A Unified Approach to the Estimation of Demand for Improved Seed in Developing Agriculture[§]

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Abstract

This paper proposes a new approach for estimating the demand for seed within a developing country context where only improved seeds are sold but adoption rates for improved varieties low. A farmer views an improved seed firstly as a derived input embodying production attributes and secondly, as a technology embodying consumption characteristics. He therefore jointly decides on its adoption and the quantity of seed required to plant a predetermined area. Drawing on the theory of demand for consumption goods characteristics and production input attributes, this paper specified and estimated non-separable household demand and consumption models using data collected from 300 farm households in Zambia during the 2003/04 crop season. The estimated results suggest that adoption rate, distance to market, level of household grain self-sufficiency, seed hand-outs and household wealth are significant in determining farmers' seed purchase decisions. Appropriate intervention strategies for increased over-all improved seed demand are recommended. It is concluded that apart from contributing to the literature on modelling farm level seed demand, the model provides a holistic approach for the joint estimation of determinants of improved variety adoption and seed demand relevant for better targeting to increase the impacts of maize breeding research in developing countries.

JEL Classification: C21, D1, O3, Q12, Q16

Keywords: agricultural household model, consumer goods characteristics, production inputs, technology attributes, non-separability, censored equations, Zambia

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Introduction

This paper proposes a new approach for estimating the demand for improved seed within a developing country context where nearly all seeds sold on the market are improved but adoption rates for improved varieties are low. The contribution of technological change to agricultural productivity in developing countries documented by Arndt, et al. (1977) is well known. Though fundamental to rural transformation, seed technological change sometimes by-passes some rural populations. It is by now widely acknowledged that the extensive growth in Asia's green revolution created welfare effects beyond the adopting farmers (Rosegrant and Hazell, 2000; Renkow, 2000). Nonetheless large numbers of rural households across Asia for whom targeting strategies were inappropriate or less effective remain food insecure. In developing countries where seed technology has made less dramatic changes in agricultural productivity, incidence of rural poverty and food insecurity is pervasive. If improved seed technology, which embodies genetic expressions for increased productivity is to make a mark on the poverty of farm households in such deprived areas, researchers must develop appropriate seed demand models that reflect farmers' decision making circumstances to facilitate individual or group targeting of interventions for increased improved seed uptake.

An improved is viewed by the farmer firstly, as a derived input for grain production and secondly, as a technology as it embodies genetic expression of the plant unfamiliar to the farmer. When a farmer decides to adopt an improved variety, he/she jointly decides on how much improved seed would be required to plant a predetermined area. Yet theoretical models and econometric methods in the past on seed demand and technology adoption have tended to assume separability between household production and consumption decisions (Feder, et al, 1985; Feder and Umali, 1993). The underlying principle of maximization of expected utility of profits under risk and uncertainty for such models is consistent with commercially oriented farm decisions in competitive markets but inappropriate in analysing subsistence agriculture with largely imperfect markets (Hiebert, 1974; Smale, et al, 1994).

Using data collected from 300 farm households in Zambia (in southern Africa), the paper demonstrates that specifying seed demand and improved variety adoption simultaneously better explained farm level maize seed demand decisions by households compared with an ordinary least squares (OLS) specification. Apart from contributing to the methodological approaches needed for estimating farm level seed demand in developing agriculture where missing markets are common, the approach affords the estimation of credible results that are important to seed sector stakeholders interested in promoting seed market development.

Conceptual framework

The household is assumed to derive utility from the set of intrinsic attributes of the food goods it consumes, the consumption of other goods, and leisure (Lancaster 1966a, b; Ladd and Suvannunt, 1976). On the basis of this theory, a household model is specified to explicitly incorporate variety attributes and used to derive seed demand equations. Let the household utility function U be defined as:

$$U[X^{g}(F, a^{c}), Z^{r}, V \mid \Omega_{h}\Omega_{l}] \quad \ldots (1)$$

where X^g is a K-dimensional vector of consumption attributes, $\boldsymbol{F}$ an M-dimensional vector of food products consumed from each plant variety harvested, a^i an M x K matrix of input-output coefficients in which each element a_{ik}^{c} maps consumption of a unit of variety i to a unit of attribute k, Z^r the consumption level of other goods, V household leisure, Ω_h household characteristics and Ω_l the local market characteristics faced by the household. It is assumed that the input-output coefficients associated with the different plant varieties are exogenous to the decision process. That is, the variety-specific intrinsic consumption attributes are fixed from the perspective of an individual household.

The household engages in the cultivation of food crops on a given piece of land using labor and seed. The variety mix (local versus improved) is dependent on the farmer's perceptions of the intrinsic characteristics or attributes of the variety.

Define the production function Y as:

$$Y[Q, G^d(V, d^p), L \mid \Omega_f \Omega_l] = 0 \qquad \dots (2)$$

where Q is an M-dimensional vector of crop products from each variety, G^d a J-dimensional function defining the relationship between the M-dimensional vector V of production scales for each crop variety grown and the relative P proportions of production attributes they yield, d^P is an $M \times J$ matrix with fixed elements d_{ik} defining this mapping, L is household labor input, and Ω_f the exogenous farm characteristics.

de Janvry et al (1991) noted that households in semi-subsistence economies often face high transactions costs of market participation, which influence their production decisions rather than exogenous market prices. Furthermore, the thinness of local grain markets suggests that quality differentials between crop varieties may be inadequately reflected in market prices. The above justifies explicitly modelling household production and consumption decisions as non-separable. Formally, the household maximizes utility by choosing the level of crop products consumed from each available variety, spending on other goods, the scale of each crop variety produced, and labor hours spent in crop production subject to the production technology, income, time, seed, land and non-negativity constraints. This may be stated as follows:

$$\max_{F,Z,v,L} U[X^g(F, a^c), Z^r, V \mid \Omega_h \Omega_l] \quad \ldots (3)$$

Subject to

$$Y[Q, G^d(V, d^p), L \mid \Omega_f \Omega_l] \leq 0 \quad \ldots (4)$$

$$(P - F^g)' P - P^y Z^y + I \leq 0 \quad \ldots (5)$$

$$\bar{S} \leq \sum_{i=1}^{g} S_i \quad \ldots (6)$$

$$S_i = 0 \; \forall i \notin \tilde{S} \quad \ldots (7)$$

$$T - L - V = 0 \quad \ldots (8)$$

$$X_i, Q_i, S_i, all \geq 0 \; \forall i \in \tilde{S} \quad \ldots (9)$$

where T is total household time available, P is a vector of crop product output prices, P^y is the price of other goods, I is exogenous income, $\tilde{S}$ is the set of crop varieties for which seed is available at the village level, and S denotes the total scale of production for the crop of interest, measured in the same units as S_i. Constraint (4), the production technology, establishes the crop production margins while the full income constraint limiting households' cash transactions is stated in constraint (5). The land constraint specified in equation (6) also captures the physical limitations of available land to households for crop production. Constraint (7) captures the effect of the magnitude of available seed (improved versus traditional) in terms of crop varieties at the village level. The time constraint (8) captures the total time available to production and home activities.

The partial Kuhn-Tucker necessary conditions for optimality for derived demand relationship, which determines the optimal production scale for each crop variety potentially grown by the household, is given as:

$$S_i = S_i(a^c, d^p, P^y, P^q, I, T, \bar{S}, \tilde{S} \mid \Omega_h \Omega_l \Omega_f) \ \forall S_i \geq 0 \qquad \ldots (10)$$

The non-separable agricultural household model implies that seed demand is functionally dependent on all the exogenous variables in the problem, including variety-specific consumption and production attributes, exogenous prices and income, household characteristics, production technology and market-related variables. Based on this reduced form derivation, the empirical model is derived below.

Empirical model

The empirical model adapts an approach similar to the one developed by Edmeades et al (2004) but differ in the target commodity and implementation. Using improved maize variety as target agricultural commodity, the model jointly estimates the probability of a farm household in Zambia adopting an improved maize variety and the quantity of seed purchased for a predetermined portion of the cropped area. For a given improved maize variety, some farmers would adopt conditioned by farm and farmer specific characteristics as well attributes of the variety while others would choose not to adopt. Even those who adopt may not allocate the whole farm to the improved variety. Therefore, the proportion of area under the improved variety is censored at zero. As a result, a censored regression model was specified using the Tobit[1] procedure derived from utility maximization underlying farmers' decision to adopt the improved technology, which may be stated as:

[1] A full mathematical treatment of the Tobit model is not included in this paper as its usage is common in applied economics research. Thorough treatments of the model may be found in Greene (2000), chapter 20, pp. 896-951.

$$Y_i = M_i\alpha + A\psi \text{ if } i^* = M_i\alpha + A\psi + \mu_i > T \text{ (Adoption)}$$
$$= 0 \text{ if } i^* = M_i\alpha + A\psi + \mu_i \leq T \text{ (Non-Adoption)} \qquad \ldots (11)$$

Where: Y_i = probability of adoption (and intensity of use) of the improved variety, M, a vector of farm- and farmer- specific attributes as well as information access variables of the adopter, A, a vector of the supply-side production and processing attributes associated with the technology, α and ψ are parameters to be estimated, i* = non-observed latent variable, μ_i is a stochastic error term, and T = non-observed threshold level.

As noted earlier, once a household has agreed to plant an improved variety, it simultaneously decides on the quantity of seed to purchase. Assuming that the variety is made available, the household seed purchase decision is conditioned by the traditional input market factors, income and some household specific attributes that may form part of the adoption decision model. The demand model may be specified as follows:

$$D_i = \varphi_k Z_{ik} + \gamma_j E_{ij} + \varepsilon_i \qquad \ldots (12)$$

where D_i is the quantity of seed demanded by the ith household (taken to mean strictly seed purchased from the seed market), ***Z*** a matrix of designed household socioeconomic factors influencing seed demand, ***E*** a matrix of exogenous input market factors, φ and γ are parameters to be estimated while ε is a stochastic error term. Variables contained in ***A*** and ***Z*** could overlap. The correlation coefficient between the errors of the two models measures the extent of correlation between the two equations. To account for any cross-equation correlation, the two models were estimated simultaneously. Note that only farmers adopting the improved varieties were included in the demand model.

Survey locations and data used

The summary descriptive statistics presented in Table 1 were obtained from a survey of 300 farm households randomly selected and interviewed in Katete, Sinazogwe and Mkushi districts in the Eastern, Central and Southern Provinces, of Zamba during the 2003/04 crop season as part of a region-wide farm level survey undertaken by the International Maize and Wheat Improvement Center (CIMMYT). There is no firm economic theory that dictates the choice of independent variables for adoption studies therefore selection of the variables in Table 2 reflecting (1) farm and farmer attributes, (2) organizational affiliation, and (3) technology specific characteristics, and their *a priori* signs were based on literature (See for example Adesina and Zinnah, 1993; Langyintuo et al., 2003).

Additional variables used in the demand model requiring clarification are FDIFICIT, WEALTH and AGPROG. To capture lack of access to seed by farmers in developing countries caused by calamities and other exogenous factors (Tripp and Rohrbach, 2001), total grain produced by each household during the 2003/04 crop season was converted into energy equivalent and compared with the household minimum energy requirement to create the variable FDEFICIT[2] (Langyintuo et al., 2005a). Using selected assets, a wealth index (WEALTH) was computed employing principal principal components analysis[3] method and used as a proxy for financial status of farm households. AGPROG was used to capture farmers benefiting from various governmental and NGO agricultural inputs support programs.

Empirical results and discussions

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[2] See Langyintuo et al. (2005a) for details.
[3] See Fimer and Pritchett (2001) for details of the analytical approach.

The estimated regression results presented in Table 3 show that the simultaneous equation specification better explains seed demand in Zambia than the OLS. The adoption model results suggest that the proportion of area devoted to the new varieties is positively related to farm size as hypothesized (Table 3 columns 3, 4 and 5). Moving a farmer from a situation of no access to credit to access would significantly improve adoption decisions. As expected, increasing improved seed cost by a unit over the local ones would result in a 10% dis-adoption rate while convincing farmers that a given improved variety is superior to the local ones in terms of yield and resistance to field pests would increase adoption rate by 20% and 6%, respectively.

Results from the seed demand estimation show that once a farmer becomes a beneficiary of a government or NGO inputs program, his/her investment in seed would decrease by as much as 33%. Increasing the proportion of land on improved seed by a percentage point would increase the quantity of seed purchased by over 50% while moving a household from a lower wealth ranking to a higher one would nearly double the quantity of seed purchased. Farmers who fail to meet their household food requirements are willing to purchase improved seed but increasing their level of self-insufficiency by a percentage point would result in a 7% decrease in seed demand.

Conclusion and policy recommendations

This paper strongly argued that in developing countries, farmers view seed first as an input and second as a technology implying that decisions on adoption and the quantity of seed demanded from the market are taken jointly. Drawing on the theory of demand for consumption goods characteristics and production input attributes, the paper specified and estimated non-separable household demand and consumption models simultaneously using farm level data collected from 300 farm households in Zambia during the 2003/04 crop season.

The results suggest that neither technological attributes nor farm and farmer specific characteristics alone can explain farmers' technology adoption decisions and clearly showed that adoption rate, distance to market, level of household grain self-sufficiency, seed hand-outs and household wealth are significant in determining farmers' seed purchase decisions. It is recommended that agricultural extension activities should emphasize field demonstrations to show the superiority of improved maize varieties over the local ones in terms of yield and field pest resistance. Farmers should be encouraged to form associations to bargain for better services including credit and engage in information exchange to reduce information asymmetry on new technologies. To have better market access for increased farm incomes, adoption rates and seed demand farmers should form innovative marketing cooperatives. Seed hand-outs meant to solve chronic seed unavailability problems must be designed so as not to destroy rural seed market development.

It is concluded that the joint estimation of technology adoption and improved seed demand provides a holistic approach to the identification of relevant factors determining seed uptake at the farm level in developing agriculture for better targeting to increase impacts of maize breeding research. Furthermore, the approach contributes significantly to the literature on modelling farm level seed demand.

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Table 1: Descriptive statistics of household in selected districts in Zambia

	Katete (n=100)	Sinazogwe (n=100)	Mkushi (n=100)	Whole sample
Household size (number)	6.0	9.8	8.5	8.1
	(3.0)	(6.6)	(5.1)	(5.3)
Economic status index of household	0.03	0.32	-0.36	0.00
	(0.95)	(1.06)	(0.89)	
Age of household head	41.5	39.6	46.8	42.6
	(13.9)	(13.7)	(13.4)	(14.0)
Female headed households (%)	25	23	27	25
Membership of associations (%)	33	29	60	41
Illiterate household heads (%)	30	22	10	21
Ownership of pair of bullocks	20	45	12	26
Ownership of bicycle	72	46	44	54
Total tropical livestock units	4.7	8.5	2.1	5.1
	(6.3)	(10.6)	(4.3)	(8.0)
Total farm size (ha)	3.5	4.3	8.2	5.3
	(2.0)	(3.7)	(10.0)	(6.6)
Cultivated land area (ha)	3.2	3.7	2.2	3.0
	(1.8)	(3.5)	(1.9)	(2.6)
Improved seed purchased (kg)	3.9	5.6	9.8	6.4
	(8.9)	(11.1)	(13.8)	(11.7)
Maize area (% of cropped area)	51	42	52	48

Table 1: (Cont.)

	Katete	Sinazogwe	Mkushi	Whole sample
Adoption rate (% of farmers)	60	62	75	66
Adoption rate (% of area)	9	11	10	10
Total income (US$)	242	220	308	256
Agriculture (% of total)	77	71	54	67
Employment (% of total)	15	22	30	23
Other sources (% of total)	7	7	16	10
Total expenditure (US$)	142	203	195	180
Food and beverages (% total)	32	52	38	40
Farm inputs (% total)	28	17	21	22
Clothes (% total)	19	14	15	16
Miscellaneous (% total)	21	17	26	22

Note: In parenthesis are standard deviations

Source: Langyintuo et al (2005a).

Table 2: Descriptive statistics of explanatory variables in the seed demand equation

Variable[1]	Definition	Mean (SD)
IMPROPN[2]	Proportion of cropped area under improved maize varieties	0.10 (0.18)
GENDER	A binary variable with 1 if household head is a male and zero otherwise	0.75 (0.43)
AGEHH$^{(-/+)}$	Age of household head	42.62 (13.98)
EDUCN	Years of formal education of household head	1.98 (0.63)
LABORF	Household labor force	5.66 (3.74)
MAIAREA	Cultivated area under maize (ha)	1.58 (1.47)
ASSOCN	A binary variable with 1 if household head belongs to a farmers' association and 0 otherwise	0.407 (0.492)
FIELDAY	A binary variable with 1 if household head has attended at least two field days in a year and 0 otherwise	0.19 (0.39)
NGOCD	Binary variable with 1 if household is a beneficiary of NGO agricultural extension program and 0 otherwise	0.20 (0.40)
CREDIT	A binary variable with 1 if household have had access to cash credit and 0 otherwise	0.72 (0.45)
RCOST$^{(-)}$	A binary variable with 1 if farmer perceives that the improved maize seed is more costly than the best local variety and 0 otherwise	0.85 (0.36)
RAVAIL	A binary variable with 1 if farmer perceives that the improved maize seed is more readily available than local one and 0 otherwise	0.14 (0.35)

Table 2: (Cont.)

Variable[1]	Definition	Mean (SD)
RSALE	A binary variable with 1 if farmer perceives it is easier to sell grain from improved maize compared with the local one and 0 otherwise	0.61 (0.49)
RYIELD	A binary variable with 1 if farmer perceives that the improved maize yields more than the best local variety and 0 otherwise	0.62 (0.49)
RPESTS	A binary variable with 1 if farmer perceives the improved variety is more resistant to field pests than the local variety and 0 otherwise	0.41 (0.49)
RSTPEST	A binary variable with 1 if farmer perceives the improved variety is more resistant to storage pests than the local variety and 0 otherwise	0.33 (0.47)
RPALATA	A binary variable with 1 if farmer perceives that the improved maize variety is more palatable than the local one and 0 otherwise.	0.10 (0.30)
SEEDPUR[3]	Quantity of seed purchased (kg)	5.50 (11.22)
FDEFICIT	A binary variable with 1 if household was food self-insufficient and 0 otherwise	0.74 (0.44)
AGPROG	Binary variable with 1 if household is a beneficiary of NGO of government agricultural input support program and 0 otherwise	0.57 (0.50)
MAIPRICE(-)4	Maize price (x1000 ZKW)	3.52 (1.56)
WEALTH	Household wealth index	0.00 (1.00)
DISTANCE (-)	Distance to output markets in physical units	26.56 (31.39)

Note: [1]Expected signs are positive except for those indicated; [2]Dependent variable in the adoption equation; [3]Dependent variable in the demand equation; [4]The Zambian currency is called Zambian Kwacha (ZKW). The exchange rate in May2005 was: 1US$ = ZKW 4850

Table 3: Joint estimation of factors influencing improved maize variety adoption and seed demand in selected districts in Zambia

Variable	Ordinary Least Squares specification (n=300)		Simultaneous equation specification (n=300)		
	Coefficient	Standard error	Coefficient	Standard errors	Elasticity at the mean
			Equation 1: Adoption model (n=300)		
GENDER	-1.4904	1.3488	-0.0278	0.0326	-
AGEHH	-0.0172	0.0422	-0.0013	0.0010	-
EDUCN	1.2806	0.9943	0.0246	0.0237	-
ASSOCN	1.6266	1.2319	0.0795**	0.0296	0.0795
LABORF	0.5326*	0.2227	0.0022	0.0038	-
FIELDAY	-1.9864	1.6384	0.0051	0.0398	-
NGOCD	-2.1551	1.6388	0.0170*	0.0340	0.0170
CREDIT	-3.1194*	1.4628	0.0734*	0.0326	0.0734
RCOST	-1.1839	1.6563	-0.0992**	0.0398	-0.0992
RAVAIL	1.3791	1.7701	0.0333	0.0424	-
RSALE	1.0617	1.2981	-0.0509*	0.0309	-0.0509
RYIELD	-1.4115	1.3516	0.2035**	0.0306	0.2035
RPESTS	-0.6495	1.2817	0.0589*	0.0309	0.0589
RSTPEST	1.1228	1.4209	-0.0478	0.0342	-

Table 3: (Cont.)

Variable	Ordinary Least Squares		Simultaneous equation specification		
	Coefficient	Standard error	Coefficient	Standard errors	Elasticity at the mean
RPALATA	4.8682**	1.9855	0.0670	0.0472	0.0670
MAIAREA	-	-	0.0430**	0.0098	-0.0430
KATETE	-	-	-0.1066**	0.0434	-0.1066
SINAZONG	-	-	-0.0627	0.0421	-0.0627
CONSTANT	-	-	0.2632**	0.0949	-
			Equation 2: Seed demand model (n=128)		
DISTANCE	-0.0186	0.0175	0.0243*	0.0167	-0.1015
FDEFICIT	0.0341**	0.0106	0.0182*	0.0083	-0.0710
AGPROG	-1.9319	1.6477	-3.7469**	1.3316	-0.3326
IMPROPN	13.5753**	2.4646	14.1244**	2.1686	0.5337
WEALTH	0.6914	0.7576	1.0281**	0.6152	-0.0004
MAIAREA	2.5086**	0.4619	2.7552**	0.4233	0.6759
MAIPRICE	-0.0001	0.0002	-0.0001	0.0002	-
KATETE	-3.4754*	2.0850	-6.4135**	1.7069	-0.3310
SINAZONG	-1.1188	2.3414	-1.9205	1.9654	-0.0991
CONSTANT	5.2690	10.4321	5.7350	9.6812	-
R-squared		0.3559	Seed demand model		0.3454
			Adoption model		0.3398

Note: * Significant at 5%; ** Significant at 1%.