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A HEDONIC MODEL OF RICE TRAITS: ECONOMIC VALUES FROM FARMERS IN WEST AFRICA

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Contributed paper selected for presentation at the
25th International Conference of Agricultural Economists, August 16-22, 2003

*This research was conducted while the author was the production economist with the West Africa Rice Development Association, Bouaké, Côte d'Ivoire. Maine Agricultural and Forestry Experiment Station External Publication 2644.

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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 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. This non-separable household model specification determined that four traits explain the willingness to pay for new rice varieties: plant cycle length, plant height, grain 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 producers' 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.

Keywords: hedonic, upland rice, West Africa, household modelling

1. Introduction

In the upland rice belt of West Africa–Guinea, Sierra Leone, Cote d'Ivoire, and the Cassamance of Senegal[1]–about 22% of 1.06 million hectare of upland rice area is planted to improved varieties. Most of these varieties were improved through derivative breeding processes, namely the collection and purification of traditional landraces grown elsewhere in the region. Generative processes, deliberate crossing of more than two parents to produce a genetically altered offspring with recombinant varietal traits, has largely failed to produce varieties adopted over a large area and cover less than five percent of cropping are despite nearly fifty years of breeding history and 44 official releases. Irrespective of the source of genetic enhancement, productivity has increased by less than $30/ha (Dalton and Guei, 2003).

The objective of this study is to derive the economic value of upland rice traits through a hedonic modeling 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 multilocational yield trials and promoted varieties for release with higher mean yields and limited yield variability. Yet studies of adoption behavior have found significant relationships between farmer's 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

[1]While Liberia is generally included in the profile of the Upland Rice belt, prolonged civil unrest has made it impossible to collect basic information about the size and scope of the rice production economy.

example, Byerlee and Heisey 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 builds upon the input characteristic modelling (ICM) and consumer goods characteristics modelling (CGCM) literature by extending the trait evaluation methodology into a less-developed country agricultural household scenario where market information is limited. By doing so, the model offers an alternative explanation for limited adoption of new seed technology and provides an economic basis for prioritizing 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 hedonic pricing model and then a description of the data collection approach. In the fifth section, three hedonic model are estimated and compared. The final section summarizes the results and presents conclusions.

2. Literature Review

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 behavioral modification or greater information on factor requirements for efficient utilization 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 heterogenous 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 (Barkely 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 (Barkely 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 maximizing hedonic pricing model, as originally presented by Griliches (1966), Lancaster (1966) and as adapted by Ladd and Savannut (1976), is presented in the context of the West African household. Hedonic consumer goods characteristic models (CGCM) have been applied to agricultural commodities such as cotton (Ethridge and Neeper,1987; Bowman and Ethridge, 1987), pork (Melton et al, 1996), and rice (Brorsen, Grant and Rister, 1984; Unnehevr, 1986). No study, however, has simultaneously estimated the value of production and consumption traits in new seed technologies. This study will evaluate an augmented model consisting of both production and consumption traits, consistent with the analytical foundation of household modelling, against the ICM and CGCM.

3. A Household Model of Virtual Pricing

Consistent with the household modeling literature, where a staple agricultural good is both produced, consumed and sold by the household, a hedonic model is specified to value production and consumption attributes. Assume that the household maximizes an additively separable utility function of consuming H staple agricultural crops, $\boldsymbol{C_h}$, M market purchased goods, $\boldsymbol{C_m}$, such that J={H∪M} and household leisure *l*. Utility, $U: \mathbb{R}_+^{J+1} \rightarrow \mathbb{R}$, is bounded, continuously differentiable, strictly concave: increasing in all arguments, nonincreasing 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 nonnegative J+1 space and will allow the household budget set defined over positive full income. Secondly, assume that the staple good varies in the number of characteristics *q*, indexed over *z*, which contribute to the utility of consumption. The utility function can then be represented as:

$$U = U(\boldsymbol{C_h}(\boldsymbol{q_{hz}}), \boldsymbol{C_m}, l) \qquad \textbf{(1)}$$

Production of the staple crop *h*, Y_h, is determined through land, (denoted as *A*), and labor (*L)* allocation and the embodied technology specific production characteristics of the crop $t(q_z)$:

$$Y = Y(L, A, t(q_z)) \quad \forall h \in H \qquad \textbf{(2)}$$

The short-run income constraint is determined by substituting the production function into the agricultural profit equation net of the opportunity cost of household supplied labor:

$$\begin{aligned} p_m C_m + p_h C_h(q_z) + wl &= p_h Y_h(L, A, t(q_z)) - wL \\ p_m C_m + p_h C_h(q_z) + wl &= \pi(p, w, t(q_z)) \end{aligned} \qquad \textbf{(3)}$$

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, L is total labor input, *w* the wage rate and *wl* represents the opportunity cost of leisure.

After forming the Lagrangian, and assuming an interior solution, relatively general first order conditions of utility maximization can be determined for the household produced good[2] as a function of the product of the marginal utility of consumption and the expression of the trait bundles:

$$\sum_{z=1}^{Z} \frac{\partial U}{\partial C_h} \frac{\partial C_h}{\partial q_{hz}} = \lambda p_h \quad \forall h \in J \tag{4}$$

Optimal allocations of land and labor in the production process may be determined as a function of prices and productivity.

$$\begin{aligned} L^* &= L^*(w, A \mid t(q_z)) \quad \forall h \in H \\ A^* &= A^*(w, L \mid t(q_z)) \quad \forall h \in H \end{aligned} \tag{5}$$

These optimal allocations can be substituted into the household's agricultural profit function and subsequently into the cash income constraint. However, the key area of interest in this model is the determining the implicit price for technology attributes. Substituting the marginal utility of income for λ and solving for prices, equation (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:*

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[2]The standard first order condition applies to the market good and, for sake of space constraints, the subsequent discussion focuses on the demand for the staple good.

$$\sum_{z=1}^{Z}\left(\frac{\partial U}{\partial C_h}\frac{\partial \pi(L^*,A^*,w|t(q_z))}{\partial U}\right)\frac{\partial C_h}{\partial q_{hz}} = p_h \quad \forall h \in J \tag{6}$$

In parentheses is the marginal rate of substitution between the consumed staple and cash income. This is multiplied the marginal yield of the characteristics in the good. As specified in (6), if the household model assumption holds, both the marginal utility of consumption and the marginal utility of income will depend upon the characteristics of the seed 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 model formulation where the observed price for the good, p_h, is dependent upon the virtual price for the characteristic $\bar{p}_z$, and a vector of measured characteristics, *z*. Equation 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 hypothesized 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 $\bar{p}_z$ vector denotes *t* production technology traits and *c* consumption traits viz.

$$p_h = \sum_{z=1}^{Z}\bar{p}_z^{\,t}\,t_{hz} + \sum_{z=1}^{Z}\bar{p}_z^{\,c}\,c_{hz} + \quad \forall h \in J \tag{7}$$

Most official varietal evaluation programs promote new varieties to the release stage based upon yield and yield stability attributes. This promotion strategy implies that the total value of the consumption traits ($\bar{p}_z^c$) in equation (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 equation (7) would reduce to the CGCM. These alternative specifications are tested against an augmented household model in the following section.

4. Experimental Methods for Implicit Valuation of Plant Characteristics

In order to assess the demand for plant characteristics by small-scale upland rice producers, a two year farmer participatory experiment was developed. In the first year of the experiment, an over-specified orthogonal composition of plant characteristics was developed consisting of modern Asian varieties, traditional varieties cultivated in Africa, and new interspecific crosses between African rice and modern Asian varieties. The composition of the selected varieties and cultivars in the trial was based on agronomic, morphological, and grain quality attributes that farmers indicated were important (Table 1). These varieties were grown under local farming conditions in a randomized unreplicated field trial in a centrally located village plot. Sixty varieties were included in the trial and each one was grown on a 15 m^2 plot.

Table 1. Important Plant Characteristics for Upland Rice Farmers

	Agronomic	Morphological	Grain Quality
Vegetative Growth	Height Seedling Vigor Tillering Ability Yield Potential Cycle	Leaf Architecture	
Maturity	Height Tillering Ability Yield Potential Cycle Fertility	Panicle Structure	
Post-Harvest	Yield		Grain Size Grain Shape Grain Color Composite "Taste" Threshing Ability Milling recovery

Source: Lilja and Dalton, 1998.

Sixty-four farm households, from eleven villages near to the western Côte d'Ivoire town of Danané, were invited to visit the field at their leisure in 1997. These farmers were selected from a stratified random sample of rice-producing households representative of those producing in the monomodal humid forest region of Côte d'Ivoire. Structured evaluations were conducted at three stages: the vegetative growth stage, approximately 55 days after seeding, at maturity and after the grain harvest. During these visits, farmer responses to semi-structured questionnaires and open-ended evaluations were collected on the varieties that each farmer wished to cultivate.

In the second growing season of the experiment, 1998, one kilogram seed samples were distributed to the participants for cultivation under their farm conditions. Post-harvest evaluation took place under household circumstances. Each household received the varieties they selected in the centralized village trials held in the first year. Structured questionnaires were administered to the household in order to qualitatively and quantitatively evaluate production, grain milling and consumption characteristics. Production traits were quantitatively measured for each of the varieties by trained enumerators. Data on the growing cycle length, plant height, the number of tillers per meters squared, and the yield of rough rice were collected. It is hypothesized 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 labor efficiency of harvesting, as also with the number of tillers, which is an instrument relating host plant weed competition to weeding labor demand. Plants that require less production labor will reduce the opportunity cost of leisure *ceteris paribus.* The implicit price of yield will be positive as utility is nondecreasing in consumption or income.

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 the quality improvements are denoted with higher scores. Three characteristics of post harvest transformation were evaluated: threshing, hand milling and head rice recovery. Four consumption traits: cooking aroma, color, cohesion, 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 consumption process would then consist of threshing, hand milling, cooking and then consuming the grain.

At the end of all evaluations, a close-ended questionnaire on the supply and purchase of local seeds was administered. This was followed by elicitation of the willingness to pay for seed of each of the tested varieties. This willingness to pay for seed is used as the dependent variable in the hedonic model. Summary statistics of the farmer evaluations of the varieties grown in the second season are presented in Table 2.

Table 2. Descriptive statistics of the variables

	Mean	Std. Deviation	Minimum	Maximum
Price (CFA/kg)	232	100.6	25	600
Production Characteristics				
Cycle length (days)	113	13.5	102	158
Height (cm)	102	22	41	274
Tillers (#/m)	152	58.8	15	387
Yield (kg/ha)	993	259.7	310	1618
Consumption Characteristics[1]				
Threshing	3.9	1.0	1	5
Milling	4.0	0.9	1	5
Head Rice Recovery	2.9	0.5	1	5
Color	2.7	0.8	1	5
Swelling	3.5	1.1	1	5
Aroma	3.6	1.0	1	5
Cohesion	2.9	0.7	1	4
Tenderness	3.3	0.9	1	5

n=256

[1]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.

5. Model Specification and Results

A quadratic algebraic functional form was specified for the hedonic pricing model. While several other functional forms, including linear, log-linear or Box-Cox transformations, have been used in hedonic models, the quadratic model allows for non-linear marginal utilities of traits. A non-nested combination of the ICM and CGCM– the household model– is specified as:

$$p_j = \alpha_0 + \sum_{i=1}^{4} \beta_i x_{ij} + \sum_{i=1}^{4} \beta_{ii} x_{ij}^2 + \sum_{k=1}^{8} \theta_k x_{kj} + \sum_{k=1}^{8} \theta_{kk} x_{kj}^2 + \sum_{l=1}^{63} \delta_l x_{lj} + v_j \qquad \textbf{(8)}$$

where p_j is the farmer's willingness to pay for seed, β, i=1..4 represents the estimated coefficients on the four production traits and the coefficients on the squared terms, θ, k=1...8 represents the estimated coefficients milling and consumption traits and the coefficients on the squared terms (both are described in Table 2) and l=1..63 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 six. The error term, v_j is normally distributed $v(0,\sigma)$. In addition to the household model, an ICM was estimated without consumption traits while a CGCM model did not include the production traits.

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 is 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. The F statistics on the production traits was 7.6 and 11.2 for the consumption traits. Both tests were significant at a 99% confidence level. In other words, both models contribute significantly to explaining variation in the dependent variable.

Parametric F- tests illustrate that ICM and CGCM do not encompass the mean effects of the household model. As stated in Mizon and Richard, a model that cannot encompass it 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. In addition, since both production and consumption traits are significant in the nested model, an underlying constraint links the decision in a nonseparable decision framework.

As a result, discussion of the parameter estimates will focus on those derived from the household model[3]. Several parameter estimates were significant in explaining willingness to pay for seed. Two production attributes–cycle length and plant height–and two consumption traits–swelling/elongation and tenderness–were significant explanatory variables in the household model. In addition, 59 of the 63 individual dummy variables were significantly different from zero. The F statistic, distributed with 59 and 172 degrees of freedom, of the null hypothesis of no individual-specific effects was 2.98 and rejected at the 99% confidence 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. In this region, farmers place strong importance on a plant that is approximately 1.1 meters in height in order to facilitate hand harvesting. Cycle length is also very important. The optimal cycle length is estimated at 108 days, more than one month shorter than locally available varieties. While the yield variable was not significantly different from zero, the cycle length reduction, given no yield effect, must also be viewed as a measure of increased productivity with respect to the length of the growing cycle.

Two consumption traits were found significant in the attribute pricing model: swelling and tenderness. Elongation and swelling are perceived as important factors relating the amount of rice

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[3]In addition to the model comparisons, the second-order terms of the quadratic were evaluated using a Wald test. The χ^2 distributed Wald statistic was 36.1 and significant at a p-value of 0.0003 indicating important curvature of the relationship between dependent and independent variables.

prepared and the amount that can effectively feed a household. A variety that "swells" is perceived as able to feed 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. Conclusions

This research has estimated a nonseparable household hedonic pricing model of upland rice attributes and tested it against more general contending models. To our knowledge, this is the first application which has combined both production traits, similar to those found in input characteristic models, and consumption traits, consistent with classic consumer goods characteristic models. Regression specification tests indicated that neither individual model encompassed the mean or variance effects of the other, thereby justifying an augmented model consistent with the household modeling literature.

Overall findings from this regression have important implications for 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. 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 two weeks before the optimal cycle length and were 20 cm lower than the optimal height. Overall, farmer willingness to pay for these released varieties was between 66% to 73% of the local varieties. The research approach has help to identify several new varieties that farmers find very valuable. Overall, 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.

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 an important 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 could lead to significant lost opportunities to increase producer and consumer surplus in agrarian economies.

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