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Variety characteristics and maize adoption in Honduras

L.H. Hintze^a, M. Renkow^{b,*}, G. Sain^c

^a *Inter-American Development Bank, Washington, DC, USA*

^b *Department of Agriculture and Resource Economics, North Carolina State University,
Raleigh, NC 27695-8109, USA*

^c *CIMMYT, San José, Costa Rica*

Abstract

This paper summarises research into factors contributing to low levels of adoption of improved maize varieties in Honduras. Empirical analysis was based on an agricultural household model which explicitly incorporates variety characteristics into the household's optimisation process. We considered a multitude of production and consumption characteristics valued by farmers, as well as an array of household socioeconomic characteristics and measures of village-specific marketing costs. Empirical results indicated that marketing costs and production characteristics are important explanators of variety choice, whereas consumption characteristics are not, and that information deficits may be an important limiting factor to adoption of improved varieties.

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1. Introduction

Maize is the main annual crop in Honduras, both in terms of its share of total cropped area and its role in direct human consumption. Approximately 25% of all arable land is planted to maize, and Hondurans' per capita maize consumption is among the highest in the world. Yet despite the potential yield gains from the adoption of improved maize varieties, and the fact that seed prices (of hybrids) are relatively low compared to other Latin American countries, the level of adoption of improved varieties of maize in Honduras is below 20%.

This paper summarises research into the factors contributing to these low levels of adoption of im-

proved maize varieties in Honduras. Our empirical work was based on an agricultural household model that explicitly incorporates variety characteristics into the household's optimisation process. We considered a multitude of production characteristics (e.g. yield, yield stability, duration and plant height) and consumption characteristics (including taste, storability and husk cover quality) that are valued by farmers, as well as an array of household socioeconomic characteristics and proxy measures of village-specific marketing costs.

We implemented our model using data collected in a survey of 167 farmers located across 34 villages in two distinctly different agro-ecological zones. In one of these zones, maize farming is highly commercialised, average farm sizes are comparatively large, and hybrids are planted by 60% of farmers. The other zone is dominated by near-subsistence farm households with smaller landholdings and much lower levels of adoption of improved varieties.

* Corresponding author. Tel.: +1-919-515-5179;

fax: +1-919-515-6268.

E-mail address: mitch_renkow@ncsu.edu (M. Renkow).

In the following section, we describe the analytical framework upon which our empirical analysis is based. Next we describe the two areas surveyed for the study and provide descriptive statistics on farmers' variety choices and seed management practices. Our empirical analyses of farmer preferences over different varietal characteristics and the determinants of varietal adoption are then presented. Some concluding remarks are found in the paper's final section.

2. Analytical framework

Our empirical analysis was motivated by an agricultural household model that generates testable hypotheses concerning the role of variety characteristics in determining farm households' varietal choice (Hintze, 2002). The model follows the tradition of the characteristics literature (Lancaster, 1966; Adesina and Zinnah, 1993; Bellon and Smale, 1998). It also draws on recent literature investigating links between market imperfections or transactions costs and households' participation in various markets (Omamo, 1998; Renkow et al., 2003). The model is general enough to be useful as a tool for studying different circumstances faced by farmers and different problems encountered in the context of variety adoption or variety choice studies (e.g. choice among multiple varieties, choice between modern and traditional varieties, allocation of land shares among more than one varieties, etc.). Here we are interested in the implications for variety choice.

We considered a household that gains utility through consumption of an array of maize characteristics (\mathbf{z}^c), as well as consumption of a composite market good (C_N) and leisure (L). The household does not acquire these characteristics directly; rather, they are contained in varying amounts by n different types (varieties) of maize grain. Let \mathbf{c} be the n -vector of varieties consumed. Each variety i is assumed to contain different quantities of m different characteristics (z_1, \dots, z_m). The combinations of characteristics provided by each variety are assumed to be non-stochastic and completely observable by households. Following Ladd and Suvannunt (1976), z_{ij} is defined as the amount of characteristic j possessed by a unit of variety i , and z_{0j} is denoted as the total amount of characteristic j consumed by the household. Household utility is defined

by the z_{0j} 's, which are, in turn, functions of the c_i 's:

$$U = U[z_{01}(\mathbf{c}), z_{02}(\mathbf{c}), \dots, z_{0m}(\mathbf{c}), C_N, L] \quad (1)$$

The household is assumed to allocate a fixed amount of land among n different varieties of maize plus one cash crop. We assumed constant non-stochastic yields per acre,¹ so that choices over the area planted to each variety are equivalent to choices over the quantity harvested. Implicit production functions, $G^i(\cdot)$, link output of each variety i (q_i) to a vector of inputs allocated to that variety (\mathbf{x}_i) and a vector of variety-specific production characteristics (\mathbf{z}_i^q):

$$G^i(q_i, \mathbf{x}_i; \mathbf{z}_i^q) = 0 \quad \forall i = 1, \dots, n \quad (2)$$

Maize produced by the household is either consumed or sold (and likewise, household consumption demands are met either through own production or market purchases). For each variety, total output is at least as great as the sum of consumption and net sales (m_i):

$$q_i - c_i - m_i \geq 0 \quad \forall i = 1, \dots, n \quad (3)$$

Finally, it is assumed that households face transactions costs (τ) when they participate in market transactions. These marketing costs encompass a wide variety of household-specific factors, including the cost of moving goods to or from the marketplace where exchange takes place, credit constraints, liquidity constraints, information gaps and other household-specific limitations on the ability to engage in market activities. For simplicity, we assumed that τ is identical for both sales and purchases (e.g. unit transportation costs to and from a central marketplace). The household's budget constraint is thus given by

$$P_C Q_C + wL + \sum_i \kappa_i^2 (p_i - \kappa_i \tau_i) m_i - p_x x - P_N C_N \geq 0 \quad (4)$$

where the κ_i 's take values of -1 , 1 , or 0 , depending on whether the household is a net purchaser, net seller or autarkic with respect to variety i .

The model is solved by maximising Eq. (1) subject to Eqs. (2)–(4). Two aspects of the model are noteworthy for their uniqueness. First, the marginal rate

¹ One could instead introduce risk into the model by assuming a known yield distribution for each variety. Alternatively, yield variability can be considered as an element of the vector of production characteristics, \mathbf{z}_i^q .

of substitution (transformation) between two varieties is a weighted sum of the marginal contribution of each variety to the total amount of each characteristic demanded (supplied). Second, these marginal rates of substitution and transformation are equated to *effective* prices (inclusive of marketing costs incurred). Taken together, these features of the model's solution imply that households might simultaneously plant multiple varieties if certain characteristics are unique to a particular variety and marketing costs are high enough to induce autarky. For this reason, in the empirical analysis that follows we will consider a multitude of production characteristics (e.g. yield, yield stability, duration and plant height) and consumption characteristics (including taste, storability and husk cover quality) that are valued by farmers, as well as various indicators of marketing costs. Moreover, because different varieties have different production requirements and respond differently to farmers' circumstances, those circumstances are taken into account as well.

3. The study area

The study was conducted in two of Honduras' 18 provinces (or *departamentos*): Olancho and Choluteca. These areas were selected to cover two different types of maize farming that are present throughout Honduras and the rest of Central America. In Olancho, most maize is cultivated on relatively productive land, chemical inputs and mechanical traction are widely used, maize yields are among the highest in the country, and farmers' maize output is principally orientated towards commercialisation. In Choluteca, smaller farms on marginal lands are more common, agriculture is more risky because of environmental characteristics (particularly drought proneness), and maize yields and marketed surplus levels are much lower than in Olancho.

A survey of the production practices and household socioeconomic characteristics of maize smallholders in these two areas was conducted during the summer of 2000.² Villages were purposively selected to rep-

resent the range of topographic and locational differences extant among Honduran smallholders. Households were then randomly selected within villages. In Olancho, 90 households (in 21 villages) were surveyed, and 77 households (in 13 villages) were surveyed in Choluteca.

Household heads were asked about growing practices, input use and output obtained regarding their maize crops planted in the *primera* and the *postrera* seasons of the 1999/2000 period. Cropping seasons follow the bimodal rain pattern observed in the study area. The *primera* (first) season usually starts in May–June. The *postrera* (second) season starts in August or September, depending on the region, the crop and the farming system. Information about planting decisions for the *primera* of 2000 was also gathered, as well as some retrospective information for the 1995/1996 cropping year. In Olancho and Choluteca, 93 and 74% of maize production occurs in the *primera* season, respectively.

The typical maize farmer in Olancho grows maize during the *primera* season and beans in the *postrera*. He may also raise livestock or grow coffee (at higher elevations), and may migrate for off-farm work, but his main activity and source of income is maize. The typical farmer in Choluteca, on the other hand, grows maize in both *primera* and *postrera* seasons, commonly intercropping maize with sorghum. In this province, off-farm work is more common and a more important source of income than it is in Olancho. In some areas of Choluteca, livestock and other minor crops are also important income sources.

In Olancho, the sample included locations ranging from villages in the valley areas next to the main paved highway to villages situated more than 2 hours away from the main paved road, where cropping land is located on the hillsides. Almost all of the villages visited in Olancho have regular access by dirt roads of varying conditions, ranging from very good to average. All dirt roads deteriorate during the rainy season, although many can still be used most of the time. There is a relatively good road network and bus service to most villages. In contrast, the road network in Choluteca is in much worse condition. Most of the roads to the Choluteca villages require four-wheel drive vehicles, even in the dry season.

² The largest amount of land under cultivation by any farm in the sample was 17.5 ha, and 75% of farms had less than 5.3 ha under cultivation (including other crops) and less than 3.5 ha of maize. There are some large farms in both areas, most of which are owned by absentee landlords.

Table 1
Number of farmers using different types of seed in Olancho and Choluteca, Honduras, 1999/2000

Seed type planted ^a	Olancho		Choluteca	
	No.	%	No.	%
Hybrids only	46	51.7	0	0.0
Recycled hybrids only	7	7.9	0	0.0
Improved OPVs only	32	36.0	7	9.1
TVs only	0	0.0	46	59.7
Hybrids and recycled hybrids	1	1.1	1	1.3
Hybrids and improved OPVs	3	3.4	0	0.0
Hybrids and TVs	0	0.0	2	2.6
OPVs and TVs	0	0.0	21	27.3
Total	89	100.0	77	100.0

^a OPV: open-pollinated variety; TV: traditional variety.

3.1. Use of hybrids, traditional varieties and open-pollinated varieties

Olancho and Choluteca are markedly different with respect to maize varieties planted. All Olancho farmers surveyed use modern improved varieties (MVs), either hybrids or improved OPVs, while in Choluteca, traditional varieties (TVs) are still planted by most farmers.³ Seed companies have worked aggressively in Olancho promoting their seed through demonstration plots and sales efforts. On the other hand, seed companies do not consider Choluteca an area in which a significant expansion of modern variety adoption could be achieved.

Table 1 presents a breakdown of farmers by the type of seed they used in 1999/2000. In Olancho, nearly two-thirds of farmers surveyed planted hybrids, and nearly all of these farmers planted hybrids exclusively (including 'recycled' hybrid seed).⁴ However, use of improved OPVs is still widespread in Olancho: nearly 40% of farmers surveyed planted improved OPVs (primarily the variety Guayape). When analysed by farm size, exclusive cultivation of hybrids was observed to be more common on larger farms in Olancho, whereas

exclusive cultivation of improved OPVs was generally confined to smaller farms (Hintze, 2002).

In Choluteca, use of hybrids is uncommon and TVs dominate maize production among farmers surveyed. Roughly 90% of all sample farmers planted TVs, either exclusively or in combination with improved OPVs. However, approximately 40% of farmers surveyed planted improved OPVs during the 1999/2000 cropping year. Many of these did so for the first time, primarily because they received the seed as relief aid following the Hurricane Mitch disaster.

4. Maize production and yields by variety

Table 2 provides data on maize area shares and yields by variety for the 1999/2000 cropping year. In Olancho, two brands of hybrids, Cargill and Cristiani, were the most common varieties planted. Yields reported for Cargill seeds (2.1 t/ha) were higher than yields for Cristiani seeds (1.7 t/ha).⁵ The third most important variety in terms of production and area share was Guayape, an improved OPV that has been very common in the area for the last 15–20 years. Contrary to expectations, reported yields from Guayape were higher than those for Cristiani. This was largely due to the fact that of the plots that suffered total crop failure due to drought, more than twice the area was planted to Cristiani seed than to Guayape seed.

Although the number of observations is small, yields for recycled Cristiani seed dropped by 17.7% compared with yields from new seed. Most recycled seed is second generation (i.e. first time reused). When asked about recycling seed practices, most farmers reported that the decrease in yield resulting from using third-generation recycled seed is so high that they prefer to obtain improved OPV seeds from members of the community if they cannot afford to purchase new hybrid seed.

In Choluteca, the great majority of plots were planted with the two TVs white and yellow *maicito*

³ Maize varieties were classified as hybrids, improved OPVs and TVs. Hybrids and improved OPVs have been developed by professional breeders. The term TVs is used here for varieties that have been used by local farmers for many generations. Through time, TVs may have mixed with some improved varieties.

⁴ Advanced generation or 'recycled' hybrid seed is hybrid seed that has been saved from previous harvests. A significant decrease in yields occurs from one generation to the next.

⁵ These yields were obtained by dividing aggregated production by aggregated area sown by seed variety. If zero production was recorded from a plot, the value was still added. Total crop failure in Olancho (due to inadequate rainfall) was reported for 6 (17.5 ha) out of 22 plots that used Cargill, versus 6 (18.9 ha) out of 42 for Cristiani. In the case of Guayape seed, 5 (10.5 ha) out of 43 plots reported total crop failure.

Table 2
Maize area shares and yields by variety in Olancho and Choluteca, Honduras, 1999/2000

Variety ^a	Olancho		Choluteca	
	Area share (%)	Yield (t/ha)	Area share (%)	Yield (t/ha)
Cargill (hybrid)	29.0	2.1	0.3	0.6
Cristiani (hybrid)	36.8	1.7	0.8	1.6
Guayape (OPV)	19.3	1.8	0.0	n.a.
HPB (OPV)	0.4	3.1	0.0	n.a.
White <i>maicito</i> (TV)	0.0	n.a.	62.3	0.6
Yellow <i>maicito</i> (TV)	0.0	n.a.	15.0	0.6
Non-identified improved	0.0	n.a.	20.5	0.7
Cargill recycled	1.3	3.5	0.0	n.a.
Cristiani recycled	6.3	1.4	0.5	1.5
Other OPV	0.7	0.6	0.0	n.a.
H5	5.7	1.5	0.0	n.a.
Another TV	0.5	0.7	0.5	2.4

^a OPV: open-pollinated variety; TV: traditional variety. The variety referred to as H5 by farmers is likely to also be one of Cristiani's lines (HS5G) obtained as post-Hurricane Mitch aid.

(literally 'little maize'). Both had similarly low observed average yields (0.6 t/ha). The area and number of plots devoted to the white variety was higher than those of the yellow variety. No large differences in yield between the two TVs appear to exist: reported beliefs about normal yields, as well as those for best possible and worst possible yields, were very similar.

5. Seed use and management

Farmers in the study area were observed to obtain their maize seed every year from a variety of sources using different acquisition methods, namely, buying it from commercial suppliers (mostly in Olancho), buying it or exchanging it from other farmers in their communities, or saving it from 1 year to the next (a common practice in Choluteca).

In Olancho, the main method of seed acquisition was purchase (45% of farmers), though a considerable number of farmers (27%) relied on seed saved from the previous harvest. Around 40% of farmers obtained seed from a store, usually in the capital of the *departamento*. A quarter of the farmers still obtain their seed from neighbours or relatives. When seed is obtained in the village it may be swapped (grain-exchanged) with

another farmer,⁶ or bought in cash at the prevailing price for maize grain.

In Choluteca, most farmers (64%) used seed saved from their own harvest; only 12% of farmers purchased seed. None of those who purchased seed did so from a store; rather, they bought it from neighbours or relatives at the prevailing grain price. During 1999, nearly one-quarter of farmers used donated OPVs that were distributed by the government (via non-governmental organisations) after Hurricane Mitch. Most of these farmers reported that this was their first experience of planting improved varieties. Post-Hurricane Mitch seed distribution programs are no longer operational, however, thus begging the question of whether or not use of improved OPVs will decline in the future.

6. Analysis of farmers' assessment of maize varieties and characteristics

Fifteen characteristics thought to be potentially important were identified during group discussions held prior to the formal survey.⁷ For each of the characteristics, farmers were asked to rate each variety using the following scale: (1) very good/good, (2) regular/average/sufficient and (3) bad. Using the ratings given by farmers, Kruskal–Wallis (KW) non-parametric tests were conducted to compare farmer assessments of individual varieties. These tests, the most appropriate for ordinal data of the kind used here (Conover, 1999), entailed a comparison of the sum of rankings obtained from pooling the ratings data of the different varieties. The null hypothesis for the KW test was that there is no difference in the rankings of varieties for a particular characteristic.

Separate analyses were conducted for Olancho and Choluteca. The results of these analyses are summarised in Table 3. Four conclusions can be drawn from the non-parametric tests and the data that under-

⁶ It is not uncommon for a farmer who believes that a neighbour's maize is genetically superior to his to ask the neighbour for some of the grain that the neighbour saved for seed from the previous harvest.

⁷ The questionnaire also enquired about which characteristics farmers consider to be more important; however, unsatisfying results were obtained from this line of questioning because farmers tended to say that *all* characteristics were very important.

Table 3
Rank mean scores per variety and non-parametric test results^a

Characteristic	Olancho		Choluteca	
	Preferred variety ^b	P-value	Preferred variety ^b	P-value
Yield	Hybrid (Cargill)	0.126	Improved OPV	0.048**
Early maturity	Hybrid (Cargill)	0.022**	TV (yellow)	<0.001***
Drought resistance	Hybrid (Cargill)	0.355	TV (yellow)	0.011**
Insect resistance	Hybrid (Cargill)	0.059*	TV (yellow)	0.118
Lodging resistance	Hybrid (Cargill)	<0.001***	Improved OPV	0.002***
Grain weight	Hybrid (Cargill)	0.025**	Improved OPV	0.096*
Taste	Hybrid (Cargill)	0.159	TV (yellow)	<0.001***
Tortilla quality	Hybrid (Cargill)	0.059*	TV (white)	0.004***
Storability	Hybrid (Cargill)	<0.001***	TV (yellow)	<0.001***
Fodder	Hybrid (Cargill)	0.064*	Improved OPV	0.226
Ease of shelling	Hybrid (Cargill)	0.195	TV (white)	<0.001***
Labour requirement	Improved OPV (Guayape)	0.153	TV (white)	0.037**
Non-labour input requirement	Improved OPV (Guayape)	0.218	TV (yellow)	0.061*
Guaranteed minimum yield	Hybrid (Cristiani)	0.039**	TV (yellow)	0.011**
Husk cover	Hybrid (Cristiani)	0.090*	TV (yellow)	0.151

^a These are KW test results comparing farmer rankings of three varieties for each characteristic. The null hypothesis is that there is no difference between variety rankings. For Olancho, varieties included two hybrids (Cargill and Cristiani) and one improved OPV (Guayape). For Choluteca, varieties included one improved OPV (Planta Baja) and two TVs (yellow and white *maicito*).

^b OPV: open-pollinated variety; TV: traditional variety.

* Significance at the 0.1 level.

** Significance at the 0.05 level.

*** Significance at the 0.01 level.

pin them. First, farmers perceive differences among varieties for some of the characteristics they consider to be important. Second, varieties that are widely used tend to be regarded as having good performance with respect to the most important characteristics. Third, for some of the characteristics evaluated, varieties that are used by the majority of farmers are outperformed by other varieties. In these cases, however, the ratings obtained by the more popular varieties indicate that they do not perform badly—just that they are not the best (Hintze, 2002). Finally, there are important differences in how farmers in Olancho and Choluteca perceive the different varieties available to them.

6.1. Olancho

In Olancho the results indicate that a number of statistically significant differences exist among varieties, but that no variety is superior for all characteristics. This implies that farmers face trade-offs and that they have to weigh up how much they value each charac-

teristic and each variety with respect to the characteristics considered valuable.

Overall, hybrids were perceived to outperform improved OPVs for all but two characteristics, and in those two cases, the differences among varieties were not significant.⁸ For nine of the characteristics, differences were significant at the 10% level or better, which could help to explain the widespread use of hybrids in Olancho. Among individual varieties, Cargill tended to dominate the other two for most characteristics.

In pre-survey focus groups, three characteristics were consistently identified by farmers as very important: yield, early maturity and drought resistance. For these three characteristics, the rankings data indicated that both hybrids tended to outperform the improved OPVs as measured by the mean ranks and the percentage of '1' ratings obtained. However, only for the

⁸ No distinction was made between first generation hybrids and recycled hybrids when collecting ratings data on each variety. It is not expected that this fact will affect the conclusions regarding variety characteristics, however, because the number of farmers in the sample who used recycled hybrids was relatively small.

early maturity characteristic did the KW test indicate a statistically significant difference among varieties.

Other production characteristics for which Cargill dominated the other varieties included insect resistance, grain weight and resistance to lodging. Cristiani was found to be statistically dominant with respect to quality of husk cover, an important trait in Olancho because maize is commonly left to dry in the fields after reaching maturity. Husk cover quality affects the extent to which maize is exposed to damage by insects and other animals during the drying period. Cristiani was also found to dominate the other varieties with respect to guaranteeing a minimum yield under less than ideal growing conditions.

In terms of consumption characteristics (taste and tortilla quality), the Cargill hybrid was individually ranked as the best among all the varieties. It is worth noting that though some farmers indicated that they preferred the improved OPVs for consumption, hybrids were still considered acceptable: none of the farmers thought that either of the hybrids were bad for tortilla preparation, and only 1 (out of 79) thought that they had a bad taste.

No statistically significant differences in labour or input (fertiliser, chemicals) requirements were observed between hybrids and improved OPVs, either as groups or individually. Farmers in the study area did not believe that hybrids require more effort or care than OPVs.

Finally, significant differences between varieties were found for two characteristics related to post-harvest management of maize, storage quality (storability) and fodder value. However, the general consensus reached in the farmer group discussions held prior to the formal survey was that neither of these characteristics are important determinants of planting decisions. All farmers now store their grain in metal silos, so post-harvest storage losses are no longer a significant concern. Likewise, fodder production is also of relatively little concern because most cattle are either grain fed or left to graze on dedicated fallow land.

6.2. Choluteca

In Choluteca, the statistical tests indicate a larger number of characteristics for which significant differences exist among farmers' rankings of varieties than

is the case in Olancho. The results suggest that TVs outperform MVs for most characteristics, yield being an important exception. These perceptions may help to explain why traditional varieties are still widely used in Choluteca.

Farmers in the area typically did not know whether a variety was an improved OPV or a hybrid (or if there is any difference between them). They usually only differentiated between *maicito* and *maizón* (literally, 'big maize'—a term used to refer to any improved or commercial variety). Most could not identify modern varieties by their commercial names, either. In contrast, farmers clearly differentiated between the characteristics of white and yellow *maicito*.

Among production characteristics, improved OPVs were rated as significantly better than TVs for yield, lodging resistance and grain weight. On the other hand, one or the other of the traditional varieties was rated significantly better in terms of attributes associated with hardiness and risk reduction, i.e. drought resistance, early maturity, input requirements, storability and guaranteed minimum yield under less than ideal growing conditions.

With respect to consumption characteristics—taste, tortilla quality and ease of shelling—farmers in Choluteca exhibited a clear preference for TVs over improved OPVs. However, it is worth noting that no respondent rated improved OPVs as having bad consumption quality. A substantial number of Choluteca farmers are used to consuming maize that they have purchased in the market, most of which is improved material grown in other parts of the country. Thus, while farmers may prefer to consume TVs, they are used to consuming non-TV maize as well.

7. Determinants of varietal choice

The results of the preceding analysis indicate that farmers perceive differences among varieties for some of the characteristics they consider to be important, that no single variety dominates the others for all characteristics, and that there are important differences in how farmers in Olancho and Choluteca perceive the different varieties available to them. As such, ascertaining which specific characteristics are primary drivers of farmers' varietal choice decisions in each region is an empirical question.

In order to assess the impact of variety characteristics on varietal choice, separate binary logit models were estimated for Olancho and Choluteca.⁹ For this analysis, farmers were classified as ‘adopters’ (dependent variable = 1) if they planted the highest yielding varieties (HYVs) available in their region and ‘non-adopters’ (dependent variable = 0) otherwise. In Olancho, the two hybrids (Cargill and Cristiani) were classified as HYVs, and the improved OPV Guayape was classified as the lower yielding variety (LYV). In Choluteca, the improved OPV (Planta Baja) was classified as the HYV and the two traditional varieties (yellow and white *maicito*) were classified as LYVs.

A dummy variable for each characteristic was created. The dummy took a value of 1 if the HYV is rated by the farmers to be better than any other variety in the farmers’ choice set, and 0 otherwise. Aggregating the available information in this way had the unfortunate (but unavoidable) side effect of inducing high correlation between the characteristics dummies. Because of this, only a subset of varietal characteristics variables could be included as explanatory variables in either regression equation.

In addition to the variables indicating individual assessments of varietal characteristics, other explanatory variables were included based on the theoretical model discussed earlier. Cropped area was included to account for possible scale effects on varietal choice. Cropped area may also serve as a proxy for household wealth, thereby entering the decision-making process through effects on consumption demand. Family size was included to account for household characteristics that might affect demand for varieties for which market imperfections exist. To the extent that market imperfections exist in agricultural labour markets, family size might also affect varietal choice via household labour supply decisions. In Choluteca, an additional dummy variable was included that took a value of 1

if households received free improved OPV seed in the aftermath of Hurricane Mitch, and 0 otherwise.

Two variables were used as indicators of marketing costs (τ in our model): distance to the nearest market centre and a road quality index. The index was based on the type of roads connecting households with the nearest market centre, as well as the state of maintenance of those roads (see Hintze (2002) for details). It took values ranging from 1 (best) to 5 (worst).

Table 4 presents the empirical results. For both areas the model fits the data well, as indicated by the proportion of correctly predicted observations, by the computed values of the pseudo- R^2 , and by the fact that the parameter estimates are generally of the expected sign.¹⁰ As noted earlier, multi-collinearity problems induced by the creation of the characteristics dummies precluded the inclusion of all characteristics variables. Consequently, we experimented with multiple combinations of variables; the results presented in Table 4 are representative of the outcomes of these experiments.

For Olancho, two production characteristics—yield advantage and early maturity—consistently emerged as having a significant positive impact on hybrid maize adoption (as well as the largest marginal effects of any of the explanatory variables). Consumption characteristics, such as tortilla quality, taste or storability, were in no case significantly related to adoption (either individually or jointly). One of the marketing cost variables (road quality) was found to have a significant effect on hybrid maize adoption, while the other (distance) did not. Farm size, although having the expected positive sign, was not significant in the estimation results presented in Table 4.¹¹

¹⁰ The pseudo- R^2 is computed as $1 - (\ln L / \ln L_0)$, where $\ln L$ is the maximised value of the log-likelihood function and $\ln L_0$ is the log-likelihood computed using only the constant term (Greene, 2000, p. 831).

¹¹ The farm size variable, however, is significant in other specifications of the model (Hintze, 2002). Additionally, membership in a production organisation was also tested as an explanatory variable, under the assumption that such organisations may help to reduce the costs for individual farmers of obtaining information about new varieties and marketing opportunities. A high level of individual statistical association between this variable and adoption was observed; however, because it perfectly predicted the dependent variable for adopting households, its inclusion rendered the binary logit adoption model inestimable.

⁹ Ideally, we would like to have estimated conditional logit models that examined preferences over all three of the varieties available to farmers in each location. Unfortunately, this was not feasible because of the large number of farmers who gave assessments of the characteristics of only one variety. This is problematic in the context of conditional logit estimation because the model implicitly assumes that farmers who assess only one variety have no options other than to plant that variety (i.e. that there are no alternatives), hence biasing the estimates.

Table 4
Binary logit estimates of adoption of higher-yielding maize varieties^a in Honduras, 1999/2000

Variable	Olancho ^b			Choluteca ^b		
	Parameter	P-value	Marginal effect ^c	Parameter	P-value	Marginal effect ^c
Constant	4.365	0.105	0.379	-1.361	0.540	-0.128
Cropped area	0.320	0.128	0.026	1.298*	0.025	0.122
Family size	-0.187	0.311	0.016	-0.367*	0.090	-0.035
Hurricane Mitch aid	-	-	-	3.963***	0.001	0.373
Marketing cost variables						
Road quality index ^d	-1.802**	0.044	-0.150	-0.884*	0.059	-0.083
Distance to nearest market	-0.060	0.222	-0.005	-0.007	0.900	-0.001
Characteristics variables						
Yield	3.063**	0.047	0.255	1.614*	0.065	0.152
Early maturity	1.561*	0.070	0.130	-0.549	0.588	-0.051
Taste	1.374	0.235	0.027	-	-	-
Tortilla quality	-	-	-	0.591	0.627	0.056

^a Higher-yielding varieties are Cargill and Cristiani hybrids in Olancho and the improved open-pollinated variety Planta Baja in Choluteca.

^b For Olancho, *N*-value, log-likelihood, pseudo-*R*² and percentage predicted correctly are 66, -17.93, 0.591 and 86, respectively, and for Choluteca these values are 72, -21.71, 0.532 and 89, respectively.

^c Average of the marginal effects calculated at each of the sample observations.

^d The road quality index ranges from 1 (best) to 5 (worst).

* Significance at the 0.1 level.

** Significance at the 0.05 level.

*** Significance at the 0.01 level.

For Choluteca, yield emerges as the only characteristics variable having a consistently significant impact on adoption of improved OPVs over traditional varieties. No evidence was found to suggest that a statistically significant relationship exists between HYV adoption and any other production or consumption characteristics condition. As in Olancho, the coefficient on the road quality variable was significant and of the expected sign, while distance was not significantly related to varietal choice. It is interesting that in both Choluteca and Olancho it appears that road quality significantly increases the probability of planting HYVs over LYVs, but that distance to the closest input market—the variable of choice in most empirical studies (e.g. Goetz, 1992)—is not a significant explainer of varietal choice.

The most striking empirical result for Choluteca is that the variable with the largest marginal effect on the probability of planting MVs is whether or not the farmer received free improved seed as post-Hurricane Mitch relief aid. The predicted probabilities of planting improved OPVs for farmers who did not receive seed was only 2%, while for those who actually re-

ceived the seed, the estimated probability was 50%.¹² This is not surprising, given that before the disaster the vast majority of farmers used only traditional varieties, and most farmers declared having used improved seed varieties for the first time after the disaster. Nonetheless, the result highlights the possibility that inadequacies in extension and other 'normal' channels for the transmission of information about improved seed varieties may represent an important limiting factor to adoption in the area.¹³

¹² These probabilities were calculated at the mean value of the continuous variables (cropped area, family size, road quality and distance to markets) and at values of 0 for the dummy characteristics variables (the modal value).

¹³ An alternative explanation, that after Hurricane Mitch farmers had no choice but to use whatever seed they could obtain, is difficult to evaluate without additional information about farmers' seed use in the following seasons. Certainly, it is difficult to discount this possibility out of hand for all farmers. However, anecdotal evidence collected by the authors suggests that a substantial number of farmers who received free seed decided not to use it, while other Choluteca farmers were able to purchase seed (both improved varieties and TVs) in the post-Mitch period, indicating that seed was not unavailable to all farmers.

Three general conclusions emerge from these empirical results. First, findings with regard to characteristics would appear to validate the traditional orientation of breeding programs around production characteristics (as opposed to consumption characteristics). Yield potential emerges as the production characteristic of most importance to varietal choice in both areas. Second, the fact that road quality is significantly associated with the planting of HYVs suggests that public investments in transportation infrastructure represent a potentially important stimulus to enhancing agricultural productivity sector via MV adoption. Third, the significance of the post-Hurricane Mitch aid variable in Choluteca highlights the possibility that low MV adoption rates in that region may be linked to some combination of information deficits and non-availability of improved seeds prior to Hurricane Mitch.

8. Concluding remarks

In this paper we investigated the factors contributing to the low levels of adoption of improved maize varieties in Honduras. One distinguishing feature of our work is that we considered a multitude of production and consumption characteristics that are valued by farmers, as well as an array of household socioeconomic characteristics and proxy measures of village-specific marketing costs.

Non-parametric tests indicated that farmers do indeed perceive significant differences among varieties, and that the specific characteristics most highly regarded by farmers vary across regions. In general, improved varieties dominate in terms of production characteristics in both production zones, but are regarded as inferior with regard to consumption characteristics in the near-subsistence regions. Zone-specific adoption equations confirm that, in both areas, production characteristics are significant explanators of variety choice, but also indicate that consumption characteristics do not have a significant impact on varietal choice in either location. These results have implications for agricultural research managers in terms of emphasis of breeding activities. One proxy for marketing costs—road quality—was consistently found to have a significant positive impact on the adoption of improved varieties in both areas. A ques-

tion arises here as to whether the negative relationship between road quality and adoption of the highest yielding variety available is due to difficulties in accessing inputs or to high costs of marketing output (or both). This is a fertile topic for future research. At the minimum, though, this finding suggests that investments in road infrastructure represent a potentially important means of stimulating agricultural productivity via MV adoption.

Finally, perhaps the most striking result from the near-subsistence area (Choluteca) is that the dominant element conditioning adoption of improved varieties appears to have been whether or not farmers received free seed in the aftermath of Hurricane Mitch. This result suggests that information deficits and/or non-availability of seed may be an important limiting factor to adoption of MVs there. Ameliorating deficits of this sort often falls to the public sector, particularly for relatively less-productive agricultural regions like Choluteca. However, given the declining role of the public sector in Honduras' seed distribution and extension systems, it is difficult to imagine that these deficits—and hence low levels of MV adoption in such low-productivity areas—are likely to be reversed in the foreseeable future.

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