Variety Characteristics and the Land Allocation Decisions of Farmers in a Center of Maize Diversity

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Introduction

Farmers and plant breeders use genetic diversity to adapt crops to heterogeneous and changing production environments. With increased global commitment to germplasm conservation, there is a growing interest in the prospects for enhancing farmers' management of genetic resources as a complementary strategy to their conservation *ex-situ*. Varieties cultivated by farmers continue to evolve genetically, retaining their adaptive potential for future changes in the environment in which they are grown; those conserved *ex situ* are, literally, "frozen" at the time of their collection.

Farmers themselves decide whether the crop populations they grow are retained or discarded. Do they have an incentive to continue growing varieties identified as key genetic resources? What is the relationship between the choices made by individual farmers and crop diversity at the community level? To investigate these issues, we use an approach that combines a characteristics model with the notion of impure public goods. We express a farmer's effective demand for a variety as the share of the crop's area he allocates to it, determined by variety-specific, household-specific and exogenous agroecological and socioeconomic factors.

Although our application is similar to the characteristics models of varietal choice estimated by Adesina and Zinnah (1993) and Barkley and Porter (1996), we include a public characteristic of varieties--their genetic diversity. The approach is also related in its motivation to that developed by Meng (1997), but differs in its use of the theory of impure public goods and the nature of the crop populations.

The data set combines household survey data with morphological characteristics of seed samples drawn from farmers' varieties, as well as secondary data on agroecology and infrastructure in the southeast region of the State of Guanajuato, Mexico. Mexico is one of the centers of domestication and diversity for maize. The southeast segment of Guanajuato is located at the fringes of one of the most commercialized agricultural regions of Mexico, the Bajio.

Conceptual Approach

To conceptualize the problem of farmer incentives to continue growing a variety or number of varieties as a land allocation decision, we draw on aspects of characteristics models (Lancaster, 1966; Ladd and Suvannunt, 1976) and on the theory of impure public goods (Cornes and Sandler, 1986). Characteristics models postulate that farmers or farm households maximize the utility from the multiple attributes of the crop produced by their choice of varieties, rather than the varieties themselves or only a single trait, such as grain output or yield. Farmers choose varieties based on the bundle of observable characteristics that each variety embodies and produces.

Seed is unique as a commodity in that it has characteristics that are private as well as those that are public (Morris et al. 1998). The public characteristics of the seed are those related to its genetic attributes, including its contribution to genetic diversity. In our approach, each choice of seed amount and variety combination jointly produces or "yields" characteristics of private value to the farmer (grain or fodder yield, processing quality) as well as a characteristic of public interest—a contribution to the diversity of genetic resources in the reference area.

We can view the choice as a model of decision-making in farm household, using maize farming in the study region as an example. In each season, the household chooses a set of n seed lots for varieties ($\mathbf{x}$) to combine with non-seed inputs (represented by an index Y) that maximizes the expected utility from a set of consumption attributes ($\mathbf{q}$). The household also chooses the amount it will consume ($\mathbf{Q}$) from the maize outputs ($\mathbf{X}$) produced by the inputs:

(1) $\underset{\mathbf{x,Q}}{\text{Max}}\ EU(\mathbf{q}|\boldsymbol{\Omega},Z)$

The set of parameters $\boldsymbol{\Omega}$ represents socioeconomic, agroecological, and other exogenous factors which condition-farmers decisions.

Consumption characteristics $\mathbf{q} = (q_{.1},\ldots q_{.j})$ may include ease of hand processing, suitability for particular dishes, or other attributes related to home consumption. The $q_{.j}$ are the total quantities of the *j*th characteristic of maize output, and q_{ij} is the quantity of the *j*th output characteristic produced by one unit of the *i*th of *n* maize types. Farm households may sell or buy any or all of the maize varieties, so that (**X-Q**) is negative for a net consumer of maize and positive for those selling more than they consume, at prices **p**.

The household faces the constraint that its expenditure on seed at prices or costs **w** and on non-seed inputs cannot exceed its exogenous income *I* (such as income from off-farm labor, other crops or migration that is earned before planting) and its expected returns from sales of its maize varieties:

(2) $Y + \mathbf{w'x} = I + \mathbf{p'(X-Q)}$.

The decision of the farm household is also constrained by the

technology for jointly-produced varieties

(3) $F(\mathbf{X}, z_h | \mathbf{x}, \mathbf{r}, Y) = 0$.

X is a vector of maize outputs for the *i* varieties grown, which is in turn a function of their production characteristics $\mathbf{r} = (\rho_{.1},\ldots \rho_{.k})$ the amount of seed planted, and non-seed inputs. Production characteristics include tolerance of abiotic and biotic stresses, and performance on a specific soil type.

A seed lot is the physical unit of grain that is planted, and the household may obtain it from its own crop, other farmers, or the formal seed system (Louette 1994). Choice of any set **x** generates not only maize outputs (**X**), but the farm household's individual contribution (z_h) to a public good, genetic diversity in the community or region (Z). If genetic diversity is defined over characteristics that are not observed by farmers (such as allele frequencies), the household's individual contribution to diversity may not be observable and we would not expect the utility function to be defined over z_h. Utility may be defined over Z when genetic diversity is observable as morphological variation, however. Z could then be interpreted as the supply of distinct characteristics in the farmers' community.

The diversity in the maize grown by a farmer can be expressed as

(4) $$z_h = z_h(\mathbf{x}, \theta, \beta) ,$$

where θ and β are parameters related to seed flows and seed management practices. Further, since "diversity" is a public characteristic, it is affected by the decisions of all farmers in the region of reference:

(5) $$Z = Z(z_1, ...z_h, ...z_m)$$ for all farmers h=1,.......m.

One analytical result of this type of model is that farmers as a group may choose seed amounts and variety combinations that are less or more than socially optimal, because they do not take into account the interaction of their choices with the choices of other farmers. Whether the public good to which farmers contribute is observable to farmers and affects their decisions is also a testable hypothesis.

Farmer demand for a variety is determined by the level of the characteristics it embodies and those of other close substitutes, the importance of the characteristic in the goals of the farm household, real prices and costs of production (**P, w,** *Y*), the exogenous factors **Ω** which condition their production choices, and the importance to the farmer of the diversity or supply of distinctive traits in the locality (alternatively, "what everybody else does", or *Z*),:

$$(6) \qquad x_i = x_i(\mathbf{P}, \mathbf{w}, Y, I; \mathbf{q}, \mathbf{r} | \boldsymbol{\Omega}, Z).$$

Estimation of the model provides information about the incentives related to farmer management of maize diversity, including information about the technical incentives that can be provided by breeding interventions (**q,r**), as well as the potential effects of policies that influence the conditions under which farmers operate (**Ω**). Similarly, estimation of equation (4) may inform us about how technical interventions in seed flows, seed selection and management practices may affect the crop's genetic diversity. The coefficient on *Z* in equation (6) tests the nature of the association between the choices of individual farmers and the public good, diversity in the farmer's community. Finally, estimation of equation (6) allows us to conduct statistical tests about whether variety-specific characteristics, household-specific characteristics, or characteristics related to the socioeconomic and agroecological environment are separately or jointly most likely to explain land allocation to varieties.

Empirical estimation

We have redefined the dependent variable in (6) as an area share to control for the effects of farm size. As we have estimated it, (6) depicts the average area share that farmers allocate to any given variety, representing the farm-level demand for any one of a set of varieties. Most of the varieties grown by survey farmers are traditional or advanced-generation improved varieties. The demand is constrained by the exogenous agroecological and socioeconomic parameters **Ω.** The subscript *i* indexes the number of varieties grown by each household *h*. In addition to the demand, the dependent variable provides indirect inferences concerning the number of varieties grown. The lower the area share, the greater the number of varieties grown by a household.

The dependent variable in (4) was estimated as a household-level Simpson index based on varieties as recognized by farmers. A third equation, depicting the effects of the seed management parameters on the level of morphological diversity at the community level, was estimated using as the dependent variable the Simpson index based on morphological classes (procedure developed by Franco et al. 1997). The predicted value of the dependent variable *Z* was then used to test the importance of the public good in farmer decision-making—in other words, whether the supply of morphological diversity or traits at the community level is associated significantly with the area allocation decisions of farmers.

For each of the equations, variables and their definitions are shown in Table 1. The sampling methodology is described in detail in the data source, Aguirre (1997).

Regression results

Regressions results for the variety choice equation are shown in Table 5. T-tests demonstrate the relevance of several of the individual agroecological parameters, varietal characteristics and household characteristics in the decision to allocate land among maize varieties. As predicted, farm households in the market-integrated zone tend to allocate more land to each variety, growing fewer. Of the household characteristics, a greater number of soil types per farm is significantly related to area share, resulting in a higher number of maize varieties on the farm.

Among varietal characteristics, those of statistical significance are related to the family's consumption of maize, rather than to the suitability of the variety for market sale or its cheapness to produce. The average area share of varieties whose most important use is for producing the staple food (*tortillas*) is nearly 0.30 percentage points higher than that of other varieties. A variety whose most important use is for the preparation of a special dish tends to occupy significantly less of the farm's maize area, since its is consumed less frequently. Most of these households both produce and consume the grain, feed, or fodder from the maize they produce. While suitability for market sales and cost of production are varietal characteristics they cited as important, criteria related to food consumption assume principal importance in explaining area allocation among varieties.

The F-value for the equation indicates that the three "scales" of factors, each relating to different types of policies, are jointly significant. When tested at the five percent level of significance, however, the null hypotheses that each set of coefficients for (1) agroecological parameters and (2) household characteristics are jointly equal to zero cannot be rejected. In other words, among survey households, variety characteristics are jointly of overriding importance in determining the area shares of maize varieties.

This result is interesting, for several reasons. First, as has been argued by Adesina and Zinnah (1993), adoption studies may have focused on household characteristics while excluding the dimension of variety characteristics. Most of the varieties considered in this study are traditional varieties, but the results of the F-tests are consistent with those of Adesina and Zinnah (1993) and underscore the need to test similar hypotheses elsewhere. In addition, the hypothesis should be tested for both the probability of adoption and the extent of adoption or land allocation decision, since these are related but distinct decisions. Second, the hypothesis tests have policy implications. Variety characteristics, unlike household characteristics and essential agroecological parameters, are amenable to plant breeding and technical interventions. Third, a finding of this type may assist in the development of policy incentives for on-farm conservation among similar communities. In these communities of southeast Guanajuato, the cultural importance of food and culinary practices remains key in explaining how farmers allocate their maize area and therefore, the varietal diversity they maintain on-farm.

Test results for the relationship between the public good *Z* and varietal choice are also shown in Table 5. When there is a greater supply of distinct traits or greater morphological diversity in a community, its farmers also grow more varieties. Farmers who are aware of the loss of genetic resources in their community grow more varieties. These interactions suggest that the actual or perceived diversity of the maize populations around them may play a role in the variety choice decisions of survey farmers.

Diversity at the farm and community levels

Regression results for the household- and community-level diversity equations are shown in Table 6. As consistent with our hypothesis and Table 5, farm households located in more market-integrated zones have a lower level of area-weighted varietal diversity. Contrary to predictions, the null hypothesis that households in the more favored of the two agroecological zones have greater diversity cannot be rejected. The number of varieties is positively associated with the household level diversity index. Farmers who typically save their seed from year-to-year also have a higher level of diversity on their farms than those who do not, presumably because they are seeking to maintain their varieties as they know them.

A comparison between the two regressions reveals points of contrast. While market integration is negatively associated with diversity at the household level, the null hypothesis that communities in the marketed-integrated zone have higher morphological diversity in their maize populations cannot be rejected. A higher average number of varieties grown on farms is associated with higher levels of morphological diversity in the community. The frequency of farmers attempting to modify their varieties through exchange and introductions of seed lots is negatively related to morphological diversity in the community. This finding is consistent with the idea that when "modifying" their varieties through mixing or combining seed, farmers are attempting to "pack" traits from more than one variety into one, blurring the morphological distinctions among them.

Conclusions and Implications

Econometric results confirm that in these communities of southeast Guanajuato, Mexico, the area share a farm household allocates to a maize variety, or the farm-level demand for that variety, is jointly affected by all three "scales" of parameters. Of overwhelming significance in that decision, however, are the set of factors related to varietal characteristics. In particular, the quality of *tortillas* and special dishes which a variety is used to produce. matters to these households, even though they are located on the fringe of one of the most commercialized agricultural zones in Mexico. The policy implications of these findings are that in general, breeding interventions may have a role to play in on-farm conservation, given the strong demand response of farmers to variety characteristics. The importance of homemade *tortillas* and other special dishes attests to the sustaining power of culture in these communities, despite the economic changes they confront and social changes they assimilate.

Market integration increases area shares allocated by farmers to any given variety and reduces varietal diversity at the farm level, although it may not decrease morphological diversity at the community level. The relationship between market integration and genetic diversity measured at different "scales" merits further research.

The regressions confirm that there is a positive relationship between the underlying morphological diversity of the maize populations in a community, the perceptions of farmers of that diversity, and the number of varieties maintained by its farmers. The negative association revealed between morphological diversity at the community level and the area shares of varieties at the household level suggests that introducing new and genetically distinct materials, whether they are improved or traditional, may increase the number of varieties grown by individual farmers. The relationship between farmers' perceptions of maize diversity in their community and their area share decisions indicates that in communities such as these, education and awareness campaigns may provide valuable support to on-farm conservation.

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Table 1. Definition of variables in regression equations

Variety choice equation	**Definition**
Dependent variable	
α	proportion of household maize area planted to farmer-named variety
Agroecological and marketing parameters	
agrozone	1=140 days growing period; 0=80 days
markzone	1=market integrated; 0=market isolated
Variety characteristics[1]	
p	most important for sale in market=1; 0 otherwise
tortillas	most important for *tortillas*=1; 0 otherwise
c	most important for low cost in purchased inputs and/or management=1, 0 otherwise
culinary	most important for preparation of a special dish =1; 0 otherwise
security	most important for production security =1, 0 otherwise
feed/forage	most important for livestock feed or forage=1, 0 otherwise
Household characteristics	
head of household	female-headed equals 1; 0 otherwise
size of household	number of people residing in household in 1995-6
cash income	household head contributed cash to farm in 1994
percent sales	percent of maize output sold in 1994
irrigated	farm has irrigated land=1, 0 otherwise
rainfed	farm has rainfed land=1, 0 otherwise
soils	number of soil types on-farm
Aggregate diversity	
lostcon	1=farmer has observed loss of varieties in the community *and* grows a seed type only to conserve it
Zpred	predicted value from community-level diversity equation
Household-level diversity equation	**Definition**
Dependent variable	
z	Simpson index[1] of farmer varieties for household
Variety and seed management	
variety choice	number of farmer varieties per household
	number of farmer varieties per community
save seed	usual practice save seed=1, 0 otherwise
modify seed[2]	usual practice modify seed=1, 0 otherwise
replace seed	usual practice replace seed=1, 0 otherwise
Community-level diversity equation	
Dependent variable	
Z	Simpson index[1] of morphological classes for community
Variety and seed management	
variety choice	average number of farmer varieties per household
	number of farmer varieties per community
save seed	proportion of farmers whose usual practice is to save seed
modify seed	proportion of farmers whose usual practice is to renew seed
replace seed	proportion of farmers whose usual practice is to replace seed

[1] Simpson index = $1-\sum_i (\alpha_i)^2$ where α is the area share in variety or class i

[2] To modify seed means that the farmer deliberately introduces or mixes seed lots for the same variety

Table 5. Estimated variety choice equation[1]

Explanatory variable	Coeff.	S.E.	Coeff.	S.E.
constant	.683+	.180	.516+	.155
agroecological zone	.0157	.0467	.0156	.0466
market integration	.128*	.0545	.0878*	.0562
p	.118	.127	.982	.127
tortillas	.295+	.115	.276+	.114
c	.116	.118	.0912	.116
culinary	-.285+	.114	-.293+	.114
security	-.0958	.122	-.0828	.122
feed/forage	.0989	.162	.0623	.160
head of household	-.0385	.0964	-.00739	.0992
size of household	-.00506	.00428	.00371	.00419
irrigated	.0419	.0681	.0522	.0682
rainfed	-.01875	.0510	-.00408	.0515
soils	-.0224*	.0137	-.0232*	.0137
percent sales	-.000189	.000514	-.000385	.000505
cash income	.0608	.0414	.0407	.0424
Zpred	-.453++	.250		
lost/conserve			-.0901+	.0431
R^2		44		44
F (16, 302)		14.96		15.08
n		319		319

[1] dependent variable is area share planted by household to each farmer-named variety

* significant at .05 with one-tailed t-test

\+ significant at .05 with two-tailed t-test ++ significant at .10 with two-tailed t-test

Table 6. Estimated household- and community-level diversity equations[1]

Explanatory variable	Coeff.	S.E.	Coeff.	S.E.
	household		community	
constant	.0982	.0124	.233	.358
agrozone	.136	.0326	-.0347	.0618
markzone	-.0892*	.0377	.143	.0666
no. varieties/household	.0374*	.0167	.159+	.0732
no. varieties/community			.0365++	.0191
save seed	.109+	.0478	.111	.176
modify seed	.0582	.0511	-.259++	.157
replace seed	.0476	.0441	.0898	.103
R^2		20		22
F (6,135); F(7,13)		6.75		.76
n		141		21

[1] dependent variable for household-level equation is Simpson index based on farmer-named varieties; for community-level equation, Simpson index is based on morphological classes (see Table 1 and text)

* significance of .05 with one-tailed t-test

\+ significance of .05 with two-tailed t-test ++ significance of .10 with two-tailed t-test