Trading off consumer preferences induced by cultural and colonial heritage: Lessons from New Rice for Africa (NERICA) in Casamance, Senegal

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Funding
This research was funded by the USAID Economic Growth Project (Projet Croissance Economique, 2009–2015), the CGIAR Program on Rice, and the Bill & Melinda Gates Foundation, Seattle, WA, USA [Grant no. OPP1194925].

Acknowledgments
We are grateful to Dr Alpha Bocar Baldé (Director General, SODAGRI, Dakar, Senegal) for his useful insights, Maïmouna Ndour (Sociologist, Africa Rice Center, Saint-Louis, Senegal) for her excellent research support and Dr. William J. Burke (Agricultural and Food Policy Consulting, Baltimore, MD, USA) for his econometric advice.
Abstract

Breeders face the challenging task of tailoring crop varieties to complex consumer preferences shaped through culture and history. The Casamance rice sector in Senegal is an interesting case; it is endowed with a 3,000-year-old cultural heritage of African rice domestication, while it was exposed to century-long colonial import substitution policies, leading to massive influx of cheap, broken Asian rice. Markets have responded to the amalgam of consumer preferences that have emerged as a result of cultural and colonial heritage by offering three standard grades of rice: 100% broken, semi-broken (35–60% broken), and unbroken (0% broken). To disentangle the trade-off between indigenous and “imported” traits and inform breeding priorities, we conducted framed field experiments with urban women in the Casamance. We assessed consumers’ revealed price premiums for replacing imported, broken Asian rice with three locally produced New Rice for Africa (NERICA) hybrids between African and Asian rice: (i) broken, fragrant NERICA 1; (ii) broken NERICA 4; and (iii) unbroken NERICA 6 featuring medium/bold grain shape. Consumers with genealogical lineages tracing back to the original domesticators of African rice put significantly higher value on locally produced NERICAs, relative to immigrants from the north and northeast, who put premiums on “imported” traits such as rice fragrance. Driven by preferences for both broken and unbroken rice, NERICA 6 outcompeted all other varieties as it mimics the grain shape of semi-broken rice while being unbroken. The latter exemplifies how breeders can strike an optimal compromise in the trade-off between cultural and colonial heritage-induced preferences.

Keywords: cultural heritage; colonial heritage; genealogical lineage; experimental auctions; willingness to pay; value chain
1. Introduction

In addition to productivity goals, a complex aspect of breeding is tailoring crop varieties to farmer, miller and consumer preferences which are often rooted in ancient cultural heritage and dynamically evolve over time as a result of historical events, population growth, immigration, policies, economic development, urbanization, dietary shifts, market trends and climate change (Bairagi et al., 2020; 2021; Britwum and Demont, 2021; Custodio et al. 2016; 2019; Demont et al. 2017; Lenaerts et al. 2019). The case of rice in Africa is interesting, with the African rice species, Oryza glaberrima, having had a long history in West Africa. O. glaberrima was traced to the Inner Niger Delta region in Mali where it was domesticated presumably 3,500 years ago (Portères 1962; 1976). From this primary center of origin, the species arrived in two secondary domestication loci about 500 years later, i.e. (i) the Guinean Futa Jallon uplands; and (ii) Guinea-Bissau, the Gambian coast, and the Senegalese Casamance (Carney 1998; Portères 1976; Linares 2002; Sharma 2010). The African rice species O. glaberrima, believed to have been domesticated prior to European arrival on the African continent was agronomically sturdy, with high tolerance for iron toxicity, infertile soils, and water depth fluctuation (Linares 2002). However, the species also had notable shortcomings, which included being overly brittle, having lower yields, and with its seeds easily scattered. Given the disadvantages with the African species, its Asian counterpart, Oryza sativa gained popularity among farmers, understood to have been adopted in the early 16th century by the peoples of the Upper Guinea Coast (Linares 2002).

In the last decade (2009–2019), rice consumption in sub-Saharan Africa has grown by 6.8% every year, while imports have risen by 7.8% annually (Soullier et al. 2020). Average per capita rice consumption in Senegal is 71kg, higher than the West African average of 39kg, and comparable to other countries with rice cultural heritage such as Sierra Leone, at
99kg, Guinea, at 97kg, and Guinea-Bissau, at 95kg (Soullier et al. 2020). To curb imports and foster self-sufficiency in rice production, the Coalition for African Rice Development (CARD) is currently developing Phase II of their National Development Strategies (NRDS) aimed at ending hunger and achieving food and nutrition security through doubling of rice production in 32 African member states by 2030 (CARD 2020). As a result of cultural heritage and massive rice imports, African consumer preferences for rice now feature a complex amalgam of (i) indigenous traits from African rice, culturally inherited from ancient rice domestication; and (ii) “imported” traits from Asian rice (Demont et al. 2017). In their challenging task of tailoring rice varieties to market demand, rice breeders need to trade off and strike a compromise between both African and Asian preferences. New Rice for Africa (NERICA) varieties were introduced across the continent to improve domestic rice production. Crossbred as a hybrid between African O. glaberrima and Asian O. sativa, NERICA has superior agronomic traits such as disease and weed resistance, high fertilizer sensitivities, early maturation, and high yields (Wopereis et al. 2008). The success of NERICA has reverberated across much of sub-Saharan Africa; it has been piloted in over 30 countries (Rice Hub 2020) and adopted in several. About 1.4 million hectares of NERICA varieties were estimated to have been cultivated in 2013.

However, little research has been conducted to analyze consumer demand for NERICAs and how the varieties are affected by (African) rice cultural heritage and (Asian) rice imports. Britwum et al. (2020) analyzed consumer preferences for NERICAs in Uganda relative to two popular market standards. Although Eastern and Southern Africa do not host a center of rice domestication, the fragrant variety Supa became indigenized in the region by Indian immigrants, which endows the region with rice cultural heritage (Demont, 2013). The authors found that the aromatic NERICA 1 failed to compete against the indigenized Supa and that agronomic genetic gains may have outweighed market traits such as fragrance.
Britwum and Demont (2021) assessed the intrinsic and extrinsic value of NERICA in an urban market in The Gambia, which hosts a secondary center of rice domestication. They found that NERICAs can successfully compete with Asian imports if their milling quality mimics Asian import quality standards. Under those circumstances, NERICAs’ competitiveness was found to be driven by colonial heritage and labeling, and somewhat eroded by cultural heritage. However, a question that devolved from these results was whether NERICAs can be bred to strike a compromise between cultural and colonial heritage.

In response to this research question, we tested several NERICAs through framed field experiments with urban women in a different secondary center of rice domestication in West Africa: the Casamance region in southern Senegal. The succeeding sections provide some theoretical as well as contextual background to our case study.

2. The cultural heritage hypothesis

The cultural heritage hypothesis claims that exposure to rice cultural heritage preserves consumers’ indigenous preferences for locally produced rice to some degree, endowing domestic rice sectors with a comparative advantage in demand (Demont et al. 2017; Soullier et al. 2020), which helps rice value chains compete with imports without requiring substantial investment in rice value chain upgrading. The cultural heritage hypothesis was first formulated by Demont (2013) and subsequently validated through market experiments by Demont and Ndour (2015) and Britwum and Demont (2021). Demont et al. (2017) provided compelling evidence for the cultural heritage hypothesis in their study on rice consumer preferences in West Africa, observing that consumers with either (i) geographical proximity to loci of African rice domestication; and/or (ii) genealogical proximity to the original domesticators of African rice, the Mandé people, feature significantly higher willingness to pay (WTP) and demand for locally produced relative to imported rice, in contrast with consumers remote from rice cultural heritage sites and genealogically unrelated to the
domesticators. Britwum and Demont (2021) connected the cultural heritage hypothesis to colonial heritage, observing that Gambian consumers who descended from original domesticators discounted locally-produced NERICAs that were milled following import standards induced by colonial heritage which is inconsistent with the indigenous trait preferences of their ancestors.

The cultural heritage hypothesis was also validated through an assessment of investment in rice value chain upgrading in 15 West African countries by Soullier et al. (2020). They observed that the highest levels of investment in value chain upgrading were found in highly productive rice sectors that are exposed to high import bills and are not endowed with rice cultural heritage, such as for example in Nigeria and the Senegal River Valley in northern Senegal. Rice sectors remote from cultural heritage do not benefit from consumers’ strong cultural attachment to local rice and therefore experience stronger competitive pressure from imports, which was found to crowd in investment in semi-industrial and industrial milling technologies aimed at improving the competitiveness of domestic vis-à-vis imported rice. On the other hand, comparative advantage in demand endowed by cultural heritage tends to “shield” rice sectors somewhat from competitive pressure from imports and reduce the need and urgency for investment in rice value chain upgrading. In other words, although in the short and medium run these sectors benefit from strong consumer demand for locally produced rice, in the long run they tend to stagnate due to complacency.

While Britwum and Demont (2021) focused on The Gambia, a country entirely ensconced in the Senegambia’s secondary center of rice domestication, Senegal presents an even more interesting case; high import bills and differences in productivity and exposure to rice cultural heritage between the north and the south have resulted in a dichotomous rice sector with highly modernized rice value chains in the northern Senegal River Valley
supplying the capital city in Dakar, and low investment in value chain upgrading in the southern Casamance (Soullier et al. 2020). Most of the rice consumer studies have focused on the Senegal River Valley (e.g., Demont et al. 2013a, 2013b; Diagne et al. 2017) though, and little research has been conducted in the southern region endowed with Senegambia’s ancient rice cultural heritage. Therefore, in the next section, we provide some historical background on the interplay between rice cultural and colonial heritage in the Casamance.

3. Rice cultural and colonial heritage in the Casamance

The rice sector in the Casamance region in southern Senegal is particularly interesting for two reasons. First, as a secondary center of rice domestication, the Senegambia is endowed with a rich, 3,000-year-old cultural heritage with inhabitants whose lineages can be traced back to two ethnic groups, the Mandé and Jola (also known by its French spelling Diola), who are thought to be among the early domesticators of African rice (Sharma 2010). Rice cultivated in the Casamance has always been primarily grown for subsistence purposes (Linares 2002), and up to date the majority of farmers only plant rice in the rainy season (USDA 2018). Secondly, as Senegal was exposed to century-long colonial import substitution policies, urban consumers in the Casamance have been exposed to massive imports of cheap, broken Asian rice. As a result, consumer preferences for rice feature a complex amalgam of (i) indigenous traits from African rice culturally inherited from ancient rice domestication; and (ii) “imported” traits from Asian rice, induced by colonial heritage.

Preference for broken rice is thus an “imported” rather than an indigenous preference. John (2015) aptly captures the historical evolution of rice preferences in Senegal, noting that imported broken rice became part of Senegalese diets after peanuts were introduced in the Senegambia region by Portuguese traders in the 16th century. The success of peanut and its consequent expansion in cultivated acreages led to a substitution away from traditional starchy staples over time. The threat this posed to food security prompted the importation of
cheap, Asian broken rice from French Indochina by colonialists from the end of the 19th century onwards. Even though colonialism ended more than half a century ago, preferences for broken rice have become ingrained in Senegalese diets. The traditional Jola people in the Casamance have preserved their preferences for unbroken rice to some degree, though (Linares 2002).

As rice grows in prominence among local Senegalese diets, so has its demand, and consequently, imports. In the last decade (2009–2019), Senegalese rice consumption grew by 8.9% every year, while imports rose by 6.8% annually (Soullier et al. 2020). Every month, 5,000–8,000 MT of imported rice from Dakar is shipped to the Casamance and sold at a major regional market in Kolda (USDA 2018). As heritage rice production in the Casamance is mostly for subsistence, the deficit in urban consumption zones is filled with imports from Dakar, which have profoundly shaped urban consumers’ taste for rice. As a result of both cultural and colonial heritage, consumer preferences for rice have become notoriously dichotomous in the Senegambia region; while the southern region of the Casamance and the Gambia feature strong preferences for locally produced rice as a result of prolonged exposure to rice cultural heritage, framed field experiments confirmed that urban consumers in the northern cities of Saint-Louis and Dakar tend to prefer imported rice (Demont et al. 2013a; 2013b; Diagne et al. 2017).

In response to the blend in consumer preferences inherited from both cultural and colonial heritage, the urban market in Kolda, the capital city of the Casamance, now offers three standard grades of rice: (i) 100% broken; (ii) semi-broken (35–60% broken); and (iii) unbroken (0% broken). The mere existence of a separate “intermediate” class of semi-broken rice, unique to the Casamance and nonexistent in urban markets in northern Senegal, reveals the market’s attempt to strike a trade-off between indigenous and “imported” preferences. Broken rice has been substituted for millet to make ceebu jen (thiebou dieune in French
spelling), the most popular rice-based fish dish in Senegal typically consumed during lunch. Since the dish is based on a mixture of rice and ingredients cooked in a single cooking pot—in neighboring Gambia, this dish is called *benachin*, translated as “one pot”—broken rice is preferred because it better absorbs the sauce and its texture is more pleasing than unbroken rice (Dieng, 2012). The popularity of the traditional *ceebu jen* dish in Kolda and the entire Senegambia region is the primary driver of preferences for broken rice. Unbroken rice, in contrast, is suitable for *niankatan* dishes, which are based on a viand with accompanying sauce and white rice, cooked and served separately. Semi-broken rice has thus emerged as a natural compromise, in that it is suitable for both *ceebu jen* and *niankatan* dishes and, hence, offers more flexibility for households that can only afford to buy one type of rice. In The Gambia, the popularity of the *benachin* dish motivated the development of 100% broken NERICA rice. Britwum and Demont (2021) subsequently validated the cultural heritage hypothesis among urban Gambians by eliciting valuation for standardized broken varieties of NERICA, finding ample support for the hypothesis: consumers with cultural heritage-induced preferences discounted the broken rice quality of NERICA, with lower WTP price premiums relative to “immigrants” who were willing to pay more. These findings, however, do not resolve the question about whether consumers with rice cultural heritage would be amenable to a compromising semi-broken rice. In this respect, Senegal’s Casamance makes for a compelling case study in validating the cultural heritage hypothesis, where markets have evolved to providing variety in terms of grain quality: broken, semi-broken, and unbroken rice offerings. It should be noted that since the heterogeneous grain quality of semi-broken rice somewhat increases cooking time, it is somewhat discounted on the market relative to 100% broken rice, i.e., homogeneous grain quality is premium-priced in the market.

These developments partly underscored the nature of NERICA development in Senegal, where adoption of the variety gained traction in 2009, increasing overall rice
productivity in areas such as the Casamance (Colen et al. 2013). Manzelli and Laghetti (2014) reported seed market shares of 15–36% for NERICA 1, 10–23% for NERICA 4, and 21–33% for NERICA 6 in the Casamance region in 2012, and noted that with the introduction of upland NERICA varieties, traditional varieties such as Ablaye mano, Ebundioulaye, Mosdonlé, Bonti, Santo, Yakola, Bandialle, and Kadiaka have progressively disappeared. Hence, in their challenging task of tailoring rice varieties such as NERICAs to market demand, rice breeders need to trade off and strike a compromise between cultural and colonial heritage-induced consumer preferences. “Imported” rice traits inherited from colonial era policies are: (i) 100% broken grains; (ii) fragrance, (iii) higher swelling capacity—thanks to the fact that imported rice is typically stored for a few years before shipping; (iv) low price; and (v) O. sativa parentage. In contrast, preferred rice traits inherited from the original progenitors of African rice domestication are: (i) unbroken grains, (ii) no fragrance, (iii) sensory quality, and (iv) O. glaberrima parentage, i.e., traits that are reminiscent of the indigenous people’s focus on taste, texture and grain quality (Linares 2002). Given these and following Britwum and Demont (2021), it was expected that consumers whose preferences have been shaped by cultural heritage would be more inclined towards unbroken rice, with inclination towards broken grains among consumers whose preferences have been influenced by imported Asian rice. In the next section, we describe our experimental protocol for disentangling the trade-off between indigenous and “imported” traits.

4. Experimental Procedures

(a) Sampling

Trained female research enumerators recruited participants from the Kolda central market in May 2012 using pictures of previous experimental procedures. Pairs of recruiters randomly approached women, and asked them about their willingness to participate in a market
research study that would span about two and half hours. Towards the objective of obtaining a random sample and making it representative of the population of shoppers in the market, every third female whose age was estimated to be between 18 and 65 years’ old was approached. It was explained that a voucher worth 2,000 FCFA, approximately US$ 4.05 (Exchange rate was US $1 = FCFA 493.28), would be offered as compensation, precisely described as an amount for “taxi back home.” This description was to preclude these payments being viewed as *quid pro quo*, as this could potentially bias bids and WTP values (Loureiro et al. 2003). This is also termed “house money” effects, where participants feel a need to submit higher bids that are inconsistent with their true value for a product out of a moral obligation to the experimenter (see Canavari et al. 2019 for detailed discussion). Those who agreed to participate were accompanied by one of the recruiters to a hotel located at walking distance from the Kolda central market. Those who did not agree to participate were asked their consent to respond to a short survey administered orally by the other recruiter. The experiments were conducted in a conference room at the hotel. A total of 202 women were approached over a four-day period; 120 agreed to participate in the experiments; 42 responded to the short survey instead; and 40 refused to participate in the experiments and the survey. Written consent was obtained from the participants and surveyed respondents. Overall, eight experimental sessions were conducted over a four-day period, one in the morning, and the other in the afternoon each day with fifteen participants in each session.

The study’s focus on women was partly informed by previous auction studies on rice in Africa, which have predominantly used women participants given their role as major rice decision makers (Demont et al. 2012; Demont and Ndour 2015). In addition, the inclusion of a collective induction treatment (CIT) round in the auction design (see section on Experimental auctions) which required word-of-mouth (WOM) exchanges of opinions would
have been more challenging with mixed-gender groups (Demont et al. 2013b), given distinct gender roles in these areas.

(b) Products

Four rice versions which differed in their bundle of attributes were used in the experiments: (i) *Riz KC*; (ii) NERICA 1; (iii) NERICA 4; and (iv) NERICA 6. *Riz KC* is an imported Indian rice brand widely known in the Kolda market and considered to be inferior, both in quality (it is widely known for its impurities and other admixtures) and price. It was thus used as the benchmark (control) against which consumers’ willingness to upgrade and replace imported rice and to pay price premiums for the alternative locally produced NERICAs were measured. While products (i), (ii), and (iii) were all 100% broken rice and largely preferred in Senegal, NERICA 6 was unbroken (see Figure 1).

Based on the grain quality analysis conducted by Traore et al. (2011) and grain shape classification reviewed by Custodio et al. (2019), unbroken NERICA 1 and 4 feature average length/width ratios of 2.89–2.91; hence their 100% broken versions can be technically categorized in the “Short/Bold/Round” category (length/width ratio of broken kernels < 2.0), while unbroken NERICA 6 features a length/width ratio of 2.44 and hence falls into the “Medium/Bold” grain shape category (length/width ratio in the range 2.0–2.9). Furthermore, NERICA 1 features fragrance, while NERICA 4 is popular for its superior yield (Kinyumu 2009; Wopereis et al. 2013). Both are among the most widely adopted in the sub-region. Hence, this set of four products was expected to capture the salient features of indigenous traits (unbroken grains, no fragrance, *O. glaberrima* parentage) versus “imported” traits (broken grains, fragrance, higher swelling capacity, *O. sativa* parentage).
(c) Experimental auctions

The Vickrey (1961) second price auction mechanism was used to elicit WTP bids due to its incentive compatible properties. The auction was framed through an endow-and-upgrade procedure to elicit consumers’ substitution behavior between the imported benchmark and locally produced NERICAs, a method widely practiced in rice auctions in Africa (e.g., see review by Demont and Ndour 2015). To familiarize participants with the experimental procedure, a training session was first conducted. After it was assured every participant understood the mechanism, they were presented one kilogram of the four rice varieties in bowls placed in a quadrangular fashion on each participant’s table. Similar to Britwum and Demont (2021), this arrangement of the bowls (arranged quadrangularly) of rice was followed to preclude any possible lining-up bias (e.g., see Demont et al., 2012), i.e., a scenario where participants unwittingly ascribe one rice type with superior quality characteristics when they are showcased linearly. The product test was blind in that the identity of the rice types was never revealed to the participants. In the course of the experiments, the visual and sensory characteristics of the uncooked and cooked rice could be examined over several successive rounds. Within each session, there were four rounds conducted, three individual rounds, and one collective round. To reduce costs, it was explained that only one of the products and rounds would be binding. The products and rounds were limited to four, considering that higher numbers of both reduce the probability of any of the products or rounds being selected as binding (Canavari et al., 2019), a phenomenon which can potentially moderate incentives for truthful telling of preferences and valuation.

Similar to Haines et al. (1988), a two-stage approach was used. First, participants were asked to choose between the benchmark rice and each of the alternative rice types.1 If

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1 The alternative rice types were presented in a random fashion during preference and WTP elicitation.
the benchmark was chosen, participants were asked whether they would still choose the benchmark if the alternative rice was priced equally. This was to differentiate those who were unwilling to upgrade (implying a negative WTP or discount for replacing imported rice with NERICA or a price premium for maintaining the imported rice benchmark despite the possibility to exchange it for NERICA) from those who were, but unwilling to pay (zero price premium for NERICAs relative to imported rice). Participants who chose the alternative over the benchmark were asked to submit bids to upgrade to one kilogram of the alternative NERICA rice, for each of the three NERICAs. A survey was administered before and after the auctions to collect participants’ socio-demographic information.

The second round of the experimental procedure examined the influence of sensory evaluations on WTP. Subjects experienced the aroma, texture, and taste of cooked versions of the four rice types including their swelling capacities. In between tasting, they were requested to cleanse their palates with water. After tasting, post-sensory WTP bids to exchange the benchmark for each of the alternative rice products were submitted in this round. The final round determined the influence of WOM social cognition on preferences and WTP. In each session, participants were grouped in fives at separate tables, and asked to collectively reach an agreed-upon bid to exchange the benchmark rice for each of the alternative types. With fifteen participants in each session, there were three groups of five participants in a WOM round. This so-called “collective induction treatment” (CIT) round (Demont et al. 2013b) was aimed at eliciting WOM exchange among participants. It was subject to a similar competitive Vickrey bidding process, which aimed at ensuring that participants would be incentivized to exchange WOM on their perceived true value of the products in order to achieve consensus on the collective bids. Following this treatment, participants went back to their individual tables and post-CIT bids were individually elicited for each of the alternative rice types. A
last round of surveys was administered after this last bidding round, this time focusing on information about rice preferences and awareness of NERICA.

As a last step, one rice variety and one of the four rounds were randomly chosen as binding, where the highest bidder was given one kilogram of the selected rice and paid the participation fee minus the bid of the second highest bidder, following the Vickrey (1961) auction procedure. Participants were then thanked for their time.

5. Demographic characteristics of the sample

Descriptive statistics of the dataset were captured in Demont et al. (2013) and Demont and Ndour (2015). Here, we generate more in-depth insights by analyzing the data through a more formal econometric approach. A summary of variables and demographic characteristics from the survey is displayed in Table 1. On attitudes, more than half of participants believed quality attributes of a variety should outweigh quantitative attributes such as price and swelling capacity. This variable was constructed from three options following a question about what participants considered the most important feature of rice for their households: that, (i) it is cheap; (ii) it has a good swelling capacity; and (iii) it is of good quality. These were captured in a dummy variable which equaled one if quality was chosen to be more important than price or swelling capacity, and zero otherwise. For awareness, just about 9% of participants had heard about NERICA from sources they trusted. This highly contrasts with the awareness levels of 38% in Uganda (Britwum et al., 2020) and 78% in The Gambia, which can be attributed to extensive promotion programs on radio and television (Britwum and Demont, 2021). The “Awareness NERICA” variable was constructed from two questions: the first asked if the participant was aware of NERICA, and if they were, to indicate their source of information (i.e., from the radio, TV, written press, forum, word-of-mouth, shop, market, or other sources). The second question asked participants: “Imagine a new rice type arrives on the market, what would be the information source you would most
trust and that would convince you on the utility of the product and why?” Options for information sources for this second question were similar to the previous. A dummy variable for “Awareness from trusted source” was constructed, and was equal to one if the information source was the same for both questions; otherwise, equal to zero.

The high average annual per-capita rice consumption of 110kg recorded in our sample was comparable to the levels of 95–99kg recorded in other secondary centers of rice domestication (Soullier et al. 2020), and even in some Asian countries (Bairagi et al. 2020). Almost 90% of participants were involved in decisions regarding rice purchase, validating the choice of using women participants. In many developing economies, women with access to income have been noted to make food decisions on behalf of their households (Quisumbing et al. 1996). With respect to characteristics that were sought in rice purchase, broken grain was a preferred characteristic, with more than half of participants typically purchasing 100% broken rice, a third semi-broken (35–60% broken) rice, and 17% unbroken (0% broken) rice. This is consistent with general preferences among Senegalese as discussed earlier and indicates the extent to which colonial heritage has influenced consumer preferences.

Despite long exposure to rice imports from Asia, fragrance does not appear to be a popular rice characteristic, which is consistent with Demont et al. (2017) and in contrast with northern Senegal (Diagne et al., 2017); among subjects, only 11% of them purchased fragrant rice. Average monthly household income was approximately FCFA 89,500, which exchanges to about US $181. Finally, our brief survey with non-participants suggests that this segment had higher opportunity costs of time as they were more likely to be wealthy, in the trading business, and employing cooking housemaids, with stronger preferences for rice quality and “imported” traits such as fragrance and weaker preferences for indigenous preferences such as unbroken grains.
The majority of respondents (88%) were from ethnicities with lineages that can be traced to the original domesticators of African rice in the secondary center of origin in the Casamance: the Jakhanke, Jola, Fula, Soninke, and Mandinka people. These groups either directly descended from the original Mandé and Jola people who domesticated the *O. glaberrima* species in the secondary center of origin, or had a long exposure to them. The other ethnic groups were Wolof, Serere, Bambara and Maure, and were considered immigrants from the north and northeast. In Figure 2, we compare the grain type preferences and top 10 criteria used in judging rice quality between both groups. In determining the 10 criteria, participants answered an open question “What criteria do you use to judge rice quality?” from which responses were subsequently ranked and grouped using the literature as a guide. Although preference patterns are fairly similar due to simultaneous exposure to century-long colonial heritage, we observe two notable differences. First, although they purchase similar shares of semi-broken rice, a larger segment of the population exposed to cultural heritage has preserved indigenous preferences for unbroken rice, while preferences for broken rice are more pronounced among immigrants. Secondly, immigrants tend to prioritize swelling capacity and unsticky grain texture, while indigenous people tend to prioritize taste and cooking quality, similar to the original domesticators of rice (Linares 2002).

2 The *Fula* people (*Pulaar* in French) are traditionally nomadic traders and cattle herders spread all over West and Central Africa. The historic origin of the *Fula* people in the Casamance is described by Quinn (1971). Alpha Moto Balde unified the *Fula* of Kaabu with the help of the *Fula* of Futa Jallon in his revolt against the Mandinka and the kings of Kaabu, which eventually led to creation of the kingdom Fuladu in the Upper Casamance, in which the *Fula* predominated, as suggested by the name. This is reflected in our sample, with 68% of sampled participants being *Fula*. Since most of the *Fula* in this region are engaged in agriculture and can be genealogically traced to the *Fula* in the Futa Jalon highland region in Guinea, another secondary center of rice domestication, we consider them to be part of rice cultural heritage in the Casamance.

3 The *Bambara* people are immigrants from the northeast (Mali). Although they are genealogically related to the Mandé group that domesticated rice in the primary center of origin in Mali, they do not trace their lineage to the people who domesticated rice in the Senegambia region 500 years later.

4 Unsticky or loose rice grains typically result from low varietal amylose content which facilitates grain absorption of oil and sauces, rendering the variety more suitable for *ceebu jen.*
6. Econometric Model

Though the Tobit model has been employed variously in consumer food studies (examples include Fox et al. 2002; Bernard and Bernard 2009; Demont et al. 2012; Rihn and Yue 2016), the fact that the same variables and parameters that determine the probability to participate also determine levels of consumption has been argued to be overly restrictive. Instead, similar to Haines et al. (1988), we model participants decisions as a two-stage process; first, the individual’s desirability to upgrade, and second, the amount of money the individual chooses to bid when they decide to upgrade (see also Burke 2009). This follows Cragg’s (1971) introduction of the double-hurdle model where different stochastic processes are specified for an individual’s willingness to participate (upgrade) and their WTP.

Assume \( d_{ijpr} \) represents participant \( i \)’s desirability to upgrade one kilogram of the benchmark rice for an alternative rice \( p \), in session \( j \) and bidding round \( r \), and \( WTP_{ijpr} \) is the amount a participant is willing to spend as captured by their submitted bids. Then,

\[
\begin{align*}
    d_{ijpr} &= 1 \text{ if } Z_{ijpr} \delta + u_{ijpr} > 0 \\
    d_{ijpr} &= 0 \text{ if } Z_{ijpr} \delta + u_{ijpr} \leq 0 \\
    WTP_{ijpr} &= X_{ijpr} \beta + \varepsilon_{ijpr} \quad (1)
\end{align*}
\]

where \( Z \) is a vector of explanatory variables that explain the desirability to upgrade, \( X \) a vector of variables that determine WTP, and \( \delta \) and \( \beta \) vectors of parameters to be estimated. The error terms, \( u_{ijpr} \) and \( \varepsilon_{ijpr} \), are assumed to be normally distributed with variance equal to 1 and \( \sigma^2 \), respectively. A participant’s desirability to upgrade, \( d_{ijpr} \), is a binary indicator which is equal to 1 if WTP is positive, and 0 otherwise. The probability a respondent decides not to submit a positive bid can be expressed as:

\[
Pr(WTP_{ijpr} = 0 | Z_{ijpr}, X_{ijpr}) = \Phi(-X_{ijpr} \beta / \sigma) + \Phi(X_{ijpr} \beta / \sigma) \Phi(-Z_{ijpr} \delta) \quad (3)
\]

The distribution of WTP being positive is given as:
\[
f(WTP_{ijpr} | Z_{ijpr}, X_{ijpr}, WTP_{ijpr} > 0) \\
= (2\pi)^{-1/2} \alpha^{-1} \exp\left\{- (WTP_{ijpr} - X_{ijpr}\beta)/2\alpha^2 \right\} \Phi(-Z_{ijpr}\delta)
\]

where \( \Phi \) is the standard normal cumulative density function.

In the econometric implementation, the probability that a respondent would upgrade the benchmark to an alternative NERICA variety is modeled as a function of non-economic variables (similar to Newman et al. 2003; Dong et al. 2004; Britwum et al. 2020). That is, it was not expected that economic variables such as income, house ownership, or household size would influence an individual’s desirability to upgrade in a considerable manner. However, given the likelihood of inconsistent parameter estimates in limited dependent variable specifications when heteroscedastic errors are present (Arabmazar and Schmidt 1981), heteroscedasticity was accounted for in the empirical model. All variables in the WTP equation were tested for heteroscedasticity, and those that emerged significant were retained in the variance portion of the model. The model was also cluster corrected, given multiple observations for each participant across different products and rounds.

(b) Hypotheses

Hypotheses regarding the signs of the included variables were generally developed from the literature. Starting with the experimental procedure, tasting and other sensory evaluations of the rice varieties were expected to lower WTP bids. Previous literature on rice in Africa (see review by Demont and Ndour 2015) has found that WTP tends to decrease after sensory evaluations. The effect of social cognition (WOM) on WTP, however, was deemed uncertain, given inconclusive reported impacts. While Demont et al. (2017) found strong evidence for both sensory experience and social cognition in reinforcing WTP, Demont et al. (2012), Akoa et al. (2016) and Britwum et al. (2020) did not find any evidence for the latter effect.

In terms of the relationship between the type of rice that households typically purchase (broken, semi-broken and unbroken) and WTP, not much has been done to guide
hypothesis. On the one hand, we could anticipate that participants’ whose households purchase semi-broken or broken rice would pay price premiums for NERICA 6, as its medium/bold grain shape mimics the texture of semi-broken rice while being an upgrade over the latter as it is more homogenous (Figure 1).\(^5\) On the other hand, since NERICA 6 is unbroken, it could also attract the market segment of households who typically purchase unbroken rice.

The impact of demographic characteristics on preferences has been found to be weak in similar studies in Africa. Particularly, income was unlikely to have a significant impact on WTP (Demont et al. 2012; Akoa et al. 2016; Demont et al. 2017). The response of participants with rice cultural heritage to the NERICAs could provide evidence in support of the cultural heritage hypothesis (Demont 2013; Demont and Ndour 2015; Demont et al. 2017; Soullier et al. 2020). If rice cultural heritage is entrenched, then it would be expected that participants with ties to early rice domesticators would have higher preferences and WTP for locally produced rice in general and NERICAs in particular, given that NERICA varieties retain some of the original characteristics of the *O. glaberrima* species. On the other hand, if colonial heritage has profoundly altered preferences, we could find the opposite effect. In any case, we expect the market segment of immigrants that have not been historically exposed to rice cultural heritage to express preferences for imported rice and pay price premiums for “imported” traits such as broken grains and fragrance, consistent with findings in northern Senegal (e.g., Demont et al. 2013a, 2013b, Diagne et al. 2017). Other insights into the cultural heritage hypothesis show that beyond the “localness” of rice, preferences can be conditioned by grain quality standards. Britwum and Demont (2021), for example, found that cultural heritage had a negative effect on WTP for NERICAs if they were presented in the colonially inherited 100% broken grain quality standard.

\(^5\) Standard locally produced broken and semi-broken rice typically feature a heterogeneous mix of grain lengths which results from millers purposely attempting to increase the rate of broken grains over unbroken grains.
7. Results

(a) Willingness to upgrade and willingness to pay

Results from the auction procedures for the three NERICA varieties, regarding participants’ willingness to upgrade and descriptive statistics of WTP are displayed in Table 2 and in Figure 3. In addition to the average bids displayed, Table 2 also shows the proportion of zero bids across products and rounds. Disaggregated by products, the first panel in Figure 3 examines respondents’ willingness to upgrade, with the second showing average positive WTP bids for the NERICAs. Given that the endow-and-upgrade auction procedure was adopted, WTP bids represent price premiums participants were willing to pay over the inferior imported benchmark variety, Riz KC, priced at 300 FCFA per kilogram (US¢ 61).

The pattern of willingness to upgrade was similar across the three products over successive rounds with approximately 80% of participants willing to upgrade the benchmark rice for NERICA. For all three products, the proportion of zero bids successively decreased across the rounds. A notable exception regarding the proportion of zero bids was observed for NERICA 6, which recorded a higher frequency than NERICAs 1 and 4 in the post-sensory round. Otherwise, zero bids were equal or higher for NERICA 4 than for the other two across all other rounds. Average bids for NERICA 1 were in the range of FCFA 61–64 (US¢ 12–13), and FCFA 51–58 (US¢ 10–12) for NERICA 4. It is apparent here that bids for these two varieties were generally close across the treatments. Incidentally, both NERICAs 1 and 4 recorded the same maximum bids of FCFA 300 (US¢ 61). Mean bids for NERICA 6 were in the range of FCFA 82–101 (US¢ 17–20), which was significantly higher than mean bids for NERICAs 1 and 4. The lowest average premium for NERICA 6 exceeded the highest premiums of both NERICAs 1 and 4, indicating the appeal of NERICA 6, both in its cooked and uncooked forms.
(b) Double-hurdle results

Results from the double-hurdle model, for both participation and purchase equations appear in Table 3. Two variations of the model were run; the first had no interaction variables, with Model 2 featuring interactions between products on the one hand and purchase habits (broken and unbroken), and cultural heritage on the other hand. The variables modeled are as explained in Table 1, with a total of 1,005 observations across the three experimental rounds (pre-sensory, post-sensory, and post-CIT) and the three alternative rice varieties examined (NERICAs 1, 4 and 6) for 115 participants after removing (accounting for) missing/incomplete observations for the explanatory variables used in modelling.

Starting with experimental rounds (the reference dummy is the post-sensory round), the probability of upgrading increased after tasting. However, the propensity to upgrade was not statistically different among the three NERICA varieties (NERICA 4 set as the reference dummy). After exchanging WOM, participants were even more likely to upgrade to NERICAs. However, neither tasting or WOM significantly affected WTP.

For the NERICA varieties, participants were willing to pay significantly higher price premiums for NERICAs 1 and 6 relative to NERICA 4, with the premium for NERICA 1 nearly overwhelmed by the discount imposed by subjects with rice cultural heritage (which can also be interpreted as a premium for fragrance paid by immigrants). For variables in the attitudes and knowledge category, two were statistically significant in the participation equation. Participants who valued quality over price were more likely to upgrade to the alternative NERICA varieties, and were willing to pay significantly higher price premiums. Similarly, and perhaps remarkably, participants who purchased the same type of rice (loyalty) were more likely to exchange the imported variety for NERICA. Higher per-capita
consumption of rice was also associated with higher WTP for the NERICA upgrades. This is consistent with similar findings in Cameroon (Akoa et al. 2016).

An interesting aspect of the results was the influence of frequent purchase of broken rice on the probability to upgrade, and WTP. Participants who typically purchased the more popular broken rice were less likely to exchange the imported rice for locally produced NERICAs. Despite this lower probability, the interaction between previous purchase of broken rice and NERICA 6 was statistically significant and positive; indicating those who purchased broken rice valued NERICA 6 higher. Moreover, while the standalone purchases unbroken coefficient was not significant, its interaction with NERICA 6 was, with participants who frequently purchased unbroken rice willing to pay higher premiums. Hence, it would appear that consumers whose preferences have either been preserved from cultural heritage or shaped by colonial heritage are willing to pay premiums for NERICA 6, underscoring the observation that NERICA 6 can be an optimal compromise for both types of preferences, confirming both hypotheses.

A key finding in the results is the impact of cultural heritage on the probability to upgrade imported rice, and WTP for the NERICA varieties. Participants whose genealogical lineages were traced to the secondary domesticators of African rice (O. glaberrima) in the Casamance were more likely to exchange imported rice for locally produced NERICAs. In addition, the significance of the cultural heritage coefficient in the purchase equation (in both Models 1 and 2) shows that participants exposed to rice cultural heritage were willing to pay substantial price premiums to substitute imported rice for NERICAs, relative to immigrants.

Several socio-demographic variables were significant. In the participation equation, traders, and participants who had at least a secondary (high school) education had a higher probability of upgrading imported rice to locally produced NERICAs. The higher propensity of upgrading among traders is consistent with findings in Uganda (Britwum et al. 2020), but
contrasts with findings in the provincial town of Saint-Louis in northern Senegal (Demont et al. 2013b). The latter town is inhabited by the same ethnic groups that are identified as “immigrants” in the southern Casamance. Thus, it is logical that traders in the north would tend to align with the dominant preferences for imported rice expressed by the majority of the population. A higher probability to upgrade among relatively educated women was also observed in northern Senegal (Demont et al. 2013a). Although less willing to upgrade the imported benchmark, participants who were members of a social group were willing to pay premiums for the NERICA varieties over the benchmark. This contrasts with findings in Cameroon (Akoa et al. 2016) and northern Senegal (Diagne et al. 2017). Most of these social groups are either professional associations or small credit associations (*tontines* in French language). Somewhat similar to findings in Uganda (Britwum et al. 2020) and Benin (Demont et al. 2020), but in contrast with trends in Dakar, Senegal (Diagne et al. 2017), Casamance households with a cooking housemaid were found to significantly discount NERICA upgrades, probably because those households are less directly involved in cleaning, sorting and preparing rice, and hence, may put a lower value on grain quality improvements.

Consistent with previous findings in northern Senegal (Demont et al. 2013a; Diagne et al. 2017), self-reported income did not have a significant impact on WTP. This is probably because income-related questions tend to be viewed as sensitive, making responses to them prone to social desirability bias. However, house ownership, arguably a good proxy for wealth, was positive and significant at the 10% level for models 1 and 2. Household income was, however, significant in the variance portion of the model, indicating high variability in income with respect to bids for the alternative rice varieties.

8. **Discussion**

Utilizing framed field experiments in Senegal’s Casamance region, this study examined consumer preferences for local NERICA varieties and the trade-off in preferences (i) between
consumers who trace their lineages to original domesticators of the African *O. glaberrima* species and immigrants; and (ii) between preferences induced by cultural heritage and “imported” traits induced by colonial heritage. Although consumers were willing to upgrade imported rice, WTP differed across the alternative NERICA upgrades. Regardless of experimental rounds, NERICA 6 fetched the highest price premiums, surpassing both NERICAs 1 and 4. NERICA 6 is thus, likely viewed as an ideal compromise between (i) the cultural heritage trait of unbroken grains with particular emphasis on grain quality and homogeneity; and (ii) the colonial heritage trait of 100% broken grains, as the medium/bold grain shape of NERICA 6 mimics 100% broken rice while keeping unbroken grain quality intact. As a result, the product is more homogenous than semi-broken rice, the market’s attempt to strike a compromise between both demands through targeted milling and grading strategies. This finding complements insights from The Gambia (Britwum and Demont 2021) and suggests that the compromise between traits induced by cultural and colonial heritage can also be successfully obtained through breeding.

A notable finding was that consumers exposed to rice cultural heritage were not only more likely to upgrade to NERICA from the imported benchmark, but also more willing to pay price premiums than “immigrants” from the north and northeast who do not have strong cultural ties to rice. These findings validate the cultural heritage hypothesis and are in line with Demont et al. (2017), who found similar behaviors among descendants from the *Mandé*, the original domesticators of rice in the primary center of origin. Moreover, Casamance consumers who preferred cultural heritage-induced traits such as quality over colonial heritage-induced traits such as low price and swelling capacity were more willing to substitute imported rice and pay for locally produced NERICAs. Since NERICAs retain characteristics from the African rice species (as a crossbreed with the Asian species), these preferences for “localness” suggest that cultural heritage in rice may have been passed on
through successive generations. For specific NERICA varieties, consumers with rice cultural heritage were willing to pay higher premiums for NERICA 6 than either NERICA 1 or 4. Aroma could consequently be overlooked as a breeding priority for consumers in secondary centers of rice cultural heritage such as the Casamance. This is likely because fragrance is not an indigenous trait from the *O. glaberrima* species, and despite exposure to imports, it is preferred by only 11% of our sampled participants (Table 1). Immigrants were more likely to choose the imported 100% broken rice, and also willing to bid higher premiums on “imported” traits such as rice fragrance, as suggested by the significantly negative coefficient of the interaction between cultural heritage and NERICA 1 (Table 3). This is consistent with findings in northern Senegal from where these immigrants originate (Diagne et al. 2017).

Although participants who preferred broken rice had a higher tendency to keep the imported benchmark rice rather than upgrade to NERICAs, they were likely to pay more for NERICA 6. As noted, preference for (imported) broken rice is induced by colonialists (John 2015). By contrast, the segment of the population that typically buys unbroken rice could be thought of as representative of the indigenous preference inherited from the domesticators of rice in the Casamance. The popularity of NERICA 6 among both consumer segments would confirm our hypothesis that NERICA 6 is a breeding compromise between preferences induced by cultural and colonial heritage and, as a result, between the two most popular dishes *ceebu jen* and *niankatan*. It is important to note that both groups pay premiums for NERICA 6, an indication that consumers who usually purchase semi-broken rice discount NERICA 6 by the same amount. This suggests that although NERICA 6 may be a compromise between cultural and colonial heritage-induced preferences and may attract both segments of consumers with broken and unbroken rice purchase habits, it is not viewed as a perfect substitute for semi-broken rice by those who prefer the latter grain type.
These results can be further illuminated within the context of earlier work by Demont et al. (2017) from five West African countries. Here, the authors found consumers with cultural heritage-induced preferences were willing to pay price premiums for local rice relative to imported rice. A further validation of this hypothesis by neighboring Gambia is echoed in findings from a recent study by Britwum and Demont (2021). Using 100% broken rice products in experimental auctions, they reveal that cultural heritage eroded price premiums for local NERICAs by 5 to 10 percentage points relative to imported rice. On the contrary, Gambian consumers with preferences altered by colonial heritage were willing to pay 7 to 12 percentage points higher price premiums for local NERICAs than imported rice. Unlike The Gambia, the evolution of rice markets in the Casamance has been unique, in that the market has naturally adapted to both cultural and colonial heritage with three rice product offerings: 100% broken, semi-broken, and unbroken rice. In this case, preferences for unbroken rice among consumers with cultural heritage preferences translate into positive price premiums for NERICA 6, while broken NERICAs 1 and 4 are discounted by this segment. Future studies can examine the extent to which varieties with a grain shape in the “short/bold/round” category (Custodio et al. 2019) are perceived and experienced as a substitute for broken grains.

Finally, and noteworthy, the USDA (2018) has noted NERICA varieties only make up about 10% to 20% of the total rice area cultivated in the Casamance region of Senegal, with local varieties such as the Sahel making up the rest. However, with the agronomic advantages of NERICA in drier conditions such as the Casamance, and given consumer acceptance of these varieties as found in this study, the case for expanding NERICA becomes increasingly compelling. Our findings from Kolda, where residents represent a blend of both urban and farming communities with a strong cultural heritage suggest the need for policy to leverage the budding consumer acceptance towards expanding local rice offerings with varieties such
as NERICA. For breeders, these findings suggest the need to strike an ideal compromise that satisfies both consumer groups, probably by including a trait mix that is not only a hybrid between Asian and African rice characteristics, but also a “hybrid” of both cultural and colonial heritage-induced preferences. The medium/bold grain shape of NERICA 6 seems to fit both categories and breeders should be commended for this successful example of market-driven breeding.

9. Conclusion

Although imported rice varieties have overwhelmed local versions in Senegal, consumer acceptance of local varieties such as NERICA should be viewed as encouraging for rice value chain development. For breeders, the outcome that the medium/bold shaped grain variety, NERICA 6, recorded higher price premiums than NERICAs 1 and 4 suggest it can successfully serve as a compromise between indigenous and “imported” traits. Future varieties tailored to this region can be successful if their grain lengths are shortened to mimic the texture of broken grains. The higher premiums consumers with cultural heritage were willing to pay overall for NERICA also reveal strong parallels in preferences between original domesticators of the African rice species in the secondary center of origin, and consumers with lineages traced to them.

Put together, our findings confirm the existence of a comparative advantage in demand for local rice varieties such as NERICAs in secondary centers of rice domestication. Given its agronomic advantages of drought tolerance and superior yields, NERICAs can potentially enhance local rice production. The more breeders manage to tailor and segment new varieties to the amalgam of preferences that are induced by both cultural and colonial heritage, the better they can reap the benefits of the comparative advantage in demand in terms of faster adoption rates, higher productivity levels, lower production risks and higher impacts on poverty and economic growth. Once the rice sector is able to move from
subsistence to surplus production, in the long run its high exposure to imports will eventually lead to crowding-in of investment in rice value chain upgrading (Soullier et al. 2020).

It should be noted, however, that although women consumers overwhelmingly make rice purchase decisions in Senegal, our study’s exclusive focus on urban women participants means our results may not be generalizable for the entire urban Casamance population, and we acknowledge this as a limitation. On a different issue, a rarely explored area in the experimental auction literature is the role of hunger and its possible impacts on sensory evaluation (see Canavari et al., 2019). Hunger was indirectly captured through the “Morning” dummy. However, more research needs to be conducted to properly capture this variable and assess its influence on social and time preferences (e.g., see Aarøe and Petersen 2013; Briz et al., 2015). These could be avenues for future research, in reproducing similar studies with a more balanced gendered sample of rice decision makers, and controlling for variables such as hunger. Nonetheless, insights from this study would be of interest to breeders, seed dealers, local rice producers, rice value chain developers, and policy makers as they shape the future of local rice in Senegal.
References

Aarøe, L. and Petersen, M.B., 2013. Hunger games: Fluctuations in blood glucose levels influence support for social welfare. *Psychological Science*, 24(12): 2550–2556.

Akoa Etoa, J. M., Ndindeng, S. A., Owusu, E. S., Woin, N., Bindzi, B. and Demont, M. (2016). Consumer valuation of an improved rice parboiling technology: Experimental evidence from Cameroon. *African Journal of Agricultural and Resource Economics*, 11(1): 8–21.

Arabmazar, A. and Schmidt, P., 1981. Further evidence on the robustness of the Tobit estimator to heteroskedasticity. *Journal of Econometrics*, 17(2): 253–258.

Bairagi, S., Custodio, M.C., Durand-Morat, A. & Demont, M. 2021. Preserving cultural heritage through commodification of Cordillera heirloom rice in the Philippines. *Agriculture and Human Values*, 38(1): 257–270.

Bairagi, S., Demont, M., Custodio, M.C. & Ynion, J., 2020. What drives consumer demand for rice fragrance? Evidence from South and Southeast Asia. *British Food Journal*, 122(11): 3473–3498.

Bernard, J.C., Bernard, D.J., 2009. What is it about organic milk? An experimental analysis. *American Journal of Agricultural Economics*, 91, 826–836.

Britwum K., Owusu, E. S. and Demont M. (2020). Confronting Genetic Gains with Markets: Retrospective lessons from New Rice for Africa (NERICA) in Uganda. *Outlook on Agriculture*, 49(4): 298 – 310.

Britwum K. and Demont M. (2021). Tailoring rice varieties to consumer preferences induced by cultural and colonial heritage: Lessons from New Rice for Africa (NERICA) in The Gambia. *Outlook on Agriculture*, in press.
Briz, T., Drichoutis, A.C. and House, L., 2015. Examining projection bias in experimental auctions: The role of hunger and immediate gratification. Agricultural and Food Economics, 3(1): 1–17.

Burke, W. J. (2009). Fitting and interpreting Cragg's tobit alternative using Stata. The Stata Journal, 9(4): 584–592.

Canavari, M., Drichoutis, A.C., Lusk, J.L. and Nayga Jr, R.M., 2019. How to run an experimental auction: A review of recent advances. European Review of Agricultural Economics, 46(5): 862–922.

CARD, 2020. Coalition for African Rice Development (CARD), Rice for Africa. https://www.riceforafrica.net, Accessed date: 1 September 2020.

CGIAR 2020. Available at http://ricepedia.org/senegal. Accessed 2 July, 2020.

Colen, L., Demont, M. and Swinnen, J. 2013. Smallholder Participation in Value Chains: The Case of Domestic Rice in Senegal. Rebuilding West Africa’s Food Potential. FAO/IFAD, 391–415.

Cragg, J. G. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. Econometrica: Journal of the Econometric Society, 829–844.

Custodio, M.C., Demont, M., Laborte, A. & Ynion, J. 2016. Increasing food security in Asia through consumer-focused rice breeding. Global Food Security, 9: 19–28.

Custodio, M.C., Cuevas, R.P., Ynion, J., Laborte, A.G., Velasco, M.L. and Demont, M., 2019. Rice quality: How is it defined by consumers, industry, food scientists, and geneticists? Trends in Food Science & Technology, 92: 122–137.
Demont, M., Zossou, E., Rutsaert, P., Ndour, M., Van Mele, P. and Verbeke, W., 2012. Consumer valuation of improved rice parboiling technologies in Benin. *Food Quality and Preference, 23*(1): 63–70.

Demont, M., 2013. Reversing urban bias in African rice markets: A review of 19 National Rice Development Strategies. *Global Food Security, 2*(3): 172–181.

Demont, M., Rutsaert, P., Ndour, M., & Verbeke, W. 2013a. Reversing urban bias in African rice markets: evidence from Senegal. *World Development, 45*: 63–74.

Demont, M., Rutsaert, P., Ndour, M., Verbeke, W., Seck, P.A. and Tollens, E., 2013b. Experimental auctions, collective induction and choice shift: willingness-to-pay for rice quality in Senegal. *European Review of Agricultural Economics, 40*(2): 261–286.

Demont, M. and Ndour, M., 2015. Upgrading rice value chains: Experimental evidence from 11 African markets. *Global Food Security, 5*: 70–76.

Demont, M., Fiamohe, R., & Kinkpe, A. T. (2017). Comparative advantage in demand and the development of rice value chains in West Africa. *World Development, 96*, 578–590.

Diagne, M., Demont, M. and Ndour, M., 2017. What is the value of rice fragrance? Consumer evidence from Senegal. *African Journal of Agricultural and Resource Economics, 12*(2): 99–110.

Dieng, M. 2012. Thiebou dieune: Senegal’s rice and fish dish. *Rice Today, 11*(3): 20.

Dong, D., Chung, C., & Kaiser, H. M. (2004). Modelling milk purchasing behaviour with a panel data double-hurdle model. *Applied Economics, 36*(8): 769–779.

Fox, J.A., Hayes, D.J. and Shogren, J.F., 2002. Consumer preferences for food irradiation: how favorable and unfavorable descriptions affect preferences for irradiated pork in experimental auctions. *Journal of Risk and Uncertainty, 24*(1): 75–95.
Haines, P.S., Popkin, B.M. and Guilkey, D.K., 1988. Modeling food consumption decisions as a two-step process. *American Journal of Agricultural Economics, 70*(3): 543–552.

John, A., 2015. The origins of Senegal’s dependency on rice imports. *Rice Today*, 28–30.

Lenaerts, B., Collard, B.C.Y. & Demont, M. 2019. Increasing global food security through accelerated rice breeding. *Plant Science, 287*: 110207.

Linares, O.F., 2002. African rice (Oryza glaberrima): history and future potential. *Proceedings of the National Academy of Sciences, 99*(25): 16360–16365.

Loureiro, M.L., W.J. Umberger, and S. Hine. 2003. "Testing the initial endowment effect in experimental auctions." *Applied Economics Letters* 271–275.

Kinyumu, D.M., 2009. Comparative study on the growth and yield of NERICA cultivated with organic and inorganic fertilizers: participatory on-farm research at Marakwet District in Kenya. *Journal of Developments in Sustainable Agriculture, 4*(2): 106–117.

Manzelli, M. and Laghetti G. 2014. Le secteur semencier dans la moyenne Casamance: Aperçu sur l’organisation et les limitations de la filière des semences de riz. In: Programme d’Appul au Programme National d’Investissement dans l’Agriculture au Senegal.

Newman, C., Henchion, M., & Matthews, A. (2003). A double-hurdle model of Irish household expenditure on prepared meals. *Applied Economics, 35*(9): 1053–1061.

Portères, R. 1962. Berceaux agricoles primaires sur le continent africain. *The Journal of African History, 3*(2): 195–210.

Portères, R. 1976. In *The Origin of African Plant Domestication*, eds. Harlan, J. R., de Wet, J. M. J. & Stemler, A. B. L. (Mouton, The Hague, The Netherlands), 409–452.

Quinn, C. 1971. A Nineteenth Century Fulbe State. *The Journal of African History, 12*(3), 427–440. https://doi.org/10.1017/S0021853700010860
Quisumbing, A.R., Brown, L.R., Feldstein, H.S., Haddad, L. and Peña, C., 1996. Women: The key to food security. *Food and Nutrition Bulletin, 17*(1): 1–2.

Rice Hub (2020). Available at http://www.ricehub.org/RT/varieties/assets-under-taat/. Accessed 2 July 2020.

Rihn, A.L. and Yue, C., 2016. Visual attention's influence on consumers’ willingness-to-pay for processed food products. *Agribusiness, 32*(3): 314–328.

Sharma, S.D., 2010. Domestication and diaspora of rice. Rice. Origin, antiquity and history, :1–25.

Soullier, G., Demont, M., Arouna, A., Lançon, F. & Mendez del Villar, P. 2020. The state of rice value chain upgrading in West Africa. *Global Food Security, 25*: 100365.

Traore, K., McClung, A. M, Fjellstrom, R., & Futakuchi, K. (2011). Diversity in grain physico-chemical characteristics of West African rice, including NERICA genotypes, as compared to cultivars from the United States of America. *ARS USDA Submissions, 1*, 435.

USDA, 2017. Senegal: Grain and feed annual. 2017 West Africa rice annual. Gain Report. Available at http://agriexchange.apeda.gov.in/MarketReport/Reports/Grain_Feed_Annual_Dakar_Senegal_4-11-2017.pdf. Accessed 17 June 2020.

USDA, 2018. Senegal: Grain and feed annual. 2018 West Africa rice annual. Gain Report. Available at https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Grain%20and%20Feed%20Annual_Dakar_Senegal_4-19-2018.pdf. Accessed 17 June 2020.
Wopereis, M. C. S., Diagne, A., Rodenburg, J., Sié, M., & Somado, E. A. (2008). Why NERICA is a successful innovation for African farmers: A response to Orr et al from the Africa Rice Center. *Outlook on Agriculture*, 37(3): 169–176.

Wopereis, M.C., Johnson, D.E., Ahmadi, N., Tollens, E. and Jalloh, A. eds., 2013. *Realizing Africa's rice promise*. CABI.

World Bank 2018 https://wits.worldbank.org/CountrySnapshot/en/SEN/textview. Accessed 3 June 2020.
Figure 1. The four rice products used in the experimental auctions
Figure 2. Preferences by grain type (small pie diagrams) and top 10 criteria used in judging rice quality (large pie diagrams) by urban consumers with genealogical lineages tracing back to the original domesticators of rice (A) and immigrants (B) in Kolda.

Notes: Pre- and post-cooking quality attributes are represented in white and black, respectively, while attributes that are typically judged before and after cooking are represented by a dotted pattern. The attributes cleanliness and purity were merged into a single category.
Figure 3. Willingness to upgrade, and average willingness to pay for NERICA.
Table 1. Variables and descriptive statistics

| Variable                        | Description                                                                 | Participants | Non-participants |
|---------------------------------|-----------------------------------------------------------------------------|--------------|------------------|
| **Experimental procedure**      |                                                                             |              |                  |
| Morning                         | 1 if field experiment was conducted in the morning; 0 otherwise             | 0.48 (0.50)  | 0.57 (0.50)      |
| **Attitudes and knowledge**     |                                                                             |              |                  |
| Quality over price              | 1 if quality is more important than price or swelling capacity; 0 otherwise | 0.58 (0.49)  | 0.81 (0.40)*     |
| Awareness NERICA                | 1 if subject was aware of NERICA from a trusted information source; 0 otherwise | 0.09 (0.29)  |                  |
| Per capita consumption          | Annual quantity of rice consumed per capita (kg)                            | 109.81 (40.63) |                  |
| Involvement                     | 1 if subject is involved in rice purchase decision making in the household; 0 otherwise | 0.86 (0.37)  |                  |
| Loyalty                         | 1 if subject usually purchases the same type of rice; 0 otherwise           | 0.74 (0.44)  |                  |
| Daily purchase                  | 1 if household usually purchases rice on a daily basis; 0 otherwise         | 0.35 (0.48)  |                  |
| Monthly purchase                | 1 if household usually purchases rice on a monthly basis; 0 otherwise       | 0.51 (0.50)  |                  |
| **Purchase habits**             |                                                                             |              |                  |
| Purchases fragrance            | 1 if household usually purchases fragrant rice; 0 otherwise                 | 0.11 (0.32)  | 0.26 (0.45)*     |
| Purchases broken               | 1 if household usually purchases 100% broken rice; 0 otherwise             | 0.52 (0.50)  | 0.60 (0.50)      |
| Purchases semi-broken          | 1 if household usually purchases semi-broken (35–60% broken) rice; 0 otherwise | 0.32 (0.47)  | 0.38 (0.48)      |
| Purchases unbroken             | 1 if household usually purchases unbroken (0% broken) rice; 0 otherwise     | 0.17 (0.37)  | 0.048 (0.22)*    |
| **Demographics**                |                                                                             |              |                  |
| Cooking housemaid              | 1 if household has a cooking housemaid; 0 otherwise                        | 0.10 (0.31)  | 0.21 (0.42)*     |
| Trader                          | 1 if subject is active in trading; 0 otherwise                             | 0.26 (0.44)  | 0.43 (0.50)*     |
| Housewife                       | 1 if subject is a housewife; 0 otherwise                                    | 0.34 (0.47)  | 0.26 (0.45)      |
| Group membership                | 1 if subject is a member of a group; 0 otherwise                           | 0.48 (0.50)  |                  |
| Household head                  | 1 if subject is head of household; 0 otherwise                              | 0.17 (0.37)  | 0.19 (0.40)      |
| Employed                        | 1 if subject is employed; 0 otherwise                                       | 0.19 (0.39)  | 0.12 (0.33)      |
| Age                             | Subject age in years                                                       | 36.60 (12.54) | 35.43 (14.42)    |
| Higher education                | 1 if subject has secondary or tertiary education; 0 otherwise               | 0.22 (0.41)  | 0.31 (0.47)      |
| Cultural heritage               | 1 if subject is genealogically related to domesticators of rice in Casamance; 0 otherwise | 0.88 (0.33)  | 0.86 (0.40)      |
| Household income                | Average household income in thousands of FCFA                              | 89.51 (86.56) | 143.37 (108.18)* |
| House                           | 1 if household owns a house; 0 otherwise                                    | 0.87 (0.34)  | 0.79 (0.42)      |
| Household size                  | Number of individuals in a household                                        | 12.08 (7.17) | 13.38 (13.59)    |
| Sample size                     | Number of surveyed participants and non-participants                        | 120          | 42               |

*denotes significance at the 10% level or lower between participants and non-participants from Wilcoxon rank sum tests.
Table 2. Descriptive statistics of WTP bids (FCFA)

|                | NERICA 1 |               | NERICA 4 |               | NERICA 6 |               |
|----------------|----------|---------------|----------|---------------|----------|---------------|
|                | % zero bids | Mean positive bid (Std Dev) | % zero bids | Mean positive bid (Std Dev) | % zero bids | Mean positive bid (Std Dev) |
| Pre-sensory    | 16.52%  | 61.17 (63.07) | 20.87%  | 50.87 (57.76) | 18.26%  | 83.83 (78.74) |
| Post-sensory   | 12.17%  | 63.44 (60.37) | 12.17%  | 58.48 (52.34) | 16.52%  | 82.17 (85.38) |
| Post-CIT       | 8.57%   | 64.00 (50.16) | 9.52%   | 57.14 (47.97) | 7.62%   | 100.71 (68.15) |
| Minimum        | 10      | 10            | 10      | 20            | 20      | 400           |
| Maximum        | 300     | 300           | 300     | 400           |         |               |

*Exchange rate: US $1 = FCFA 493.28*
Table 3. Double hurdle model: Determinants of desirability to upgrade from benchmark and willingness to pay for NERICA varieties in Kolda, Casamance

| Parameter                          | Tier 1: Participation equation | Tier 2: Purchase equation |
|------------------------------------|---------------------------------|---------------------------|
|                                    | Model [1]                        | Model [2]                 |
| **Coefficient (SE)**               | **Coefficient (SE)**             | **Coefficient (SE)**      |
| Morning                            | -0.108 (0.250)                   | -8.483 (19.339)           | -8.243 (19.319) |
| Pre-sensory                        | -0.218 (0.113)*                  | 9.375 (7.748)             | 9.913 (7.749)  |
| Post-CIT                           | 0.278 (0.159)*                   | 3.997 (9.363)             | 3.891 (9.432)  |
| NERICA 1                           | 0.090 (0.102)                    | 17.093 (7.973)**          | 53.209 (19.249)**  |
| NERICA 6                           | -0.007 (0.118)                   | 51.007 (12.281)***        | 78.189 (40.815)*  |
| Quality over price                 | 0.436 (0.218)**                  | 45.215 (22.686)**         | 45.936 (22.573)**  |
| Awareness NERICA                   | 0.174 (0.342)                    | -10.340 (41.774)          | -11.471 (42.848) |
| Per capita consumption             | 0.003 (0.002)                    | 0.637 (0.301)**           | 0.647 (0.306)**  |
| Involvement                        | -0.275 (0.334)                   | -49.682 (32.569)          | -51.830 (32.755) |
| Loyalty                            | 0.518 (0.205)**                  | -42.682 (27.979)          | -44.547 (28.445) |
| Daily purchase                     | -0.165 (0.332)                   | -22.413 (37.851)          | -20.774 (37.931) |
| Monthly purchase                   | 0.081 (0.289)                    | 5.522 (37.322)            | 6.224 (37.644)  |
| Morning                            | -0.108 (0.250)                   | -8.483 (19.339)           | -8.243 (19.319) |
| Purchases broken                   | -0.444 (0.210)**                 | -12.989 (19.141)          | -25.721 (19.826) |
| Purchases broken x NERICA 1       |                                  |                           | 5.317 (14.014)   |
| Purchases broken x NERICA 6       |                                  |                            | 28.709 (14.675)** |
| Purchases unbroken                 | -0.017 (0.301)                   | -12.096 (23.735)          | -33.514 (25.443) |
| Purchases unbroken x NERICA 1     |                                  |                            | 29.238 (19.093)  |
| Purchases unbroken x NERICA 6     |                                  |                            | 30.618 (15.276)** |
| Cooking housemaid                  | 0.285 (0.359)                    | -114.977 (68.139)*        | -120.140 (67.825)* |
| Trader                             | 0.974 (0.325)*****               | 36.690 (35.780)           | 37.128 (35.944)  |
| Housewife                          | 0.101 (0.270)                    | 77.520 (60.519)           | 80.858 (60.715)  |
| Group membership                   | -0.317 (0.188)*                  | 36.821 (18.281)**         | 35.599 (18.445)*  |
| Household head                     | -0.264 (0.290)                   | 18.015 (26.641)           | 18.958 (26.619)  |
| Employed                           | -0.160 (0.266)                   | 67.513 (43.584)           | 70.537 (43.946)  |
| Age                                | 0.012 (0.011)                    | 0.429 (0.790)             | 0.437 (0.804)    |
| Higher education                   | 0.687 (0.314)****                | -35.955 (30.893)          | -38.474 (31.578) |
| Cultural heritage                  | 0.445 (0.260)*                   | 66.079 (34.243)           | 100.166 (36.821)**  |
| Cultural heritage x NERICA 1      |                                  |                            | -45.803 (20.003)** |
| Cultural heritage x NERICA 6      |                                  |                            | -48.803 (42.946) |
| Household income                   | -1.269 (1.235)                   | -1.199 (1.321)            | -1.199 (1.321)  |
| Household income squared           | -0.022 (0.019)                   | -0.025 (0.022)            | -0.025 (0.022)   |
| House                              | 71.195 (39.659)*                 | 74.208 (39.703)*          | 74.208 (39.703)*  |
| Household size                     | 2.358 (2.426)                    | -2.308 (2.450)            | -2.308 (2.450)   |
| Constant                           | -0.297 (0.771)                   | -38.268 (63.699)          | -83.470 (66.391) |
| Variance: constant                 | 12.303 (12.356)                  | 9.704 (12.160)            | 9.704 (12.160)  |
| Variance: household income         | 1.475 (0.528)****                | 1.560 (0.547)**           | 1.560 (0.547)**  |

Log pseudolikelihood = -4871.473 = 4868.816

Notes: Number of observations = 1,005. Model [1] has no interaction terms. Model [2] features interactions between products, purchase habits and cultural heritage; * p<0.1, ** p<0.05, *** p<0.01; SE = standard error. Standard errors are robust and cluster-corrected. NERICA 4 is the reference dummy. 

* Variance inflation factors (VIFs) vary between 1.22 and 6.87, with an average of 2.03, alleviating possible multicollinearity concerns among the variables.