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# Prospects for locally produced nutrient-dense rice in Liberia: How import preferences and agronomic traits shape consumer demand and farmer adoption

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**Abstract**

*This study examines whether Liberian consumers are willing to pay for new, locally produced nutrient-dense rice, and if farmers are willing to grow such rice. Further, the study investigates the role of preferences for imported rice and agronomic traits, respectively, in relation to willingness to pay and willingness to grow new nutrient-dense rice in Liberia. Contingent valuation surveys were conducted of 543 rice consumers and 557 farmers, and linear regression and logistic models were applied to the data. Ninety-one percent of rice consumers were willing to buy nutrient-dense rice and pay a price premium of 8% on average. Consumers who prefer imported rice to local rice are willing to pay less for locally produced nutrient-dense rice than those who do not. Ninety-two percent of rice farmers were willing to grow nutrient-dense rice varieties. Preference for yield reduces the odds of growing nutrient-dense rice. These results have implications for introducing nutrient-dense rice varieties in Liberia.*

**Key words**: nutrient-dense rice, contingent valuation, willingness to pay, willingness to grow, Liberia

## 1. Introduction

Liberia is among the most food insecure countries in Africa. According to the Ministry of Agriculture (2024a) and the Food and Agriculture Organization (2025), an estimated 81% of the country's 5.5

million people experience moderate to severe food insecurity, while nearly half of all households are affected. This widespread food insecurity contributes to high levels of child malnutrition, with approximately 30% of children under the age of five experiencing stunted growth (Ministry of Agriculture 2024a). In addition, with 52% of the population living on less than $1.90 per day (Ministry of Agriculture 2024a), and the vast majority of the population – approximately 93% – unable to afford a nutritious diet (Food and Agriculture Organization 2025), the country faces a vicious cycle: widespread poverty leads to poor nutrition, which in turn undermines health, productivity and income, thereby reinforcing poverty. Nutrient enhancement of crop varieties could help alleviate food and nutrition insecurity in Liberia.

The nutrient content of crop varieties can be increased through conventional breeding methods (biofortification) or agronomy (agronomic biofortification). Crop varieties targeted for nutrient enhancement are those with superior agronomic, cooking and eating quality traits that, if adopted by farmers, would significantly increase the supply of those staples. Assuming price elastic supply and demand, the resultant reduction in prices spurs greater demand for and consumption of nutrient-dense staples. This essentially means that consumers are able to increase their intake of health-enhancing nutrients at no additional cost (Bouis *et al*. 2024). In this case, nutrient enhancement is a supply-side intervention that directly mitigates nutrition insecurity, defined as a perpetual lack of access to adequate nutrients. However, its ability to mitigate both food and nutrition insecurity can also come from the demand side, whereby consumer awareness of the health benefits of nutrient enhancement increases the demand for nutrient-dense crops. If crop markets are working perfectly, farmers are able to obtain a fair share of the price premiums that consumers are willing to pay for nutrient-dense crops, and would therefore be motivated to adopt these crop varieties.

Locally produced nutrient-dense rice has the potential to alleviate food and nutrition insecurity in Liberia because rice is the single most important staple crop in the daily diet of a typical Liberian household. It accounts for 50% of daily adult calorie intake (World Bank 2023; Ministry of Agriculture 2024a), and at least 44% of the country's food import bill (Central Bank of Liberia 2022). Also, rice is the most widely cultivated crop, with at least 56% of households engaged in its cultivation (Liberia Institute of Statistics and Geo-Information Services 2024). Consumption increased by 63% between 2008 and 2022 (Cooper 2023), and the government intends to increase rice production by 50% between 2024 and 2030 (Ministry of Agriculture 2024b).

Introducing nutrient-dense rice in Liberian domestic rice value chains would be met with two challenges. The first is the abundance of imported rice on the market. At present, the country imports 70% of the rice it consumes (Ministry of Agriculture 2024b). If this is wholly or partly due to consumers preferring imported rice to local rice, there will not be significant benefits to consumers from introducing locally produced, nutrient-dense rice. Second, knowledge of the correlation between agronomic traits preferred by farmers and farmers' willingness to adopt nutrient-dense rice varieties is limited. This is a pertinent concern because nutrient enhancement rides on the back of the most preferred agronomic traits to hasten the adoption of the resulting varieties.

To understand how consumer and farmer preferences affect the demand for and supply of nutrient-dense rice, we pose the following questions: how much are Liberian consumers willing to pay for a nutrient-dense rice variety?[1] Does the preference for imported rice affect the willingness to pay for locally produced nutrient-dense rice? Are Liberian farmers willing to grow nutrient-dense rice varieties? How do the most preferred agronomic traits influence farmers' willingness to grow

[1] In this study, we do not consider rice of which the nutrient content is enhanced through postharvest processes such as parboiling and direct (industrial) fortification.

nutrient-dense rice varieties? This study attempts to answer these questions using data from consumer and farmer surveys.

We contribute to the literature in two ways. First, the results of this study have direct implications for increasing the competitiveness of Liberia's rice industry. The government is striving to achieve self-sufficiency in rice, which means that domestic rice must compete favourably with imported rice. Nutrient-dense rice is expected to be introduced as an addition to domestic rice value chains, rather than through imports; therefore, by examining whether the preference for imported rice over domestic rice is associated with willingness to pay (WTP) for nutrient-dense rice, this study is able to recommend ways of introducing and sustaining nutrient-dense rice in the Liberian market. Second, by determining how the most preferred agronomic trait influences the adoption of nutrient-dense rice varieties, this study informs the design of new, nutrient-dense varieties that at least meet farmers' expectations.

The remainder of the paper is organised as follows. Section 2 explores the empirical literature related to the paper's four research questions, while Section 3 presents the conceptual frameworks and empirical methods. In Section 4, we present the data and discuss the relevant descriptive statistics. The results are presented and discussed in Section 5, and Section 6 concludes with relevant recommendations.

## 2. Related literature

### 2.1 Consumer WTP for nutrient-dense crops

There appears to be consensus in the literature that consumers are willing to pay price premiums for nutrient-dense crops (see, for instance, De Groote *et al*. 2011; Birol *et al*. 2015; Oparinde *et al*. 2016; De Steur *et al*. 2017; Meier *et al*. 2020; Herrington *et al*. 2023; Oswalt 2024). In the studies reviewed by Birol *et al*. (2015), price premiums for nutrient-dense crops were found to be significantly higher than those for conventional crops, ranging from 8% to 50%. According to the systematic review by De Steur *et al*. (2017), consumers are willing to pay 21.3% more on average for nutrient-dense crops, and the premiums on nutrient-dense rice range from 3.8% to 38.3%. Furthermore, De Steur *et al*. (2017) analysed the methodological and contextual factors that may be critical to eliciting consumer WTP values for nutrient-dense food. This is important, because nutrient enhancement with minerals (but not vitamins) makes the attribute a credence one and thus difficult to evaluate. Methodological factors include, but are not limited to, value-elicitation methods, the type of respondent, the study environment (home vs. central location), information, and participation fees, whereas contextual factors include, among other things, the type of nutrient-dense food, the target nutrient, the setting (urban vs. rural) and the breeding technique (conventional breeding vs. genetic modification). The authors of the current study applied a meta-analysis of 23 studies, of which 10 concerned rice biofortified with vitamin A or iron. They did not find statistically significant differences in WTP values between stated and revealed preference methods, or between the different types of settings. In most of these and other studies, such as Chowdhury *et al*. (2011) and Meerza *et al*. (2023), providing information on the benefits of nutrient enhancement was shown to significantly increase price premiums for nutrient-dense crops.

The effect of preferences for imported or local food on consumer valuation of a locally produced nutrient-dense crop variety may depend on consumers' perceptions of quality, individual tastes, and ethnocentric attitudes. However, we did not find any study that has empirically examined this relationship. Therefore, the preceding studies have informed four aspects of the current study, viz. type of respondent, setting, elicitation method, and information. Regarding the type of respondent,

we elicited WTP for nutrient-dense rice only from respondents in households that did not cultivate rice, whereas urban and peri-urban areas were selected as the setting for the consumer survey, as rice cultivation rarely occurs in these areas. However, we first ascertained that the respondents were not from rice-growing households. For the elicitation method, we opted for the straightforward and inexpensive stated preference approach. Finally, we provided information about the health benefits of consuming nutrient-dense rice prior to eliciting WTP.

### 2.2 Farmer acceptance and adoption of nutrient-dense crop varieties

A recent systematic review by Samuel *et al*. (2024) identified 24 studies with farmers on biofortification, all of which were conducted in Africa and Asia. Somewhat similar to our study, some studies have examined willingness to grow and adoption as the outcome variables of interest. The finding by Muthini *et al*. (2019), namely that variety awareness increases the possibility of adopting a biofortified bean variety, speaks to the possible effect of farmer preferences for agronomic traits on adoption. Likewise, Jenkins *et al*. (2018) revealed, albeit qualitatively, the likely effect of preferences for agronomic traits on the adoption of orange-fleshed sweet potato (OFSP). However, Shikuku *et al*. (2019) showed that farmers who held positive perceptions of the yield, disease resistance and maturity period of OFSP varieties were more likely to grow them. In a latent class analysis of farmers' evaluation of biofortified sorghum, Chinedu *et al*. (2018) reported that farmers who preferred sorghum seed with more micronutrients also preferred high-yielding seed. Recently, Castro-Pacheco *et al*. (2024) sought to develop a breeding line selection index that combines farmer criteria (productivity, earliness and grain appreciation/quality) with measured agronomic and nutritional traits (yield and zinc concentration). Although zinc concentration was found to be negatively correlated with grain appreciation, it positively influenced farmer acceptance of rice varieties when farmers were informed about the nutritional benefits of a relatively high zinc content. The acceptance rate of the varieties increased by 11% on average, with variations among different farmer groups ranging from 1.8% to 32.1%.

## 3. Conceptual framing and empirical methods

### 3.1 Lancaster's consumer utility theory and WTP

The basic starting point when examining consumers' willingness to pay for a locally produced nutrient-dense rice variety is Lancaster's (1966) theory of utility. Lancaster's idea is that utility is derived not from the good per se, but from its characteristics. Therefore, consumers aim to maximise a utility function defined in an attribute space, subject to a budget constraint defined in a goods space.

How is WTP related to utility? Research suggests a complex relationship between WTP and utility values. Some studies find a correlation between WTP and utility, indicating that WTP can measure preference strength (Cunningham & Hunt 2000), but others argue that WTP is only indirectly related to utility and may not fully capture social choice complexities (Anand 2000). According to Kovalsky and Lusk (2013), WTP values may not always reveal underlying utility, as they can be influenced by arbitrary information. Another complexity arises from the nature of the underlying utility function. Exponential utility functions tend to be better at approximating consumer preferences, but linear functions perform better at predicting WTP (Scholz *et al*. 2015). These findings highlight the nuanced nature of WTP as a measure of underlying utility, suggesting that, while WTP can provide valuable insights, it may not always fully reveal true utility values and should be interpreted cautiously in economic and marketing contexts.

Our empirical strategy for estimating the effect of preference for imported rice on the WTP for a nutrient-dense domestic rice variety was straightforward. We estimated the equation:

$$WTP_i = \delta_0 + \delta_1 X_i + \delta_2 D_i + \varepsilon_i, \quad (1)$$

where $WTP_i$ denotes the amount that consumer $i$ is willing to pay for a kilogram of nutrient-dense domestic rice; $X$ is a vector of household-specific control variables, including the respondent's age, gender, marital status, education attainment, main activity, household size, household monthly income, and household monthly expenditure on food; $\delta_1$ is a vector of coefficients associated with these variables; $D$ is an indicator of whether the consumer prefers imported to domestic rice; and $\varepsilon$ is a zero-mean error term. We tested the null hypothesis: $H_0: \delta_2 = 0$.

### 3.2 Derived demand for farm output and choice of technology

A farmer's decision to grow a new and nutrient-dense rice variety can be analysed in the context of the derived demand that the farmer faces for farm output – either paddy or milled rice or both (see, for instance, Mafuru *et al*. 2007). It is derived demand in the sense that it results primarily from consumer demand for rice at the retail level of the market. As such, it is essentially influenced by the output price that the farmer receives (i.e., farm or wholesale price of either paddy or milled rice – whichever they sell) and the retail price of milled rice. According to the hedonic pricing theory of Rosen (1974), these equilibrium prices depend on the products' attributes. More precisely, price is a weighted combination of a product's attributes. Therefore, assuming that the farmer's objective is profit or revenue maximisation, their decision to plant a new rice variety will be influenced by the variety's production (agronomic) attributes, such as yield; milling attributes, such as milling recovery; and consumption attributes, such as aroma, all of which enable the farmer to obtain the highest possible output and output price.

The farmer's choice of technology can be modelled as a discrete choice on the basis of the theory of random utility maximisation (McFadden 2002). The theory, also known as random utility theory, postulates that, given several alternatives, an individual will choose an alternative that maximises their utility, and the utility provided to the individual by the chosen alternative is a function of the individual's characteristics and the attributes of the alternative. As described in Grafton *et al*. (2008), individuals choose one alternative from a discrete set of goods, and each good has a vector of quality attributes and a price. The individual's problem is to maximise their utility subject to the budget and other constraints. Solving this problem results in a conditional, indirect utility function that depends on the chosen alternative. That is, the utility the individual obtains is associated with only the attributes of the chosen alternative. However, the conditional indirect utility function is deterministic, as it is what is observed by the researcher, yet there are some important but unobserved factors that influence the individual's choice. Thus, a random error component is included in the conditional indirect utility function, hence the name, random utility model.

The empirical form of the conditional indirect utility function can be augmented by including the individual's characteristics – other than income – that relate to their tastes, preferences and circumstances. In the present study, the characteristic of interest was the farmer's preferred agronomic trait. Thus,

$$v_{in} = \beta_0 + \beta_1 m_i + \beta_2 w_i + \beta_3 Q_i + \beta_4 Z_i + \beta_5 Y_i + \epsilon_i, \quad (2)$$

where $v_{in}$ is the indirect utility of individual $i$ associated with alternative $n$, $m$ is income, $w$ is the price of the alternative, $Q$ is a vector of the attributes of the alternative, $Z$ is a vector of the individual's

socioeconomic and demographic characteristics other than income, $Y$ is the most preferred agronomic attribute, $\epsilon$ is the random error term, and $\beta_0, \ldots \beta_5$ are the parameters to be estimated.

As explained earlier, we believe that preferences for agronomic attributes are important in the farmer's decision to grow a nutrient-dense rice variety, but we did not have any prior notions regarding the direction of influence. The presence of unobserved factors influencing choice means that the individual's choice cannot be predicted exactly. Therefore, the norm is to predict the probability of choosing an alternative. To this end, logit and probit models have been widely used to analyse binary choices. They are quite similar and give qualitatively similar results (Gujarati 2003), but we opted for the logit model because of its relative simplicity. Taking the logistic transformation and substituting it in Equation (2) gives us the empirical model:

$$ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 m_i + \beta_2 w_i + \beta_3 Q_i + \beta_4 Z_i + \beta_5 Y_i, \quad (3)$$

where $P_i$ is the probability of choosing alternative $n$. Since there were no nutrient-dense rice varieties on the Liberian market at the time of this study, we estimated Equation (3) without $w$ and the vector $Q$. The variables included in vector $Z$ are the respondent's gender, education attainment, age, household size, marital status, and number of years of residence in the village as a proxy for the strength of social networks and community ties.

### 3.3 Data and descriptive statistics

Data were obtained in July 2024 from separate surveys of rice-consuming and rice-growing households in Liberia's four major rice-growing counties of Bong, Lofa, Nimba and Margibi. Random walks were used to select the study households because of the lack of sampling frames. Since many rice-consuming households also grow rice, respondents from such households might not be able to separate their preferences for consumption traits from those for agronomic traits. To avoid this situation, 543 households that do not cultivate rice were selected for the consumer survey, and they were mostly located in urban and peri-urban areas (137 (25%) in Bong, 129 (24%) in Lofa, 143 (26%) in Nimba and 134 (25%) in Margibi). The farmer survey covered 557 households, the majority of which were located in rural areas (147 (26%) in Bong, 126 (23%) in Lofa, 156 (28%) in Nimba and 128 (23%) in Margibi). Structured questionnaires were administered through face-to-face interviews with the respondents.

To elicit consumer willingness to pay for a kilogram of nutrient-dense rice, we used contingent valuation (CV), a stated preference survey-based approach. We asked the respondents an open-ended question about the amount they were willing to pay after we had provided them with basic information on the health benefits associated with nutrient-dense rice to reduce hypothetical bias. The predictor variable of interest in the consumer survey was consumer preference for imported rice to local rice, which was captured as a yes/no dummy variable. To elicit farmer willingness to grow a nutrient-dense rice variety, we employed the same CV approach, but in this case we asked a simple closed-ended dichotomous-choice (yes or no) question. Similarly, we provided basic information, but we were cautious not to speculate about the agronomic characteristics of a nutrient-dense rice variety.

The predictor variable of interest was the farmer's most important agronomic trait. We asked the farmers to rank the different traits (agronomic and others) in descending order of importance. With respect to money income, we obtained data on household monthly expenditure as a proxy, because it was easier to obtain household expenditure data from rural households than to obtain income data.

Income in rural areas is usually informal, seasonal, highly variable and comes from diverse sources; therefore, it is difficult for farmers to recall it fairly accurately.

Summary statistics of variables from the consumer and farmer surveys that were used in the regression models (with the exception of county dummies) are presented in Tables 1 and 2. Virtually all consumers had never heard of nutrient-dense crops. Nonetheless, upon explaining to them what they are and the health benefits of consuming them, 91% were willing to buy a nutrient-dense product if available and affordable to them and, from Table 1, it can be seen that consumers were willing to pay 0.83 USD/kg on average for nutrient-dense rice. This value is slightly higher than the national average price of 0.75 USD/kg for imported rice (5% broken) that prevailed in the market two months prior to the survey (Diongue & Anderson 2024), and higher than the average price of rice, of 0.77 USD/kg, estimated from the survey data. In essence, consumers were willing to pay a price premium of approximately 0.06 USD/kg, or 8%, for nutrient-dense rice.

**Table 1: Summary statistics from the consumer survey**

| Variable | Mean | SD | Min | Max |
|---|---|---|---|---|
| Willingness to pay for nutrient-dense rice (USD/kg) | 0.83 | 0.40 | 0 | 3 |
| Household monthly income (USD) | 253.47 | 184 | 30 | 1 500 |
| Household monthly expenditure on food (USD) | 108.56 | 53.47 | 20 | 500 |
| Respondent prefers imported to local rice (1 = yes, 0 = no) | 0.59 | 0.49 | 0 | 1 |
| Respondent's gender (1 = male, 0 = female) | 0.24 | 0.43 | 0 | 1 |
| Respondent attained university/tertiary education (1 = yes, 0 = no) | 0.15 | 0.36 | 0 | 1 |
| Household size | 5.11 | 2.02 | 1 | 18 |
| Respondent's age | 38.96 | 12.59 | 18 | 86 |
| Respondent's main activity (1 = trading, 0 = otherwise) | 0.53 | 0.50 | 0 | 1 |
| Respondent's marital status (1 = married, 0 = otherwise) | 0.52 | 0.50 | 0 | 1 |

In addition, a majority (59%) of consumers preferred imported rice to local rice. They attributed their preference for imported rice to its cleanliness, better taste, greater swelling capacity, aroma, ease of cooking and slender grains. The average household monthly income was USD 253, whereas the average household monthly expenditure on food was USD 109, implying an average food expenditure share of 43%. It was estimated at 53% in 2013 (World Food Programme 2013) and is now comparable to the 41% calculated from the statistics in Aggarwal *et al*. (2022). According to Smith and Subandoro (2007), food expenditure shares of > 75%, 65% to 75%, 50% to 65% and < 50% imply very high, high, medium and low vulnerability to food insecurity, respectively.

**Table 2: Summary statistics from the farmer survey**

| Variable | Mean | SD | Min | Max |
|---|---|---|---|---|
| Willing to grow nutrient-dense rice variety (1 = yes, 0 = no) | 0.92 | 0.27 | 0 | 1 |
| Household monthly expenditure (USD) | 118.09 | 65.73 | 10.42 | 579.17 |
| Respondent's gender (1 = male, 0 = female) | 0.63 | 0.48 | 0 | 1 |
| Respondent has no formal education (1 = yes, 0 = no) | 0.47 | 0.50 | 0 | 1 |
| Household size | 5.88 | 2.19 | 2 | 19 |
| Respondent's age | 46.15 | 12.03 | 19 | 95 |
| Yield is most important trait (1 = yes, 0 = no) | 0.66 | 0.48 | 0 | 1 |
| Respondent's marital status (1 = married, 0 = otherwise) | 0.82 | 0.39 | 0 | 1 |
| Number of years respondent has lived in the village | 35.92 | 16.27 | 1 | 80 |

The majority of the farmers had not heard about nutrient-dense crops before the survey. However, as shown in Table 2, upon receiving some basic information about them, 92% of the rice-farming households were willing to grow nutrient-dense rice varieties. The few that were not willing to grow it said that it was because they had never seen it, had no knowledge of its agronomy, and did not know its taste. At present, only vitamin A cassava and vitamin A maize have been tested in Liberia,

and the only country in Africa in which a biofortified rice variety has been developed and tested is Madagascar (HarvestPlus 2022). The variety Mavitrika was biofortified with zinc through agronomic biofortification, also known as ferti-fortification (Africa Rice Center 2024).

Most rice farmers (66%) considered yield to be the most important trait, whereas only 4% and fewer than 1% considered early maturity and disease resistance, respectively, to be the most important. The importance of yield is not surprising in a country where average yields are as low as 1.3 t/ha, and which the government aims to increase to an average of 3.1 t/ha by 2030 (Ministry of Agriculture, Republic of Liberia, n.d.). Furthermore, yield is critical to food security insofar as it influences food availability and household income. The average household monthly expenditure is USD 118, which, unsurprisingly, is less than half of the average income of urban households.

## 4. Results and discussion

Before presenting and discussing the results of our regression analyses, we start by discussing an estimation issue that is pertinent to the internal validity of the study – causal identification. That is, have we identified causal relationships between our predictor variables of interest and the dependent variables, or have we simply established correlations? This issue arises because the observational nature of our data means that it is more likely than not that there are confounding factors that we have not accounted for, leading to potential endogeneity of our predictor variables – preference for imported rice to local rice (in the consumer WTP model) and the most preferred agronomic trait (in the farmer willingness to grow model). To solve the identification problem in observational data, a quasi-experimental approach involving the use of an instrumental variable (IV) is usually applied. The IV must be a strong predictor of the potentially endogenous variable, but it must be exogenous to the dependent variable. And herein lies our challenge – we were unable to find IVs that fulfilled the two conditions. Therefore, we did not interpret our regression coefficients as strictly suggesting cause-effect relationships. Rather, they probably depict partial correlations.

### 4.1 Consumer WTP for nutrient-dense rice

Table 3 presents the results of the ordinary least squares regression. A double logarithmic model (with standard errors that are robust to heteroskedasticity) fit our data the best. The model was statistically significant at the 1% level, with a goodness of fit of 53%. We controlled for heterogeneity across counties using Margibi as the reference county, and found considerably greater willingness to pay in each county, especially Lofa and Nimba, at the 1% level of significance.

As expected, an increase in household income is associated with a statistically significant increase in the amount that consumers are willing to pay for nutrient-dense rice, but the magnitude is quite small. Using contingent valuation, Ongudi *et al*. (2017) reported that income is positively associated with consumer WTP for biofortified pearl millet in Kenya. The same result was obtained for iron-biofortified finger millet in India by Meier *et al*. (2020) through an experimental auction, and by (Rizwan *et al*. 2022) for zinc-biofortified wheat in Pakistan through a hypothetical choice experiment. The coefficient of household food expenditure was negative, as expected, but statistically insignificant.

**Table 3: Linear regression results of consumer willingness to pay for nutrient-dense rice in Liberia**

| Variables | Coefficient | *t*-statistic | *p* value |
|---|---|---|---|
| Ln Household monthly income | 0.08<br>(0.03) | 2.37 | 0.018 |
| Ln Household monthly food expenditure | -0.05<br>(0.06) | -0.94 | 0.348 |
| Preference for imported rice | -0.11<br>(0.03) | -3.20 | 0.001 |
| Gender | -0.05<br>(0.04) | -1.35 | 0.179 |
| University/tertiary education | 0.07<br>(0.05) | 1.33 | 0.184 |
| Ln Household size | -0.03<br>(0.05) | -0.69 | 0.489 |
| Ln Age | -0.04<br>(0.05) | -0.83 | 0.407 |
| Main activity | 0.01<br>(0.04) | 0.21 | 0.837 |
| Marital status | -0.01<br>(0.04) | -0.16 | 0.874 |
| Bong county | 0.21<br>(0.06) | 3.37 | 0.001 |
| Lofa county | 0.97<br>(0.05) | 19.55 | 0.000 |
| Nimba county | 0.67<br>(0.05) | 12.45 | 0.000 |
| Constant | -0.66<br>(0.27) | -2.45 | 0.015 |
| N = 518<br>Prob > F = 0.00<br>R-squared = 0.53 | | | |

Notes: The figures in parentheses are robust standard errors; the dependent variable is the natural log of the amount that consumers are willing to pay for a kilogram of nutrient-dense rice; and Ln stands for Napierian logarithm. The sample was restricted to households not growing rice.

Turning to our variable of interest, we rejected our null hypothesis; holding other factors constant, consumers who prefer imported rice to local rice are associated with an 11% lower WTP[2] for nutrient-dense rice than those who do not at the 1% level of significance. This result means that the preference for imported rice has a potentially demonstrable effect on consumer WTP for a newly introduced and locally grown nutrient-dense rice variety. The potentially adverse effect of the preference for imported rice on willingness to pay for local rice was also observed by Akoa Etoa *et al*. (2016) in Cameroon; using experimental auctions, they reported that two-thirds of the participants perceived local rice parboiled with improved parboiling technology to be imported and consequently paid a price premium of 5%, while discounting traditionally parboiled rice by 2%. Thus, efforts to introduce a nutrient-dense rice variety must confront both real and perceived quality differences between local and imported rice and perhaps habit persistence, which, according to Akaeze (2010), might also explain consumer preference for imported rice.

### 4.2 Farmer willingness to grow a nutrient-dense rice variety

Table 4 presents the maximum likelihood regression results of farmer willingness to grow a nutrient-dense rice variety. The coefficients are the log-odds of a farmer's willingness to grow the variety, but

[2] This is the approximate interpretation of the result. The exact interpretation is (exp(-0.11) – 1) x 100 = 10.5%.

to ease interpretation, we converted them to odds ratios by exponentiating them. This essentially reveals how much the odds of a farmer's willingness to grow the variety change for a one-unit increase in the predictor variable. For example, for a unit increase in the farmer's years of residence in their village, the odds of them wanting to grow a nutrient-dense rice variety decrease by approximately 5%. Farmers with strong social networks and community ties might hesitate to grow a new crop variety because of social norms and peer pressure, especially if their social groups are against new varieties. The effect of age is positive and statistically significant at the 5% level of significance; a unit increase in age increases the odds of a farmer wanting to grow the variety by 6%.

**Table 4: Logit regression results of farmer willingness to grow nutrient-dense rice in Liberia**

| Variables | Coefficient | *z*-statistic | *p* value |
|---|---|---|---|
| Household monthly expenditure | -0.001<br>(0.002) | -0.24 | 0.812 |
| Years of residence in village | -0.05<br>(0.02) | -2.87 | 0.004 |
| Gender | -0.12<br>(0.47) | -0.25 | 0.806 |
| Lack of formal education | 0.63<br>(0.40) | 1.57 | 0.116 |
| Household size | -0.05<br>(0.08) | -0.64 | 0.523 |
| Age | 0.06<br>(0.02) | 2.49 | 0.013 |
| Yield | -3.19<br>(1.02) | -3.13 | 0.002 |
| Marital status | 1.14<br>(0.48) | 2.38 | 0.017 |
| Constant | 4.05<br>(1.25) | 3.23 | 0.001 |
| N = 553<br>LR Chi-squared (8) = 52.09<br>Prob > Chi-squared = 0.00<br>Pseudo R-squared = 0.17 | | | |

Notes: The coefficients are log-odds and the figures in parentheses are standard errors; the dependent variable is the willingness to grow nutrient-dense rice (1 = yes, 0 = no).

The coefficient of yield is negative and statistically significant at the 1% level. The odds (i.e., exp (-3.19) = 0.04) that farmers would want to grow a nutrient-dense rice variety are only 4% of what they would be if they did not consider yield to be the most important agronomic trait. In other words, the odds of them wanting to grow a nutrient-dense rice variety decrease by 96% because of their perception of yield as being the most important agronomic trait. Clearly, farmer preference for yield could have a substantial negative impact on the likelihood of adopting nutrient-dense rice varieties. Our conjecture is that this could simply be due to ignorance of the yield performance of such varieties. Yield is so important to Liberian farmers that, without prior knowledge of and experience with the performance of nutrient-dense varieties, farmers would not want to risk growing a new variety unless they are sure it will produce high yields. Our data reveal that only 12% of rice farmers were aware of participatory variety selection (PVS). This low incidence of PVS awareness can only amplify the potentially negative effect of preference for yield on the willingness to grow nutrient-dense rice varieties.

### 4.3 Robustness checks

The kernel density estimate of the amount that consumers were willing to pay for nutrient-dense rice shows it to be heavily skewed to the right, implying that the mean is greater than the median,

consequently making the latter a somewhat better measure of central tendency. Therefore, to evaluate the robustness of the results in Table 3, we undertook a (quantile) regression to the median without logarithmic transformation of the variables. The results show that the coefficients on all the variables, except the respondent's main activity, retained their signs and, in any case, the coefficient on the main activity remained statistically insignificant. However, more importantly, we again found that there is a negative and statistically significant relationship between the preference for imported rice and the WTP for nutrient-dense rice. To assess the robustness of our logit model results, we estimated a less parsimonious model to determine whether our coefficient estimates were stable. Specifically, we controlled for awareness of PVS and found that it was positive but statistically insignificant, and that the signs and magnitudes of all the other variables did not change. In addition, we re-estimated the model using the probit model and linear probability model (LPM) to determine whether the results were robust to the choice of estimator. The LPM is particularly important when causal identification is problematic because of the use of observational data (Bellemare 2015). From both models, we obtained results that were similar to those of the logit model. Therefore, our regression results in Tables 3 and 4 are reasonably robust.

## 5. Conclusions

The findings from the two surveys point to demand-side and supply-side constraints that both reduce the adoption and market potential of new nutrient-dense rice varieties. When combined, they reveal a reinforcing loop: farmers will avoid growing nutrient-dense rice because they perceive no strong yield advantage, and consumers prefer imported rice to local rice, further reducing market incentives for new nutrient-dense rice.

These results have important implications for the introduction of nutrient-dense rice varieties in Liberia. It is imperative to address consumer perceptions and farmer incentives simultaneously by positioning nutrient-dense rice as a high-quality, market-relevant product with competitive yield performance, supported by awareness campaigns, branding and tailored extension. This requires addressing the extrinsic and intrinsic attributes in relation to which local rice lags imported rice, including – but not limited to – those reported in this study. Akoa Etoa *et al*. (2016) and Demont (2013) have proposed quality dedifferentiation as a short- to medium-term strategy that could significantly improve the quality perception of local rice. It aims to enhance the extrinsic attributes of local rice in a way that would make it similar to imported rice. On the farmers' side, the introduction and dissemination of high-yielding nutrient-dense rice varieties necessitates raising awareness through, for example, on-farm demonstrations that nutrient enhancement is not achieved at the expense of yield performance.

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