A household hedonic model of rice traits: economic values from farmers in West Africa

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Abstract

New crop varieties often have been promoted in developing countries based upon superior yield vis-a-vis locally available varieties. This research presents a hedonic price model for upland rice by drawing upon the input characteristics and consumer good characteristics model literature. Model specification tests determine that a combination of production and consumption characteristics best explains the willingness to pay for new upland rice varieties. The household model specification determined that five traits explain the willingness to pay for new rice varieties: plant cycle length, plant height, grain colour, elongation/swelling and tenderness. Yield was not a significant explanatory variable of the willingness to pay for seed. The implications of this model are two-fold. First, varietal development and promotion must include post-harvest characteristics in addition to production traits when determining which varieties to promote for official release. Secondly, non-yield production characteristics such as plant height and cycle length are significant factors in producer’s assessments of the value of a new variety. Overall, this paper provides an alternative explanation for limited adoption of modern upland rice varieties in West Africa: varietal evaluation programs have focused too narrowly on yield evaluation and have not promoted varieties with superior non-yield characteristics than locally available varieties.

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1. Introduction

Upland rice farmers in West Africa continue to cultivate locally adapted traditional rice varieties despite nearly 50 years of varietal development, official release and diffusion of modern varieties. Recent studies have determined that over 50 improved varieties have been released but less than 11% of the 900,000 ha of crop land in the upland rice belt of West Africa—the Cassamance of Senegal, Guinea, Sierra Leone, Liberia and western Ivory Coast—is planted to modern upland varieties (Dalton and Guei, 2003). An additional 31% of this area is planted to traditional landrace varieties transferred across borders from one region of Africa into neighbouring countries and to a
lesser extent from Latin America. These purified landraces were produced without the use of modern plant breeding techniques but are planted to nearly three times greater area than modern varieties.

The objective of this study is to derive the economic value of upland rice traits through a hedonic price modelling approach. One criticism of modern rice breeding programs is that they have not incorporated desirable consumption attributes and non-yield production traits into new varieties. Varietal development has occurred at agricultural research stations where varietal improvement focused on improving crop yield and panterritorial yield stability. National varietal release mechanisms evaluated new plant materials in agronomically managed multi-locational yield trials and promoted varieties for release with higher mean yields and limited yield variability. Yet studies of adoption behaviour have found significant relationships between farmers' subjective perceptions of grain milling and cooking attributes in addition to yield (Adesina and Baidu-Forson, 1995; Adesina and Zinnah, 1993). Limited adoption of improved varieties promoted through this procedure may indicate an inefficient evaluation process. As an example, Byerlee and Hisey (1996) indicated that maize breeding programs have paid insufficient attention to post-harvest evaluation of grain quality, storability and small-scale processing.

The following model presents a method to evaluate new varieties which broadens selection criteria to include production cost-saving attributes, grain processing and consumption traits in addition to yield and yield-related attributes. This study integrates the input characteristic modelling (ICM) and consumer good characteristic modelling (CGCM) literature and extends the trait evaluation methodology into a less-developed country agricultural household scenario where market information is limited. In order to do so, an experimental market for traits is simulated. The hedonic price model offers an alternative explanation for limited adoption of new seed technology and provides an economic basis for prioritising plant breeding objectives and allocating research funding.

The following section presents a review of key literature on technology and variety development. It is followed by an analytical justification of the pricing model and then a description of the data collection approach. In the fifth section, three hedonic models are estimated and compared. Estimation of underlying demand functions for traits, through second stage regressions, is not pursued in this paper. The final section summarises the results and presents conclusions.

2. Explanations of limited varietal adoption

*Ex post* impact assessments largely explain the varietal adoption process using land allocation adjustment and joint production models (Smale et al., 1994). These theories focus on four competing explanations of the adjustment process: varietal portfolio selection, safety-first consumptive failures, farmer experimentation (Cameron, 1999; Shampine, 1998) and sluggish input reallocation or fixity (McGuirk and Mundlak, 1991). Each of these explanations views the improved variety as an exogenous finished technology that requires producer behavioural modification or greater information on factor requirements for efficient utilisation of technology traits.

Alternatively, limited adoption can be explained as a failure of the technology development process to produce varieties (or resource management practices) adapted to heterogeneous production conditions or with traits valued by producers and consumers (Pingali et al., 2001). Input characteristic models have identified economically valuable production traits in developed country agriculture but have not been explored for use in technology assessment in less developed countries. Input characteristic models have been used to correlate farmer varietal (or livestock breed) selection with inseparable bundled sets of genetic attributes or traits (Barkley and Porter, 1996; Melton et al., 1994; Schroeder et al., 1992). Application of neoclassical ICMs, largely based upon disaggregating breed or variety price into derived implicit values of embodied genetic traits, have been limited by unobservable data (Melton et al., 1994). Limited information on the economic value of traits may be an explanation for slow varietal replacement and turnover (Barkley and Porter, 1996).

This study diverges from the ICM literature in order to incorporate evaluation of consumption in addition to production traits. In order to do so, a modification of the utility maximising hedonic pricing model, as
formally proposed by Court (1941), advanced by Griliches (1966), Lancaster (1966) and as adapted by Ladd and Savannunt (1976), is presented in the context of the West African agricultural household. Hedonic consumer good characteristic models have been applied to agricultural commodities such as cotton (Ethridge and Neepor, 1987; Bowman and Ethridge, 1984), pork (Melton et al., 1996), and rice (Brorsen et al., 1987; Unnevehr, 1986). Lambert and Wilson (2003) identified the inefficient signalling of desirable end-user characteristics from producers to processors as a source of economic loss in the US wheat market. This study will evaluate a similar problem for small-scale agricultural producers in a developing country and determine the importance of both production and consumption traits through input characteristic and consumer good characteristic models.

3. A household model of virtual pricing

Consistent with the household modelling literature, where staple goods are produced, consumed and sold by the household, a hedonic model is specified to value production and consumption attributes of those goods. Assume that the household maximises an additively separable utility function of consuming $H$ staple agricultural crops, $C_h$, $M$ market purchased goods, $C_m$, such that $J = \{H \cup M\}$ and household leisure $l$. Utility, $U: \mathbb{R}_{h+1}^J \rightarrow \mathbb{R}$ is bounded, continuously differentiable, strictly concave: increasing in all arguments, non-increasing in the second derivatives while restricting the cross derivatives to produce a well behaved utility function with $U(0) = 0$. This formulation allows utility to be defined over non-negative $J + 1$ space and will allow the household budget set defined over positive full income. Secondly, assume that the staple good expresses a number of different characteristics $q$, indexed over $t$, of which a subset $c$ contributes to the utility of consumption. Utility can then be represented as a function of the purchased goods, leisure and the embodied characteristics of the household produced staple:

$$U = U(C_h(q^*_h), C_m, l)$$

(1)

The production function for the staple crop $h$, $Y_h$, is single valued and non-joint. Output is determined by the amount of land, $A$, and labour $L$, allocated to production and the embodied technology specific production characteristics of the crop, $T$. The remainder of the $z$ characteristics, indexed over $t$, can be thought of impacting production traits and potential such that $Z = \{C \cup T\}$:

$$Y_h = Y_h(L, A|T(q^*_h)) \quad \forall \ h \in J$$

(2)

The utility maximising household’s short-run income constraint is determined by substituting the production function into the agricultural profit equation net of the opportunity cost of household supplied labour and land:

$$p_m C_m + p_h C_h(q^*_h) + w l = p_h Y_h(L, A|T(q^*_h)) - w l - r_a A,$$

$$p_m C_m + p_h C_h(q^*_h) + w l = \pi(p_h, w, r_A|T(q^*_h))$$

(3)

where $p_m$ and $p_h$ are the prices for both market and staple commodities, $Y_h$ is the household’s production of the staple commodities ($Y_h > C_h$), $w$ the wage rate, $wl$ represents the opportunity cost of leisure and $r_a$ defines the rental rate of land.

After forming the Lagrangian, and assuming an interior solution, relatively general first-order conditions of utility maximisation can be determined for the household produced good as a function of the product of the marginal utility of consumption and the expression of the trait bundles:

$$\sum_{z=1}^{Z} \frac{\partial U}{\partial C_h} \frac{\partial C_h}{\partial q^*_h} = \lambda p_h \quad \forall \ h \in J$$

(4)

Optimal allocations of land and labour in the production process may be determined as a function of the opportunity cost of labour, defined by the wage rate, land rental rate and technology productivity:

$$L^* = L^*(w, r_A|T(q^*_h)) \quad \forall \ h \in H,$$

$$A^* = A^*(w, r_A|T(q^*_h)) \quad \forall \ h \in H$$

(5)

These optimal allocations can be substituted into the household’s agricultural profit function and subsequently into the income constraint. However, the key area of interest in this model is determining the implicit price for technology and consumption attributes. Substituting the marginal utility of income for $\lambda$ and solving for prices, Eq. (4) may be rewritten in order to express the demand for traits as a function of
the marginal utility of income and the technical expression of the trait in the staple viz:

$$\sum_{z=1}^{Z} \left( \frac{\partial \pi(w, r|T(q_z))}{\partial C_h} \right) \frac{\partial C_h}{\partial q_z} = p_h \quad \forall h \in J$$  \hspace{1cm} (6)

In parentheses is the marginal rate of substitution between the consumed staple and cash income where income is a function of technology traits. This is multiplied by the marginal yield of the consumption characteristics in the good. As specified in (6), if the household model assumption holds, the marginal utility of consumption and the marginal utility of income will depend upon both consumption and production characteristics of the variety.

Since it can be shown that the marginal yield of characteristics for most goods is constant and that the implicit price for the attribute is also constant, this equation can be reduced to the familiar hedonic price model formulation where the observed price for the good, $p_h$, is dependent upon the virtual price for the characteristic $z$, and a vector of measured characteristics, $z$. Eq. (7) expands this generality to encompass both the production and consumption traits of the new technology since income (and leisure) is a function of the production traits. As such it is hypothesised that the unbiased specification of a hedonic pricing model for an agricultural household can be specified as a combined ICM and CGCM model where the superscript on the $\Phi$ vector is divided to denote $T$ production technology traits and $C$ consumption traits viz:

$$p_h = \sum_{z=1}^{Z} \Phi_T q_z^T + \sum_{z=1}^{Z} \Phi_C q_z^C \quad \forall h \in J$$  \hspace{1cm} (7)

Most official varietal evaluation programs promote new varieties to release and diffusion stage based upon yield and yield stability attributes. This promotion strategy implies that the total value of the consumption traits ($\Phi^T_z$) in Eq. (7) is negligible. In such a case, the model will reduce to a classic ICM. If production characteristics are not important to the agricultural household, then Eq. (7) would reduce to the CGCM. Determining the appropriate hedonic pricing model is critical to deriving the welfare impact of trait improvement through second stage demand models. Rosen (1974) indicates that first stage models contain less than complete information but that they are useful in determining structural parameters of interest. These alternative specifications are tested against an augmented household model in the following section.

4. Experimental methods for implicit valuation of plant characteristics

Although many countries have diverse populations of traditional varieties, the observed variability of variety characteristics is limited. As a result, survey methods would find insufficient variability in trait expression to correlate with market prices in hedonic modelling. In order to assess the demand for plant characteristics by small-scale upland rice producers, a 2-year farmer participatory experiment was developed that introduced new varieties into the producers' choice set.

In the first year of the experiment, a garden of rice varieties was planted in a central village location in western Ivory Coast. In this garden, modern Asian varieties, traditional varieties cultivated in Africa, and new interspecific crosses between African rice and modern Asian varieties were planted and grown under local farming conditions in a randomised unreplicated field trial. Sixty varieties were included in the trial and each one was grown on a 15 m² plot. Slightly more than 90% of all varieties were new introductions into the area.

Sixty-one farm households, from 11 villages near to the western Ivorian town of Danané, were invited to visit the trial at their leisure for three structured interviews in 1997. These farmers were selected from a stratified random sample of rice-producing households representative of farms in the monomodal humid forest region of Ivory Coast. On average, producers from these households were uneducated, 42 years old, supported five children, a spouse and one parent, and earned limited agricultural and non-agricultural income. These producers cultivated 1.5 ha of food crops, an average of three different rice varieties, and had 19 years of rice growing experience each. Cumulatively, the participating producers possessed 1320 years of rice production experience.

Formal interviews were conducted at three stages during the production season: the vegetative growth stage, approximately 55 days after seeding (in-field), at maturity (in-field) and after the grain harvest (at the
village center). During these interviews, farmers evaluated the varieties by responding to structured questionnaires and open-ended qualitative evaluations. At each visit, producers were allowed to select varieties to plant under their own growing conditions in the following season with no limit placed on the maximum number of choices.

In the second growing season of the experiment, 1998, 1 kg seed samples were distributed to the participants for cultivation under their farm conditions. Each household received the union of the varieties they selected from the three visits held in the first year. As such, this procedure circumvents information asymmetries that may lead to an end-user over- or undervaluing a variety due to imperfect signalling of performance in the first year of the trial. Recently, Lambert and Wilson identified a similar information transfer inefficiency as a source of market failure between producers and processors in wheat markets.

Farmers were responsible for growing the varieties they selected and it was emphasised that they should do so using the same cultivation practices as on their primary household rice fields. No farmer applied biochemical inputs outside of the new varieties. Structured questionnaires were administered to the household to evaluate production, grain milling and consumption characteristics. Trait evaluation focused on characteristics producers identified as important during the first year evaluations (Table 1). Farmer criteria were referenced against scientific criteria in the Standard Evaluation System for Rice and this correspondence allowed quantitative evaluation of qualitative producer assessments (INGER, 1996).

Variety evaluations were held to assess production traits during the growing season and at harvest. A third visit was made to assess post-harvest characteristics and conducted at the farm household. Evaluations were conducted by the farmers and trained field assistants at the same time. In this manner, the enumerators could probe qualitative responses with measurement; for example measuring height in centimetre when a farmer only indicated that a variety had “good” height. During the growing season, data on the cycle length, plant height, the number of tillers per square meter, and the yield of rough rice were collected.

It is hypothesised that the implicit price on cycle length will be negative since farmers with earlier maturing varieties will be able to capture short-term rents in local markets or relieve early season food deficits, prior to the main rice harvest of longer-cycled traditional varieties. The implicit price will be positive on height as it relates positively to labour efficiency of harvesting, as also with the number of tillers, which is an instrument relating host plant weed competition to weeding labour demand. Plants that require less production labour will reduce the opportunity cost of leisure ceteris paribus. The implicit price of yield will be positive as utility is non-decreasing in consumption or income.

Post-harvest evaluation took place under household circumstances. Full physical evaluation of grain milling traits, and chemical evaluation of grain quality characteristics, for all farmer grown varieties was not possible due to prohibitive time and research costs. Instead, farmers evaluated milling and consumption relative to their traditional varieties on a 5-level qualitative Likert scale. All implicit prices are expected to be positive since quality improvements are denoted with higher scores. Three characteristics of post-harvest transformation were evaluated: threshing, hand milling and head rice recovery. Five sensory consumption traits: cooking aroma, colour, cohesion, swelling/elongation and grain tenderness were evaluated. These characteristics are grouped under “consumption” traits as the local practice is to store harvested grain while still attached to the panicle head. The local consumption process consists of threshing, hand milling, cooking and then consuming the grain.

Farmers were not financially compensated for their participation in the experiment but they retained all grain produced in their fields, except for samples taken by researchers. All participation was consensual and there was no producer attrition between the two seasons of the experiment except for one death. Many of the characteristics introduced into the choice set of the producers were novel, for example early maturation and short stature. Many criticisms of contingent valuation of environmental goods focus on the intangibility of valuing the environmental good in question. The primary purpose of the 2-year evaluation was to maximise producer experience with these traits in order to minimise any bias introduced through unfamiliar and abstract traits.
Table 1
Important upland rice traits identified by farmers at three growth stages in the first year of the experiment

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>Agronomic</th>
<th>Morphological</th>
<th>Grain quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetative growth</td>
<td>Height, Seedling vigor, Tillering ability, Yield potential, Cycle</td>
<td>Leaf architecture</td>
<td></td>
</tr>
<tr>
<td>Maturity</td>
<td>Height, Tillering ability, Yield potential, Cycle</td>
<td>Panicle structure</td>
<td></td>
</tr>
<tr>
<td>Post-harvest</td>
<td>Yield</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At the end of all evaluations, a close-ended questionnaire on the supply and purchase of local seeds was administered to determine producer participation in the local seed market. All producers indicated that they had purchased seed in the past. A second series of questions asked the farmer to rank all varieties, including their favoured traditional variety, in terms of the most preferred to the least preferred.

This was followed by elicitation of the willingness to pay for seed of each of the tested varieties in an open-ended framework. Producers were informed that they could purchase more seed of the varieties they planted but that quantity available for purchase was limited and that they will be required to purchase their seed at the beginning of the next season upon delivery. They were then requested to state their willingness to pay for a kilogram of seed and the area that they wished to plant to the variety. Recent studies on the contingent valuation of public goods have shown that the open-ended bid process leads to “fairly certain” willingness to pay statements (Welsh and Poe, 1998). This stated willingness to pay for seed is used as the dependent variable in the hedonic model. Finally, after valuing each variety, each was rated in a dichotomous choice framework to determine whether the variety would be replanted in the following season if they receive all of the seed they requested. Summary statistics of the farmer evaluations of the varieties grown in the second season are presented in Table 2.

5. Econometric specification and results

Willingness to pay responses was screened for economic validity and consistency with several tests. A test of the mean willingness to pay for varieties that the farmer wished to replant versus those that were not to be replanted, under the assumption of unequal

Table 2
Descriptive statistics of the variables

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price (CFAF/kg)</td>
<td>232</td>
<td>101.0</td>
<td>25</td>
<td>600</td>
</tr>
<tr>
<td>Cycle length (days)</td>
<td>113</td>
<td>13.6</td>
<td>102</td>
<td>158</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>101</td>
<td>41</td>
<td>41</td>
<td>168</td>
</tr>
<tr>
<td>Tillers (#/m²)</td>
<td>152</td>
<td>8.6</td>
<td>15</td>
<td>387</td>
</tr>
<tr>
<td>Yield (kg/ha)</td>
<td>995</td>
<td>260.8</td>
<td>150</td>
<td>1618</td>
</tr>
</tbody>
</table>

Consumption characteristics:

- Threshing
- Milling
- Head rice recovery
- Aroma
- Cohesion
- Colour
- Swelling
- Tenderness

All consumption characteristics were evaluated in relation to the farmer’s local variety where 1 = very poor, 2 = poor, 3 = equal to local variety, 4 = better, 5 = much better.

n = 250.
variances, indicated a significant difference (265 and 91 CFAF/kg respectively, t = -20.15, P < 0.001). As a sample, the significant difference between the two classes of varieties indicates that the instrument generated economically valid responses for the group.

Secondly, for each producer, ordinal preference rankings of the varieties were compared against stated willingness to pay for seed to determine whether stated varietal preferences coincided with expressed expenditure patterns for seed. Under the Axiom of Revealed Preference, a variety is weakly preferred over another if expenditure for the variety is non-decreasing when compared with an inferior variety and strictly increasing if the variety is strongly preferred. Thirty percent of the producer rankings were consistent with the Strong Axiom of Revealed Preference, 55% consistent with the Weak Axiom of Revealed Preference, and 15% of the stated rankings violated the transitivity of expenditure. Of the nine violations, all but one occurred with a single intransitivity indicating that nearly all producers understood the willingness to pay elicitation instrument and responded to the instrument in an economically consistent manner. The violations occurred only when producers undertook compound comparison of five, six or seven varieties.

Table 3
Regression estimates and standard errorsa

<table>
<thead>
<tr>
<th></th>
<th>Household</th>
<th>ICM</th>
<th>CGCM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>S.E.</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Cycle length</td>
<td>-15.701**</td>
<td>6.478</td>
<td>-1.134</td>
</tr>
<tr>
<td>Height</td>
<td>5.499*</td>
<td>1.719</td>
<td>8.539*</td>
</tr>
<tr>
<td>Tiller</td>
<td>0.178</td>
<td>0.280</td>
<td>-0.603***</td>
</tr>
<tr>
<td>Yield</td>
<td>0.071</td>
<td>0.109</td>
<td>0.160</td>
</tr>
<tr>
<td>Cycle length²</td>
<td>0.071*</td>
<td>0.026</td>
<td>0.014</td>
</tr>
<tr>
<td>Height²</td>
<td>-0.025*</td>
<td>0.008</td>
<td>-0.037*</td>
</tr>
<tr>
<td>Tiller²</td>
<td>-7.43E-04</td>
<td>6.88E-04</td>
<td>1.07E-03</td>
</tr>
<tr>
<td>Yield²</td>
<td>-8.17E-06</td>
<td>5.37E-05</td>
<td>-3.59E-05</td>
</tr>
<tr>
<td>Threshing</td>
<td>-2.392</td>
<td>18.710</td>
<td></td>
</tr>
<tr>
<td>Milling ease</td>
<td>-16.222</td>
<td>22.210</td>
<td></td>
</tr>
<tr>
<td>Head rice recovery</td>
<td>15.225</td>
<td>26.330</td>
<td></td>
</tr>
<tr>
<td>Aroma</td>
<td>50.089</td>
<td>31.460</td>
<td></td>
</tr>
<tr>
<td>Cohesion</td>
<td>15.362</td>
<td>34.080</td>
<td></td>
</tr>
<tr>
<td>Colour</td>
<td>51.299**</td>
<td>24.970</td>
<td></td>
</tr>
<tr>
<td>Swelling</td>
<td>50.619*</td>
<td>21.640</td>
<td></td>
</tr>
<tr>
<td>Tenderness</td>
<td>70.279*</td>
<td>27.710</td>
<td></td>
</tr>
<tr>
<td>Threshing²</td>
<td>1.268</td>
<td>2.740</td>
<td></td>
</tr>
<tr>
<td>Milling ease²</td>
<td>3.945</td>
<td>3.155</td>
<td></td>
</tr>
<tr>
<td>Head rice recovery²</td>
<td>0.940</td>
<td>4.882</td>
<td></td>
</tr>
<tr>
<td>Aroma²</td>
<td>-2.092</td>
<td>4.440</td>
<td></td>
</tr>
<tr>
<td>Cohesion²</td>
<td>-0.369</td>
<td>6.208</td>
<td></td>
</tr>
<tr>
<td>Colour²</td>
<td>-5.750</td>
<td>4.461</td>
<td></td>
</tr>
<tr>
<td>Swelling²</td>
<td>-5.409***</td>
<td>3.278</td>
<td></td>
</tr>
<tr>
<td>Tenderness²</td>
<td>-8.129***</td>
<td>4.345</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>300.900</td>
<td>417.800</td>
<td>-244.190</td>
</tr>
</tbody>
</table>

F test on individuals 15.540*  8.230*  11.240*
Log likelihood -1346.05  -1434.55  -1384.31
Adjusted R² 0.589  0.239  0.468

n = 250.
* Standard errors computed using White’s heteroskedasticity consistent covariance matrix.
** Statistically significant at the 99% confidence level.
*** Statistically significant at the 95% confidence level.
**** Statistically significant at the 90% confidence level.
A quadratic algebraic functional form was specified for the hedonic pricing model of upland rice to allow for non-linear marginal utility of traits. While several other functional forms, including linear, log-linear or Box-Cox transformations, have been used in hedonic models, no consensus has emerged on the preferred functional relationship. The household hedonic model is specified as a nested combination of the ICM and CGCM:

\[
p_{ijl} = \alpha_0 + \sum_{i=1}^{4} \beta_i x_{ijl} + \sum_{i=1}^{4} \theta_i x_{ijl}^2 + \sum_{k=1}^{8} \theta_k x_{kj} + \sum_{l=1}^{59} \delta_l x_{lj} + \nu_{jl}
\]

where \( p_{ijl} \) is the willingness to pay for seed of upland rice variety choice \( j \) by producer \( l \), \( \beta_i, \ i = 1, \ldots, 4 \) represents the estimated coefficients on the four production traits and the coefficients on the squared terms, \( \theta_k, \ k = 1, \ldots, 8 \) represents the estimated coefficients milling and consumption traits and the coefficients on the squared terms (both are described in Table 2) and \( \delta_l, \ l = 1, \ldots, 59 \) represents binary variables for the participants in the study. Individual specific dummy variables are included in the regression to capture unbalanced systematic variation related to individual choice of the number of varieties evaluated under farm conditions. An average producer chose four varieties but some chose only two and others seven. The error term, \( \nu_{jl} \) is normally distributed \( \nu(0, \sigma) \). In addition to the household model, an ICM was estimated without consumption traits while the CGCM did not include the production traits. OLS regression results, using White's heteroscedasticity consistent covariance matrix to calculate standard errors, are presented in Table 3.

Two specification tests were conducted in order to determine the appropriate model of attribute pricing. In the household model, a joint F-test that the production characteristics were equal to zero was tested against the alternative that they were not. An identical test was conducted on the consumption characteristics. Both tests evaluate whether the estimated mean effects are important explanatory variables of willingness to pay for the rice varieties. Both exceeded respective critical values at the 99% significance level (Table 4). In addition to the F-tests, likelihood ratio tests of the household model against restricted versions of the ICM and CGCM exceeded critical \( \chi^2 \) values at the 99% significance level. Both tests indicate that the combination of the ICM and CGCM in the household model contribute significantly to explaining variation of the dependent variable.

Parametric F- and likelihood ratio tests illustrate that ICM and CGCM do not encompass the explanatory power of the household model. As stated by Mizon and Richard (1986), a model that cannot encompass its alternatives has important omitted variable weaknesses and is only useful in so far that it leads to identification of a rival model of greater general specification. While the household model has strong analytical appeal, few empirical studies have tested whether alternative challengers can encompass its predictive power.

As a result, discussion of the parameter estimates will focus on those derived from the household model. Several parameter estimates were significant in explaining willingness to pay for seed. Two production attributes (cycle length and plant height) and three consumption traits (colour, swelling/elongation and tenderness) were significant explanatory variables in the household model. In addition, 57 of the 59 individual dummy variables were significantly different from zero. The F-statistic, distributed with 59 and 166 degrees of freedom, of the null hypothesis of no individual-specific effects was 15.55 and rejected at the 99% significance level.

One important finding of the household model was the lack of significance on the variable measuring...
yield. In addition, the variable measuring tillers, the proxy for weed competition, was also insignificant. In most varietal evaluation programs, yield is used as the deciding measure of comparative performance, in addition to yield stability. This model finds that farmer willingness to pay for seed was not influenced by overall yield performance nor weed competitiveness.

Plant production attributes play an important part in determining willingness to pay. Many of the advances in the Green Revolution concentrated on increasing the harvest index through introducing semi-dwarfing genes. Model results indicate that farmers in this region place strong importance on a plant that is approximately 1.1 m in height in order to facilitate hand harvesting. Cycle length is also highly significant. The optimal cycle length is estimated at 111 days, more than 1 month shorter than locally available varieties.

Three consumption traits were found significant in the attribute pricing model: colour, swelling/elongation and tenderness. Farmers preferred milled varieties with a whiter colour and hence cleaner separation of the seed coat from the grain. Elongation and swelling are perceived as important factors relating the amount of rice prepared and the amount that can effectively feed a household. A variety that “swells” is perceived as able to feed a household since it generates more food volume with less grain. The optimal value for this characteristic is 4.5. Tenderness is related to the amylose content and gel consistency of grain and the optimal value is approximately 4.3 on the Likert scale or “more tender than my local variety.”

6. The impact of misspecification

Comparison of the predictive power of the three models can be used to determine the impact of misspecification. The predicted willingness to pay for each variety is derived from the three models and compared against the price for local varieties purchased in the marketplace prior to the growing season. This is an analogous, but economic, comparison to the current practice of evaluating yield performance of challenger varieties to the yield levels of existing released varieties in the promotion process. The average pre-planting price of upland rice seed is 250 CFAF/kg.

Under the household specification of the model, 93 of the 250 variety choices exceeded the market price of 250 CFAF/kg while only 84 and 89 under the ICM and CGCM respectively. All three models predicted a value inferior to the market price of local varieties in 53% of the cases, and in excess of the threshold in 21%. Overall, 74% of the cases were insensitive to the model used to estimate the willingness to pay. On the other hand, over one quarter of the cases produced contradictory results. While the three equations categorised the majority of the observations into a common category, the differences are statistically significant at the 99% level and lead to the conclusion that by using the ICM or CGCM, instead of the household specification, the variety will be incorrectly categorised. The results of a Type II error, where the false null of the ICM or CGCM is used to evaluate the willingness to pay is that 19.1 and 9.4% of the cases, respectively, are incorrectly categorised when compared against the household model. The financial implications of a miscategorisation, that is releasing a variety that is inferior or not releasing a variety that is superior to local alternatives, can be profound especially in limited resource nations with high opportunity costs to extension and development alternatives. Furthermore, using an inconsistent hedonic price model in a second stage demand equation, following the models of Bartik (1987) and Epple (1987) who reevaluate the estimation procedure of Rosen (1974), would generate biased estimates of ex ante welfare gains to trait improvement. This bias could lead to a misallocation of scarce research resources.

7. Conclusions

This research has estimated a household hedonic pricing model of upland rice attributes and tested it against more restricted contending models. Regression specification tests indicated that neither individual model encompassed the mean effects of the other, thereby justifying an augmented model consistent with the household modelling literature.

Overall findings from this regression have important implications for national and international institutes engaged in developing new plant varieties.
for small-scale producers. Had either the ICM or CGCM predicted farmer willingness to pay for new varieties, then data collection could be tailored to collect these key pieces of information for feedback into technology development. Doing so could lead to significant savings in research expenditures.

On the other hand, failing to incorporate both production and consumption traits, or focusing on the wrong attribute, could lead to biased and inappropriate varietal promotions. This research found that yield was not a significant attribute in determining farmer willingness to pay for new varieties yet this trait has served as the defining factor for promoting a new variety for official release. Overall, evaluating only on production characteristics will lead to 19.1% of all varieties misclassified as inferior. Several improved modern varieties in this study were recently released by national authorities. Under farmer controlled production conditions, these varieties did yield more than the local checks. However, they had lower consumption trait evaluations, matured 2 weeks before the optimal cycle length and were 20 cm shorter than the optimal height. Willingness to pay for these released varieties was between 66 and 73% of the local varieties and farmers indicated that they would not plant these varieties in the following cropping season.

The research approach has helped to identify several new varieties that farmers find very valuable. Farmers valued several traditional landraces and new crosses of African and Asian varieties over locally available cultivars by up to 15%. These varieties had superior consumption attributes, heights in excess of 110 cm, and cycle lengths around 115 days. In addition, economically important variety traits have been identified to improve the efficiency of future technology generation strategies. Future research will derive ex ante estimates of welfare gains to trait improvement in a second stage demand equation controlling for the endogenous determination of trait price and the simultaneous decision of quantity consumed.

This research offers an alternative explanation for the lack of adoption of modern upland varieties despite a long history of their release in the region. The defining character used to evaluate upland varieties, yield, was inappropriate. Social scientists have a fundamental role to play in the varietal evaluation process and need to refocus national agricultural development agencies on evaluating a broader set of plant characteristics beside yield and stability. Failing to do so may lead to significant lost opportunities to increase producer and consumer surplus in less developed agrarian economies.

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