Saharan Africa as a whole. Findings suggest a preference for unbroken, parboiled, slender rice (Twine et al., 2022). A preference for rice sold in urban markets, compared to rural markets, is also identified (Twine et al., 2022). In addition to their contribution to the rice preference literature, Twine et al. (2022) add to empirical analysis by running a variety of tests to ensure the robustness of their results.

Research Objectives and Contributions

Our study provides a nonhypothetical study of urban consumer preferences for rice in Nigeria. According to the World Bank, 2022), the share of urban population in Nigeria has grown from 35% in 2000 to 53% in 2021. This, combined with the fact that rice per-capita consumption is higher among urban than rural households (Gyimah-Brempong and Kuku-Shittu, 2016), highlights the relevance of focusing on urban consumers. Our study adds to the existing literature by examining in detail how consumer preferences vary by location (Abuja, Kano and Lagos) and origin (domestic vs. imported). Consumer preference has previously been treated as constant across all of Nigeria, ignoring the fact that domestically produced rice (typically of lower quality) is often consumed in the north with higher quality, imported rice, being consumed more frequently near the coast (Lagos). It is important to understand whether Nigerian consumers place the same valuation on quality attributes between imported and domestically produced rice. Specifically, do consumers simply value imported rice more because of the perception of quality, or do the physical attributes themselves drive the wedge in price between imported and domestic rice in Nigeria? Understanding what drives rice price, for both domestic and imported rice, will help rice producers, rice importers, rice scientists and policymakers better fulfill the demands of Nigerian consumers.

Consumer preferences for milled rice with different broken percentage are of particular importance for its potential consequences. Because broken rice is often perceived as being "poor" in appearance, it demands a significantly lower price at the global retail level – often selling at roughly 40% less than their whole kernel counterparts in 2020 (USDA, 2022). Broken rice provides the identical nutritional content as whole rice and could even combat food insecurity more efficiently than whole rice because of its lower global price (Richardson et al., 2022). Thus, it is important to ascertain whether consumers express their preferences for broken rice via the price they pay and if that preference is consistent across all degrees of broken; if not, there are implications for both imported rice and domestic rice. For example, if percent broken only matters to consumers beyond some threshold, that preference has important implications. Preferences for broken or nonbroken domestic rice can influence investments made in domestic rice processing and breeding. Among imported rice, we argue that importing rice with higher percentage of broken at a lower price may help to combat Nigeria's chronic food insecurity issue. As rice consumption in Nigeria continues to grow, a better understanding of consumers' preferences for rice quality characteristics, specifically as it pertains to the effect of broken percentage, beyond the simple comparison of imported versus domestic, will become more important from a food security standpoint.

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Better understanding consumer preferences in Nigerian main urban cities (Lagos, Abuja and Kano) has two important implications. First, by understanding consumer rice preferences, vendors, producers, the domestic rice industry and importers can more closely provide rice with attributes that consumers desire. This is important for countries that currently export to Nigeria, countries that hope to export to Nigeria in the future, and the Nigerian government and agricultural scientists that develop more effective domestic rice policies. Similarly, if the Nigerian government understands what consumers want in their rice purchases, it can direct domestic research and development funds to develop those traits in domestic rice production in an effort to increase consumers' acceptance of domestic rice. Since the 2007–08 global rice crisis, there has been a concerted effort for rice self-sufficiency in Nigeria. While self-sufficiency poses many obstacles, understanding the attributes consumers value and those they do not is an important step toward reaching sustainable self-sufficiency. Simply producing enough rice is not sufficient if consumers refuse to consume it or demand a large discount. Secondly, better segmenting the market according to desired rice traits means that consumers could buy rice at the quality that fits their preferences and budget constraints. This could reduce the amount of household income currently being spent on rice, without decreasing the per capita annual consumption. By properly segmenting the market, there is also potential for new, low-income consumers to enter the market if there is an indication low-quality, low-cost rice would be desired. Importantly, this study provides information related to whether quality attributes such as length, width, chalkiness, and broken percentage are driving imported rice prices, or if all imported rice is simply perceived to be of higher quality and thus carries a premium.

The results of this study first show the effect of each quality variable individually on the price of rice across Nigeria. The quality attributes most valued by consumers should have the largest impact on the price. Based on the quality variable's impact on price, we consider the functionality of the market, which assumes both consumers and vendors have full information. For this study, a market is considered to have full information when consumer's preferences (determined by previous literature and the survey given during data collection) are matched with the quality and price of the product in the market. Conversely, if the preferences of the consumers do not match the drivers of price in the market, the consumer may be making purchasing decisions without full information. For example, a consumer might pay a premium for rice that they believe has a low degree of broken rice. If the rice had been mislabeled, maliciously or not, and had a higher degree of brokenness, then the consumer's signaled preference for a low degree of broken rice might not be accurately represented in the results. All this to say, an insignificant quality attribute coefficient could signal (1) indifference or (2) a lack of full information at the time of purchase.

Materials and Methods

Theoretical Framework

We estimate the consumers' valuation of selected rice quality attributes by rice origin (domestic and imported) and location (Lagos, Abuja and Kano) using a hedonic pricing model. The underlying theory of the hedonic price model comes from Lancaster's theory of demand, stating that the consumer's value of a good is derived from the attributes that make up the good (Lancaster, 1971). Here, the hedonic pricing model assumes that rice is a basket of quality characteristics whose associated values each differentially contribute to its price. The price is the competitive equilibrium price reached in a market with both consumers and producers (Rosen, 1974). The market equilibrium price paid by consumers is a function of physical characteristics of rice, such that:

$$P_i = \alpha X_i + \varepsilon_i. \tag{1}$$

Where P_i represents the price paid by the consumer i, X_i is a matrix of physical attributes of rice, α are parameters to be estimated, and ϵ_i is the normally distributed error term. Following is a discussion of the variables representing the physical attributes of rice.

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With rice commonly being purchased from an open bag in Nigeria, we focus on visually discernable traits, from looking at either the rice or the packaging, rather than characteristics that could only be determined after the rice was cooked and consumed. Existing literature (Twine et al., 2022) often includes analysis of chemical characteristics, such as peak viscosity and amylose content; however, this information is not known to consumers at the time of purchase, nor is possible for them to ascertain and thus should not affect consumers' decision at the time of purchase. Even if a consumer consistently purchases rice from the same vendor, chemical characteristics, like visual characteristics, may not remain constant. Thus, our study only considers characteristics that can be visually determined at the time of purchase by consumers.

The first quality characteristic of interest is *Broken* rice, defined as percentage of kernels less than three-fourths the sample average length. Milled rice is composed of broken and head (whole kernel) rice and is the result of removing the hull and bran from the rough rice. *Broken* is measured as the percent weight of broken rice relative to the weight of milled rice. The variable *Broken* is defined as

$$\text{Broken}_i = \frac{\text{WB}_i}{\text{WM}_i} * 100. \tag{2}$$

Where WB_i is the weight of broken rice and WM_i is the weight of milled rice (head plus broken) in sample i.

Chalkiness in rice occurs when the kernel has some degree of opaqueness in the back, belly or core of the kernel (Ashida, Iida, and Yasui, 2009). The chalkiness can be attributed to incomplete or poor packing of starch, resulting in air pockets within the grain (Custodio et al., 2019; Singh et al., 2003). Due to the weakened structure, kernels with high levels of chalkiness are more susceptible to breakage. The increased likelihood of breakage and the visually unappealing appearance, means chalkiness has consistently been considered in prior literature (Cuevas et al., 2016; Custodio et al., 2019; Unnevehr, 1986). A SeedCount machine provides a precise measurement of chalkiness from a sample of rice, using two different metrics The first method, percent chalky, measures the percent of kernels that surpass a chalkiness threshold (50% chalky), whereas the second method, chalk impact, is a measure of area that is chalky in the total sample. While the two measures yield very similar results, chalk impact most closely mirrors how a consumer would judge chalkiness. Rather than consider how many kernels are highly chalky, a consumer will more readily judge chalkiness by the total amount of chalkiness that can be seen.

The *chalk percentage* is defined as the weight of rice kernels with half or more of their area opaque and chalky relative to the weight of the milled rice sample (United States Department of Agriculture Grain Inspection, Packers and Stockyards Administration Federal Grain Inspection Service, 2009). The variable *Chalk percentage* is defined as

$$\text{Chalk percentage}_\text{i} = \frac{\text{WC}_\text{i}}{\text{WM}_\text{i}} * 100 \tag{3}$$

where WC_i is the weight of chalk rice in sample i.

The size of rice is measured by the *length* and *width* of the kernels (in millimeters), and consequently variables *Length* and *Width* represent the average length and width across all kernels n in sample i.

Finally, the shape of rice in sample i is measured by the length-to-width ratio (LWR) as follows:

$$\text{LWR}_i = \text{Length}_i / \text{Width}_i. \tag{4}$$

The standard deviation for length and width was included as a variable to account for the homogeneity of the rice shape in a similar fashion as Cuevas et al. (2016). Conventional thought would suggest a negative relationship between the standard deviation for length and width and the price of rice.

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The Nigerian government and institutional/regulatory agencies' targeted intervention in rice markets has focused on increased rice production more than its efforts towards ensuring end-use quality. Enforcement of rice quality standards throughout Nigeria has been nearly nonexistent without strong controls for implementation (Bello et al., 2020). As such, we add a variable that asked consumers "Do you think authorities (e.g. government and rice marketers) control the rice quality standards in the market?" This variable, $Trust_i$, attempted to elicit if consumers trust the information (origin, broken percentage, etc.) given about the rice they purchased. $Trust_i$ is measured using a binary variable equal to one if consumers reported trusting authorities to monitor market standards and quality, and zero otherwise.

Data Collection

The data used in this study consists of 261 long-grain rice samples collected from consumers in open air markets in Lagos (87), Abuja (88), and Kano (86), Nigeria, in October 2019. The three cities in the study represent three different geographical and sociodemographic areas. Kano, the second largest Nigerian city, is in Northern Nigeria and is primarily served by the domestic rice market. Abuja is the capital city located in central Nigeria and has been traditionally served by domestic and imported rice. Lagos, the largest city in Nigeria, is a coastal city with easy access to ports and, consequently, imported rice. Within each city, different markets were visited to capture variations in socioeconomic and rice consumption characteristics. With varying geographic, sociodemographic, and economic features, these three cities provide a holistic view of Nigerian urban rice consumers.

Prior to data collection, the survey and survey methods were approved by the University of Arkansas Internal Review Board. We assembled a team of local enumerators, who approached and invited consumers that had purchased rice as they left the markets. In exchange for their participation, each participant received a flat fee equivalent to 3 USD. The enumerator asked each participant the price they paid (Naira/kg) for the rice they had just purchased. While this price was not observed, there would be little incentive for the participant to fabricate their answer as they had already been paid a flat fee for the survey and there would be nothing to gain from lying. A small sample of rice (around 500 g) was collected from each participant, followed by the administration of a questionnaire containing questions about the socioeconomic as well as the rice purchasing and consumption characteristics of the household, including whether the rice was purchased from an open bag, whether they know the origin of the rice bought (domestic or imported), and if the rice was parboiled or nonparboiled.

While our sampling approach is convenient as practically all adults are part of the population of consumers we targeted, we recognize that directly purchasing from the consumer may have some limitations. First, we recognize that since participation is voluntary, participants in households that purchased larger amounts of rice might be more likely to participate. However, once we control for household size, the median kg of rice per person per week (0.69 kg) is similar to the mean (0.71 kg). Combined with a wide range of household sizes, from 2 to 20 people, we have little evidence that our sample is biased toward large rice purchases. Second, it is possible the rice was purchased by a proxy, for example a housemaid or relative. While we recognize this as a possibility, since participants could voluntarily decline to participate prior to knowing about the monetary benefits, it is unlikely that proxies make up a significant portion of our sample. The third limitation is our small sample size. Given the physical labor constraints and the dependence on foot traffic at each market, our sample size is relatively small. However, other similar studies using hedonic price models to evaluate rice preferences have used similar sample sizes. For example, Cuevas et al. (2016) has a sample size of 128, which was then broken down by income giving a sample size as small as 40 observations. In the seminal work in this field, Unnevehr (1986) used sample sizes ranging from 86 to 118 observations. While we recognize the limitations of the sample size, our sample size is in line with similar types of studies.

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Our sampling method also offers several benefits. The consistent payment, irrespective of the price paid (in total or per kg) for rice, reduces the incentive for participants to overstate the price paid for the purchased rice. Importantly, the participant had no knowledge of the survey until after they had made an actual rice purchase in the market, meaning their purchasing behavior would be unaffected by the survey. Moreover, since participants had just purchased the rice in the market, there was a low probability that they would not have remembered the price they paid and therefore make up a price for the survey.

Additionally, by surveying rice consumers and collecting samples from actual rice purchasers in open air markets, the preferences, revealed in the quality of rice purchased, are nonhypothetical. Collecting rice from a recent purchase of a consumer, rather than purchasing the rice from the vendor directly, also guarantees the observation is actively being bought and sold in the market and accurately represents the price paid by consumers.

The rice samples were analyzed in the Department of Food Science Rice Processing Lab at the University of Arkansas to determine the selected rice quality attributes. The SeedCount Image Analysis System (Next Instruments, 2015) was used to quantitatively analyze the rice quality of each sample. From the SeedCount results, we could quantify what the literature has defined as the most important search attributes for rice in Nigeria, percent broken, length, width, and chalkiness for each of the samples.

Empirical Approach

The hedonic price model (equation 1) was estimated separately for imported and domestic subsets. The segmentation of the markets was motivated by the heterogeneity between imported and domestic rice and further supported by the significance of the imported binary variable in a pooled model (Table 2, Column 5). In order to have hedonic price functions for different subsets, there are two necessary conditions (Freeman, Herriges, and Kling, 2014). First, the structure of demand, the structure of supply, or both must be different across segments, and second, purchasers in one market segment must not participate significantly in other market segments (Freeman, Herriges, and Kling, 2014). The existing literature indicates that consumers view imported and domestic rice differently, making it likely the demand structure of imported rice is different from that of domestic rice, satisfying the first condition. When asked, 95% of respondents indicated they always or almost always purchase the rice from the same vendor, so the second condition is also likely to hold. With both conditions met, separate hedonic price functions can be estimated for imported and domestic rice. An alternative specification would have been to include imported interaction terms, rather than segment the hedonic price functions. However, the satisfaction of the necessary conditions for market segmentation listed above, and the ingrained differences between imported and domestic rice, led us to choose estimating separate models.

A true hedonic model suggests only the inclusion of product attributes (Costanigro and Mccluskey, 2011); however, recent literature within the rice preference space has also begun to expand to include purchaser characteristics as well. Purchaser characteristics include household income, size and per-capita rice consumption (Cuevas et al., 2016). We used a stepwise procedure to identify relevant variables to include beyond the rice quality characteristics of interest. Household-level characteristics, such as household rice consumption and household income, were included. As over 95% (249 out of 261) of the respondents reported always or almost always purchasing rice from the same market vendor, unknown external marketing shocks influencing the purchase of the rice does not appear to be a factor in determining rice purchases. With a minimal chance of external shock influencing rice purchase, endogeneity between household rice consumption and market shocks should not be present. On the other hand, there is a risk that the anticipated price of rice influences the quality of the rice. Meaning, rice that is of higher quality is handled and transported more carefully to preserve the anticipated higher price. While we recognize this as a potential source of endogeneity, given the level of information lost in the

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Table 1. Price and quality variable summary

	Full Data Set			Data Subsets		
	Imported	Domestic	All	Kano	Abuja	Lagos
Price						
Min	391.7	250	250	250	250	380
Mean	530.30[a]	398.9[b]	433.2	344.80**	495.50***	487.60***
Max	625	1000	1000	500	1000	780
SD	58.25	120.09	120.62	73.38	120.32	97.73
LWR						
Min	1.64	2.34	1.64	2.49	2.44	1.64
Mean	2.87[a]	2.69[b]	2.75	2.75*	2.83**	2.67***
Max	3.89	3.19	3.89	3.27	3.89	3.22
SD	0.27	0.12	0.21	0.17	0.23	0.19
Length SD						
Min	0.41	0.4	0.4	0.41	0.45	0.4
Mean	0.56[a]	0.62[b]	0.56	0.65*	0.56**	0.58*
Max	0.67	3.06	3.06	3.06	0.82	1.12
SD	0.05	0.22	0.18	0.3	0.05	0.08
Width SD						
Min	0.12	0.08	0.08	0.08	0.08	0.09
Mean	0.15[a]	0.14[a]	0.15	0.16*	0.14*	0.14**
Max	0.21	1	1	1	0.21	0.2
SD	0.02	0.07	0.06	0.1	0.02	0.02
Broken (%)						
Min	0.4	1.7	0.4	1.7	0.4	2.1
Mean	5.31[a]	9.03[b]	7.77	9.11*	7.71*	6.52**
Max	20.8	36.8	36.8	36.8	26.2	23.7
SD	2.96	7.03	6.23	8.57	5.45	3.36
Chalk impact						
Min	0	0	0	0	0	0
Mean	1.10[a]	20.00[b]	13.62	19.61*	8.58*	12.81*
Max	51.12	98.06	98.06	98.06	97.99	97.66
SD	6.09	30.28	26.44	29.15	23.68	25.37
Origin (count)						
Imported	88	–	88	15	44	29
Domestic	–	173	173	71	44	58
Observations	88	173	261	86	88	87

Variables with different letters (a,b,c) indicates statistical difference in means at the 5% level, estimated with a *t*-test, between Imported and Domestic in the full data set.

Variables with differing stars (*, **, ***) indicates statistical difference at the 10%, 5%, and 1% across data subsets (Kano, Abuja, and Lagos), estimated with a *t*-test.

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Table 2. Impact of rice quality variables on price

Variable	[1] (Imported)	[1] (Domestic)	[2] (Imported)	[2] (Domestic)	[3] (Imported)	[3] (Domestic)	[4] (Imported)	[4] (Domestic)	[5] (Pooled)
Constant	5.394***	6.562***	5.361***	6.439***	5.464***	5.919***	5.927***	6.287***	5.655***
	(0.392)	[0.988]	(0.402)	[0.826]	(0.414)	[0.789]	(0.379)	[0.772]	[0.314]
LWR	0.309***	−0.354	0.319***	−0.125	0.308**	0.029	0.162*	−0.172	0.117
	(0.094)	[0.439]	(0.097)	[0.357]	(0.098)	[0.341]	(0.095)	[0.344]	[0.112]
SD length	0.123	−0.238	0.108	−0.268**	0.120	−0.245*	0.042	−0.128	−0.115
	(0.138)	[0.157]	(0.142)	[0.135]	(0.144)	[0.128]	(0.128)	[0.105]	[0.089]
SD width	−0.118	−0.063	−0.128	−0.001	−0.103	−0.04	0.020	0.028	−0.008
	(0.12)	[0.120]	(0.125)	[0.105]	(0.127)	[0.103]	(0.110)	[0.084]	[0.073]
Broken	0.033	−0.061**	0.035	−0.061**	0.033	−0.053**	−0.027	−0.050**	−0.059***
	(0.028)	[0.029]	(0.029)	[0.025]	(0.030)	[0.025]	(0.029)	[0.021]	[0.016]
Chalk impact	0.001	−0.005	0.001	−0.006	0.001	−0.005	0.001	−0.004	−0.001
	(0.001)	[0.004]	(0.001)	[0.004]	(0.001)	[0.005]	(0.001)	[0.003]	[0.001]
Household kg per week	–	–	−0.015	−0.173***	−0.010	−0.169***	−0.002	−0.090**	−0.077***
			(0.026)	[0.039]	(0.026)	[0.037]	(0.022)	[0.035]	[0.029]
Trust authorities	–	–	−0.01	0.015	−0.026	0.097	−0.054*	0.027	−0.01
			(0.028)	[0.069]	(0.030)	[0.068]	(0.028)	[0.067]	[0.036]
Income 60,000–99,999	–	–	–	–	0.006	0.035	−0.011	0.061	0.035
					(0.044)	[0.072]	(0.038)	[0.071]	[0.049]
Income over 100,000	–	–	–	–	−0.036	0.197***	−0.017	0.125	0.093*
					(0.043)	[0.072]	(0.038)	[0.082]	[0.056]
Abuja	–	–	–	–	–	–	0.184***	0.239***	0.253***
							(0.033)	[0.067]	[0.039]

(*Continued*)

Table 2. (*Continued*)

Variable	[1] (Imported)	[1] (Domestic)	[2] (Imported)	[2] (Domestic)	[3] (Imported)	[3] (Domestic)	[4] (Imported)	[4] (Domestic)	[5] (Pooled)
Lagos	–	–	–	–	–	–	0.111***	0.277***	0.247**
							(0.035)	[0.039]	[0.029]
Imported	–	–	–	–	–	–	–	–	0.173***
									[0.029]
R^2	0.146	0.109	0.15	0.268	0.173	0.356	0.412	0.504	0.615
Observations	88	173	88	173	88	173	88	173	261

***, **, * denote $P < 0.01$, $P < 0.05$ and $P < 0.1$, respectively.
( ) indicates OLS standard erros and [ ] denotes robust standard errors.

smuggling of high- and low-quality imported rice it seems unlikely to play a significant role in our estimates. Using the stepwise procedure, we demonstrate our product attributes are robust to specification, as the sign, magnitude, and level of statistical significance remain consistent.

The preferred model includes a matrix of independent variables X_i, containing rice quality attributes as well as household's rice-purchasing characteristics. The rice attribute variables considered include (1) *LWR*, (2) *standard deviation of average kernel length*, (3) *standard deviation of average kernel width*, (4) *percent broken*, and (5) *chalk impact*. Length and width were considered separately, but ultimately the *LWR* (typically defined as rice shape) was used in the preferred model. *LWR* has been used in prior literature as a metric for kernel shape (Unnevehr, 1986). The consumer's eye more readily sees kernel shape (*LWR*), rather than length and width without the context of the other. Rather than segment the kernel shape, *LWR* was considered as a continuous variable, as there is no universal classification of kernel shape or length (Custodio et al., 2019). The consistency of our results as we expand beyond the traditional hedonic price model led us to include the purchaser characteristic variables in our preferred model. The variables representing rice-purchaser characteristics include (1) *weekly kilograms of rice purchased per household* and (2) *trust of authorities*[1].

The model was also estimated with fixed income effects such that:

$$P_i = \alpha X_i + \beta Z_i + \varepsilon_i. \tag{5}$$

Where Z_i is a vector of binary income variables. We defined three household income variables, (1) under 59,999 Naira/month, (2) between 60,000 and 99,999 Naira/month and (3) over 100,000 Naira per month, following Okpiaifo et al. (2020). Finally, we included binary variables for location L_i (Kano, Accra and Lagos) to control for specific location effects such that:

$$P_i = \alpha_i X_i + \beta_i Z_i + \gamma_i L_i + \varepsilon_i. \tag{6}$$

The significance of the city-fixed effects indicated each city could potentially have a different hedonic price function. As described before, two necessary conditions must be met in order to estimate different hedonic price functions for subsets (Freeman, Herriges, and Kling, 2014). Given the different geographic access to rice, varying sociodemographic makeups, and diverse economic industries in the three cities, it seems plausible to have different supply and demand structures, satisfying the first condition. The second condition also holds, as the distance between cities prevents consumers from purchasing rice in different cities.

We identified a log–log hedonic price model as the preferred functional form for continuous variables based on the results from the MacKinnon–White–Davidson PE test (petest function - RDocumentation, n.d.). After the PE test confirmed the functional form, the Ramsey Reset test was used to determine that the inclusion of nonlinear combinations of variables would not improve the fit, as such quadratic terms were not included in the preferred specification (resettest function - RDocumentation, n.d.). Binary variables remain linear, giving a log-linear interpretation. Accordingly, the coefficients a_j associated with the continuous variable j is interpreted as the percentage change in price due to a 1% change in j, which is the elasticity. To estimate the percent difference in price and the absolute difference in price, the method outlined by Wooldridge in *Introductory Econometrics: A Modern Approach* was applied (Chapter 6: Multiple Regression Analysis: Further Issues, 2013).

All models were estimated using R Studio version 4.0.2. Upon estimation, models were tested for heteroskedasticity. For any model found to be heteroskedastic, the heteroskedasticity robust standard errors were estimated, using HC3 (Long and Ervin, 2000), and reported. For the remaining models, Ordinary Least Squares (OLS) standard errors were reported. The variance inflation

[1]The error term for this specification includes unobserved preferences that potentially correlate with quantity consumed and trust, creating possible endogeneity. As such, the trust and quantity consumed coefficients should be treated with caution.

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factor (VIF) was used to check for multicollinearity. For each variable, the VIF was below five, indicating multicollinearity is not a significant concern.

Piecewise Analysis

Given their importance, the broken coefficients, by city, were analyzed to determine if the relationship between price and broken had a breaking point, to be consistent with recent literature (Saha et al., 2021). That is, is there a threshold at which the impact of percent broken on the price of milled rice changes in one way or another, which could be understood as a change in consumer WTP for milled rice based on its broken percentage. To estimate a potential break, we used equation (2) in a linear form and the segmented function from the segmented package in R Studio. A piecewise analysis was estimated to ascertain if the effect of an independent variable (in this case *broken*) on rice price varies over the observed ranges (Toms and Lesperance, 2003). The question resolved by the piecewise regression is whether the association between broken and price changes in magnitude or significance within the range of broken rate values in our sample. The steps involved in a piecewise analysis include (1) identifying the breakpoints in our variable of interest, while holding all other variables in our function constant and (2) the estimation of the regression using those breakpoints to identify the slope for each segment and assess whether the slopes for each segment are statistically different from zero. The resulting piecewise linear function can reveal a breaking point of the broken slope and the slopes before and after that point along with their significance level. A piecewise analysis was conducted for the full data set and for each city individually, allowing each to have a distinct breakpoint. Using the new segmented slopes and range of brokens for the full data set and each city, it is possible to graph the estimated price in Nigerian Naira for each city for different levels of brokens while holding all else constant at their mean.

Results and Discussion

Summary Statistics

The lowest income group reported a monthly income of less than 59,999 in Nigerian Naira (One USD = 414 Naira as of June 29, 2022), which consisted of 28 observations. The middle-income group, reporting monthly income between 60,000 and 99,999 Nigerian Naira, consisted of 100 observations. The highest income group, reporting monthly income of 100,000 Nigerian Naira and above, consisted of 133 observations. In our survey sample from Kano, six respondents reported having a monthly income of below 59,999 Nigerian Naira, 48 reported monthly income between 60,000 and 99,999, and 32 indicated income above 100,000 Nigerian Naira. In Abuja, 22 consumers were reported to be in the low-income group, 43 in the middle-income group and 23 in the highest income group. Lagos has the most high-income consumers in this study at 78, with only nine consumers reporting middle income and zero in the lowest income group. Our sample is 34% imported rice and 66% domestic rice, which is a similar rate of domestic (26%) and imported (74%) as found by Twine et al. (2022), and to that estimated from USDA (2022), which indicates that 70% of the rice consumed in Nigeria is domestic and 30% imported.

During the survey, information about other socioeconomic variables including gender, household size, household rice consumption, and education level were collected (Appendix Table 1). Respondents were also asked questions about their rice preferences and rankings (Appendix Table 2). Of the 261 participants interviewed, 53 were male and 208 were female (Appendix Table 1). The ratio of men to women is unsurprising, as existing literature in Nigeria indicates women are the primary decision-makers for household food preparation and consumption (Danso-Abbeam and Baidoo, 2014; Nwachukwu and Achike, 2020; Onya, Okezie, and Ejiba, 2019). The average household size was 6.58 people with a minimum reported household size

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of two and the largest being 20, which is slightly larger than the 2015 Nigeria average household size of 5.52 reported in the 2015 General Household Survey (General Household Survey (Panel), 2015 - Nigeria Data Portal, 2015). Household rice consumption ranged from 0.6 kg per week to 14.40 kg per week, with an average of 4.61 kg of rice per week. Of those interviewed, 49 had an elementary education or less, 117 had a high school education, 92 had university education, and 5 had post-graduate education.

Summary statistics for each of the quality variables of interest by income level and origin are presented in Table 1 for the full sample and city subsets, with statistical differences denoted. We see a statistical difference between imported and domestic rice in the full sample for the LWR, length standard deviation, percent broken and chalk impact. Chalk impact does not statistically differ across any of the cities. The remaining quality characteristics, LWR, standard deviation of length and width, and percent broken, statistically differ from at least one location to another. Together, this shows that rice preferences and availability are not consistent across Nigeria. Parboiled rice is the only characteristic that does not vary. All the samples in the study were of parboiled rice, which was expected as most consumers in Nigeria prefer the taste and texture of parboiled rice (Bamidele, Abayomi, and Esther, 2010; Fakayode, Omotesho, and Omoniwa, 2010; Ogunbiyi, 2011).

For the full sample, price ranged from 250 to 1,000 Nigerian Naira/kg, with a mean of 443.63 Naira/kg. In Kano, the average price was the lowest at 344.80/kg Nigerian Naira, without any statistical difference ($P > 0.1$) between prices paid between income levels. The highest average price was in Abuja at 495.50 Naira per kg, with the highest income group paying statistically a higher ($P < 0.05$ and $P < 0.01$, respectively) price compared to the middle- and lower-income group. Lagos had an average price of 487.60 Naira per kg, with no observations in the lowest-income group and no statistical difference ($P > 0.1$) between the middle- and highest-income group.

Length-to-Width Ratio

When looking at the regression results in Table 2 (column [3]) with imported and domestically produced rice disaggregated, we see that the *LWR* coefficient is 0.308 and significant ($P < 0.05$) for imported rice, and insignificant ($P > 0.1$) for domestic rice. This indicates a 1% increase in *LWR* for imported rice will lead to a 0.305% increase in price. There is a 47% price difference between imported rice with the lowest and the highest LWR, holding everything else constant (Table 3). The difference translates to a price difference of \$0.60[2] or 249 Nigerian Naira per kg between the lowest and highest LWR (Table 4). The significant price impact of *LWR* is consistent with prior literature (Adeyeye et al., 2010), which indicated a preference amongst Nigerians for long slender rice kernels. The matching of known preference with market availability and price indicates that, on average, the Nigerian market as a whole appropriately prices imported rice based on the kernel shape, at least in terms of sign and significance. The statistically insignificant impact of kernel shape on the price of domestic rice may result from the fact that the shape of domestic rice (mean *LWR* of 2.69 and standard deviation of 0.12) is more homogeneous than that of imported rice (mean *LWR* of 2.87 and standard deviation of 0.27, Table 1), and therefore the effect of *LWR* is less important.

When segmented by city (Table 5), Kano is the only city where the LWR significantly influences price ($P < 0.05$). For Kano, there would be a 28.8% price difference between the observations with the lowest and highest *LWR*, translating to \$0.25 or 104 Nigerian Naira. The significance could be attributed to the fact that Kano has the largest percentage of domestic rice (82.6% domestic in Kano compared to 50% and 66.7% in Abuja and Lagos, respectively) in its markets, and domestic rice tends to be less slender than imported kernels. As such, consumers could be willing to pay a premium for slenderer rice. With prior literature (Adeyeye et al., 2010) documenting a preference for long, slender kernels in Nigeria, the indifference (signaled by statistical insignificance ($P > 0.1$))

[2]1 USD = 414 Nigerian Naira as of June 29, 2022.

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Table 3. Percent difference in price between maximum and minimum independent variable level, holding all else at the mean

Variable / Subset	Imported	Domestic	Kano	Abuja	Lagos
LWR	47%	–	28.8%	–	–
SD length	–	48.8%	42.6%	–	–
SD width	–	–	–	–	–
Broken	–	16.1%	12.4%	47.6%	36.5%
Chalk impact	–	–	13.8%	–	–
Kg per week	–	52.5%	22.8%	–	49.1%
Trust authorities	–	–	–	–	–
Income 60,000–99,999	–	–	–	–	–
Income over 100,000	–	19.6%	–	13.5%	10.2%

Note: Only statistically significant variables were considered.

Table 4. Difference in price (in Naira) between maximum and minimum independent variable level, holding all else at the mean

Variable/Subset	Imported	Domestic	Kano	Abuja	Lagos
LWR	249	–	104	–	–
SD length	–	−170	−131	–	–
SD width	–	–	–	–	–
Broken	–	−63.2	−42	−260	−174
Chalk impact	–	–	−49.4	–	–
Kg per week	–	−228	−78.7	–	−261
Trust authorities	–	–	–	–	–
Income 60,000–99,999	–	–	–	–	–
Income over 100,000	–	78.3	–	68.6	47.5

Note: Only statistically significant variables were considered.

found in Abuja and Lagos is surprising, especially when considering Abuja and Lagos have a statistically ($P < 0.01$) higher price than that found in Kano, and a higher proportion of imported rice when compared to Kano (50% in Abuja and 33.3% in Lagos compared to 17.4% imported rice in Kano). This could indicate consumers are making purchase decisions based on incomplete or inaccurate information, for example by assuming higher priced rice is of higher quality (e.g., higher LWR), which leads to a gap between quality and price.

Length Standard Deviation

Looking at the preferred model estimates ([3] in Table 2) segmented by imported and domestic, the *standard deviation of length* is statistically significant ($P < 0.1$) among domestic rice only. The

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Table 5. Impact of rice quality variables on price by city

Variable	Kano	Abuja	Lagos
Constant	4.842***	6.334***	7.047***
	(0.529)	(0.822)	(0.631)
LWR	0.561**	0.268	−0.264
	(0.221)	(0.242)	(0.203)
SD length	−0.215**	0.029	0.025
	(0.093)	(0.299)	(0.105)
SD width	0.028	0.291	−0.065
	(0.074)	(0.198)	(0.126)
Broken	−0.040**	−0.116**	−0.152***
	(0.019)	(0.050)	(0.031)
Chalk impact	−0.005**	−0.003	−0.002
	(0.002)	(0.003)	(0.002)
Household kg per week	−0.110***	0.009	−0.218***
	(0.037)	(0.040)	(0.025)
Trust authorities	0.095	−0.040	−0.220
	(0.060)	(0.050)	(0.197)
Income 60,000–99,999	−0.037	0.050	–
	(0.065)	(0.058)	
Income over 100,000	0.012	0.135*	0.102**
	(0.068)	(0.068)	(0.046)
R^2	0.526	0.355	0.588
Observations	86	88	87

***, **, * denote $P < 0.01$, $P < 0.05$ and $P < 0.1$, respectively.

coefficient of −0.245 indicates that a 1% decrease in length standard deviation would increase price by 0.245%. This would result in a 48.8% price difference between domestic rice with the highest and lowest *length standard deviation*, holding all else constant. This corresponds to a price difference of $0.41 or 170 Nigerian Naira per kg. The negative coefficient indicates a preference for more homogenous rice kernel length for domestic rice. The statistical insignificance of *length standard deviation* in imported rice can be attributed to the 19% lower ($P < 0.01$) average length standard deviation found in imported rice compared to domestic rice and smaller range of *length standard deviation* observed in imported rice (0.41 minimum and 0.67 maximum compared to a minimum of 0.40 and a maximum of 3.06) (Table 1). Therefore, choosing imported rice could be a heuristic for consumers seeking homogenously shaped kernels.

The same preference for lower *length standard deviation* is observed in Kano, where the *length standard deviation* suggests a 42.6% difference in price between the most and least homogenous length rice from Kano, which is $0.32 or 131 Nigerian Naira per kg. *Standard deviation of length* is not statistically significant ($P > 0.1$) in Abuja and Lagos, likely due to the smaller range of *length standard deviation* (0.45–0.85 and 0.4–1.65, respectively) (Table 1). With a lower range of values, consumers likely expect the rice to have a homogenous length.

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Broken

Looking first at domestic rice (Table 2), the estimated coefficient is −0.053 ($P < 0.05$), which means that a 1% increase in the *percent broken* of milled rice decreases the price of milled rice by 0.053%. This would lead to a relatively small difference in price of 16.1% between rice with the minimum and maximum *percent broken* levels. There would be a $0.15 or 63.2 Nigerian Naira per kg difference between the least and most broken observation, holding all else at the mean. Imported rice has a statistically significantly ($P < 0.01$) lower percent broken than domestic rice (5.31% average broken among imported rice compared to 9.03% broken in domestic rice) and a smaller range of percent broken (0.4–20.8% among imported samples, compared to 1.7–36.8% among domestic rice) (Table 1).

The statistical insignificance ($P > 0.1$) of the *percent broken* for imported rice (Table 2) seems to indicate one of two things. The first potential explanation is that consumers purchase imported rice with the expectation that it is of higher quality, meaning consumers perceive that imported rice has a lower percent broken. If this is true, indifference to *percent broken* could be attributed to consumers' lack of sensitivity to small differences in *percent broken* found in imported rice. The second potential explanation is that consumers do not discount for broken rice among imported rice and are indifferent to the level of *percent broken* when rice is imported. This could be attributed to the fact that generally, rice imported from Thailand or India have a good appearance (relative to domestic Nigerian rice), and therefore, consumers are not sensitive to the presence of brokens. Consumers could overlook *percent broken* in imported rice, as imported rice generally has a consistent, well-milled appearance even when broken. In any case, our results suggest that consumers are not sensitive to the level of broken rice in imported milled rice.

Taken together, the insignificance ($P > 0.10$) among imported rice and the minimal price impact among domestic rice does not demonstrate a complete indifference to *percent broken* in rice. It does, however, indicate that broken kernels are not a top priority for rice consumers based on their revealed preferences. This is consistent with the survey results (Appendix Table 2). When asked the three main reasons, they selected the rice they bought, broken was never selected out of the nine options listed. The relatively small price impact of *percent broken* does not seem to point to a market failure. Instead, it would indicate the market recognizes consumers relative indifference to *percent broken*.

Percent *broken* is statistically significant for domestic rice and in all three cities. There would be a 12.4%, meaning a $0.10 or 42 Nigerian Naira, difference in price between milled rice with the lowest and highest percent broken in Kano. In Abuja, there is a 47.6%, $0.63, or 260 Nigerian Naira difference in price between milled rice with the highest and lowest percent broken in Abuja. In Lagos, the estimated coefficient is −0.152 ($P < 0.01$). The price difference between the sample with the most and least broken would be 36.5%, $0.42, or 174 Nigerian Naira, giving Lagos the largest percent difference in price and absolute difference in price as a function of the broken rates estimated from the samples. The difference in discount for *percent broken* by city responds as expected by income level. With Kano having the lowest average income, the smaller discount shows some willingness-to-accept a lower quality (higher percent broken) rice. Lagos and Abuja have higher discounts for percent broken, indicating consumers are willing to pay a premium for higher quality rice.

Chalky

Chalk impact is statistically insignificant ($P > 0.1$) across all models. For the full data model, the difference between near 0 and 98.06 chalk, still does not give a statistically significant price impact of chalkiness.[3] This indicates *chalk impact* is not a major driver of price, which is backed up by our survey responses, from which only one person out of 261 responses, or 0.3% of responses,

[3]Actual minimum value was 0.000001.

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indicated chalkiness was in their top three priorities when purchasing rice. Because the results are congruent with the responses in the survey, the minimal price impact of *chalk impact* would indicate that the market is accurately matching consumer preference to the product that is available in the market.

Household Rice Consumption

The kilograms of rice purchased weekly per household was statistically significant ($P < 0.01$) for the domestic rice, Kano, and Lagos models. All the coefficients were negative, indicating if a household purchased more rice in a week, the estimated price they paid per kg would decrease. For the domestic subset, there would be a 52.5% or \$0.55, which is 228 Nigerian Naira, difference in price, holding all else equal. Intuitively, this result is expected. As more rice is needed, most likely as a result of a larger household size, the amount that can be spent per unit decreases. Weekly household rice consumption was used rather than per person rice consumption, calculated by dividing household consumption by household size, for two reasons. First, when kg per person was used in the model in place of kg per household, the coefficients were very similar for all significant coefficients while producing a lower R-squared. Secondly, by using *kg per household,* we capture the impact on price associated with both a change in consumption per person and total household consumption level; whereas kg per person would only capture the price impact of a change in per person consumption. By selecting to use kg per household, we capture the total impact of a change in consumption, while we recognize it leaves us unable to disentangle the impact of change in consumption per person and change due to household size.

In Kano, holding all else equal, the percent difference in price would be 22.8% giving an absolute difference in price of \$0.19 or 78.7 Nigerian Naira. Kano consumers had by far the lowest average price, so the smaller impact of increasing household consumption can be explained by the fact that Kano consumers were already paying a lower price. Lastly, in Lagos, the coefficient is -0.218 ($P < 0.01$) leading to a 49.1% or \$0.63, equating to 261 Nigerian Naira, difference in estimated price.

Trust Authorities

The binary variable *Trust* equals one when consumers indicated on the survey that they believed some official entity monitored the quality standards in the market. *Trust* was not statistically significant ($P > 0.1$) in any model. In the survey, less than 20% of consumers indicated that they trusted that some officiant was monitoring the quality of the market. With a low percent of respondents indicating trust in the market, it is difficult to determine whether truth in the market could statistically influence WTP for rice.

Income

The binary variable for having a monthly income above 100,000 Nigerian Naira is statistically significant and positive for domestic rice overall ($P < 0.01$), as well as in Abuja ($P < 0.1$) and Lagos ($P < 0.05$). The income effect in Kano is not statistically significant. The domestic model (Table 2), a household with monthly income above 100,000 would pay 19.6% ($P < 0.01$) more per kg of rice than a household with a monthly income below 59,999. Similarly, in Abuja households making more than 100,000 per month spend 13.5% more per kg of rice than those with a monthly income below 59,999 (Table 5). In Lagos, a household with a monthly income above 100,000 would pay 10.2% more per kg of rice than a household making between 60,000 and 99,999 per month. Together, this indicates those with higher incomes are paying more per kg of rice when compared to those with lower income. Fixed effects for education, often a proxy for income,

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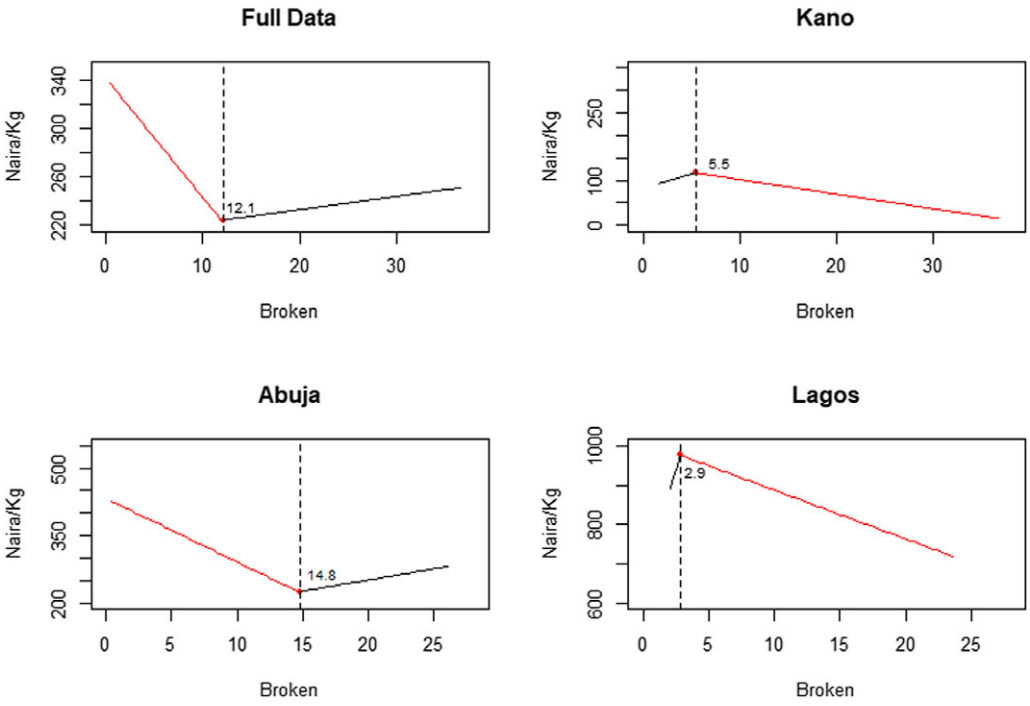

Figure 1. Broken breakpoint by city.

were also tested. The results were similar, but the income fixed effects model explained more of the variance and thus remained in the preferred model.

Linear Piecewise Function

Across the full sample and location subsamples (Kano, Abuja and Lagos), the negative broken coefficients were always significant ($P < 0.01$). Moreover the positive slopes for percent broken (which would indicate a preference for higher *percent broken*) were statistically insignificant (Figure 1). We find that the coefficients (change in price due to a % change in broken percentage) change with the level of broken percentage; overall the discounts (negative coefficients) flatten in all data and in the Abuja subset, whereas the discounts increase after the breakpoint in Kano and Lagos.

For the full data set, *percent broken* is discounted at a rate of 9.84 Nigerian Naira for every percentage broken from 0.4% broken to 12.1% broken. Beyond 12.1% broken, the discount is no longer statistically significant ($P > 0.1$). With the discount for *percent broken* beginning low, at 0.4% broken, there seems to be little tolerance for *percent broken* when considering preferences for Nigeria as a whole. Furthermore, the average level of *percent broken* for all of Nigeria is 7.77%, which falls within the statistically significant discount range ($P < 0.01$). Together, the low *percent broken* threshold for discounting brokens and the average level of *percent broken* falling within the discount range shows that while the discount for *percent broken* is small, there is a clear preference for milled rice with low percent broken.

In Kano, the *percent broken* had no significant ($P > 0.1$) effect on the price of milled rice below 5.5%, which should be expected given the difficulty of visually discerning differences in percent broken at such low levels. From 5.5% broken and extending to the maximum amount broken of 36.8%, the price of milled rice decreased by 3.24 Nigerian Naira for every 1% increase in the

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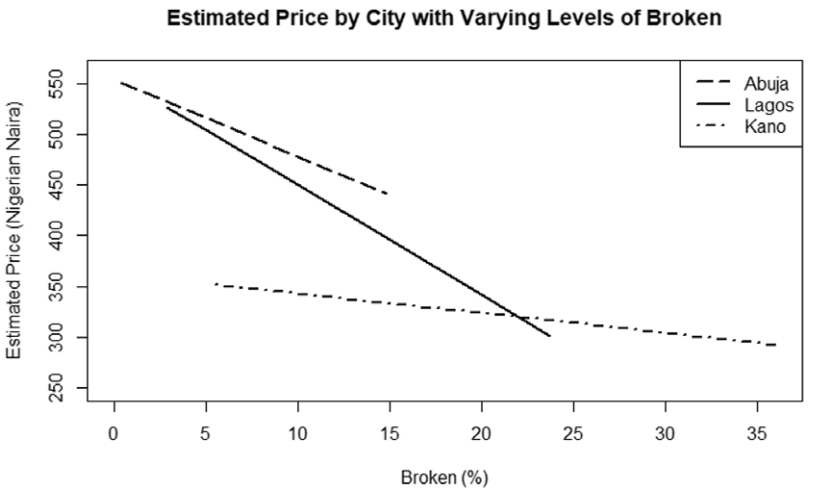

Figure 2. Estimated price by city with varying levels of percent broken.

percentage broken. In Abuja, the price of milled rice decreased by 14.15 Nigerian Naira for a 1% increase in percentage broken up to a 14.8% rate, making Abuja the most sensitive market when it comes to percent broken. The price of rice was not discounted at percent broken above 14.8% broken. This result is expected given that rice with more than 15% broken makes up only 10% of our rice samples in Abuja. In Lagos, the price of milled rice is discounted at a rate of 12.39 Nigerian Naira for a 1% increase in percent broken above 2.9%. Similar to what happened in Kano, one explanation for the indifference at low levels of percent broken could be that it is very difficult to visually discern differences at such low rates.

Using the ranges of significance from the segmented functions, we estimated rice price per kilogram for different levels of broken, holding all else constant. The graph of estimated price by percent broken by city is in Figure 2. From the graph, we can see *percent broken* is discounted the least in Kano, even though the estimated price is also the lowest in Kano. Discount rate for percent broken (Table 2) and estimated milled rice prices (Figure 2) are similar in Abuja and Lagos. These estimates are consistent with earlier results.

Conclusion

Rice is increasingly becoming a staple food in sub-Saharan Africa. Nigeria, the largest producer of rice in Africa and the second largest importer of rice globally, is a key piece in the discussion on emerging rice preferences in Africa. In Nigeria, rice is often sold from an open bag, as was the case for nearly 75% of our observations, suggesting quality control should be a priority. Since rice is commonly purchased from an open bag, consumers can determine the general quality of rice. However, it would be difficult for a consumer to visually distinguish between different levels of a quality characteristic. For example, visually it would be difficult to distinguish between 5% and 15% broken rice options, yet a consumer would likely expect a difference in price between the two. In a context like Nigeria where smuggled rice is common, information about the quality of the rice could be tampered with, lost, or simply not provided in the transport to the final market. The lack of full information, which could occur for a variety of reasons, could in part explain some of the inconsistent results we discussed. If lack of full information in the market is taken advantage of, the price of milled rice in markets can be artificially inflated. For high-income consumers, the inflated price is often viewed as a signal the rice is of higher quality leading to increased purchase which can further drive up the price. Meanwhile, low-income consumers

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are priced out of the market and unable to express their preferences, as the lower quality, but nutritionally sound, rice is priced artificially high. This scenario can form a self-reinforcing cycle that has obvious food security implications.

Our study finds that for most quality characteristics, markets seem to reflect what consumers reported they preferred. Still, there are a few areas for concern. For example, the insignificance of LWR, an established preference amongst Nigerian consumers, points to the potential for market failure. If high-income consumers in Abuja and Lagos are interpreting a higher price to mean higher quality, there is an incentive to increase price regardless of quality as high-income consumers could equate price to quality. There are variables insignificant in Abuja and Lagos that were significant in Kano, which could indicate regional differences in rice preferences or a potential market failure. For example, shape characteristics (*LWR* and *length standard deviation*) are significant in Kano but not in Abuja and Lagos. The indifference in Abuja and Lagos could indicate consumers are using price or rice origin as a heuristic for quality while vendors are not matching quality with price accurately. Alternatively, consumers in Abuja and Lagos could have different preferences, especially as imported rice is more common in those areas. Further research is warranted to differentiate the impact of regional preferences from the use of heuristics in place of full information. The development and enforcement of quality standards could give consumers full information when purchasing rice and therefore increase future consumer welfare if lack of information is causing welfare losses. It is possible that enforcing quality standards, and therefore requiring vendors to accurately report the quality of rice, would lower the price of lower quality rice. By ensuring lower quality rice is available at a price that matches its quality, new low-income consumers could then enter the market and express their demand for rice. These outcomes would only be possible if enforcing rice quality standards and the costs associated with them are minimal relative to current rice price.

This study also provides critical insights into consumer preferences across Nigeria. Even with an established preference for imported rice, the Nigerian government has taken steps to reduce rice imports in an effort to improve self-sufficiency. Improving domestic rice quality, so that it is more congruent with consumers' preferences, will help move Nigeria toward self-sufficiency, while also allowing existing importers of rice to Nigeria to better fit consumer preferences. In Nigeria as a whole, we find a preference for rice with homogeneous (low standard deviation) long slender kernels and a discount for increased percent broken. This could suggest a policy where the Nigerian government either segregate domestic rice varieties (as to lower the standard deviation of length which can come from blending rice varieties during milling) and focusing agricultural research and development on new rice varieties which mill better. *Chalk impact* has no statistically significant impact on the price of milled rice. One of the main findings of this paper is that populations with different income levels seek different quality attributes. For example, those in the low-income group generally discount less than the total population for undesirable quality attributes.

The results of this study provide insight into the varying degrees of information availability and accuracy of open bag rice markets in urban Nigeria while also determining the drivers of rice price. The results of this study will be helpful for Nigerian policy makers in two ways as they determine domestic and trade policies for rice. First, the results of this study can serve as a guide for rice-breeding programs in Nigeria dedicated to improving the quality of domestic rice varieties. The use of older rice varieties that do not serve consumer's preference will not improve rice self-sufficiency in Nigeria. Rather, breeding programs dedicated to improving rice varieties used in domestic production should focus on the attributes that match consumers preference. For example, our study finds a clear preference for a slender kernel but a robust indifference to *chalk impact*. Based on these results, time and resources should be dedicated to making improvements in kernel shape rather than kernel chalkiness as this will provide consumers with rice for which they have expressed demand. In order to take steps toward rice self-sufficiency, the first step will be to align rice varieties used domestically with the quality traits consumers' desire.

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Secondly, this study can be useful for Nigerian rice policymakers as they create programs for the milling sector. As noted previously, most domestic rice is milled by small- and medium-scale mills while large scale mills are reserved for high-quality, premium rice varieties that can already compete with imported rice quality. Once domestic rice varieties are improved, the next logical step will be to put policies in place that will improve the small- and medium-scale mills responsible for the majority of domestic rice milling in ways that meet consumers preferences. For example, even among domestic samples, cleanliness was not a factor in our study, despite a documented preference among consumers for clean rice, because all of the rice was clean and did not have foreign matter. Rather than dedicate more resources to improving the cleanliness of domestic millers, which our study indicates already meets consumers preferences, policymakers and millers alike should focus instead on milling practices that reduce percent broken, making domestic rice more in line with the preferences our study documented.

The results of this study offer insight into the rice preferences of Nigerian consumers that can guide policy so that domestic rice can better match the quality consumers desire. Beyond Nigeria's push for self-sufficiency, the results of this study will be useful for those currently exporting rice to Nigeria. By understanding the demands of Nigerian consumers, rice can be appropriately allocated to match quality traits with consumer preference. In all, this study serves as a guide to point decision-makers across the rice supply in the right direction to best improve consumer welfare in Nigeria.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/aae.2022.38

Data availability statement. The data that support the findings of this study are openly available in https://github.com/bep011/Nigeria_data

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