

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

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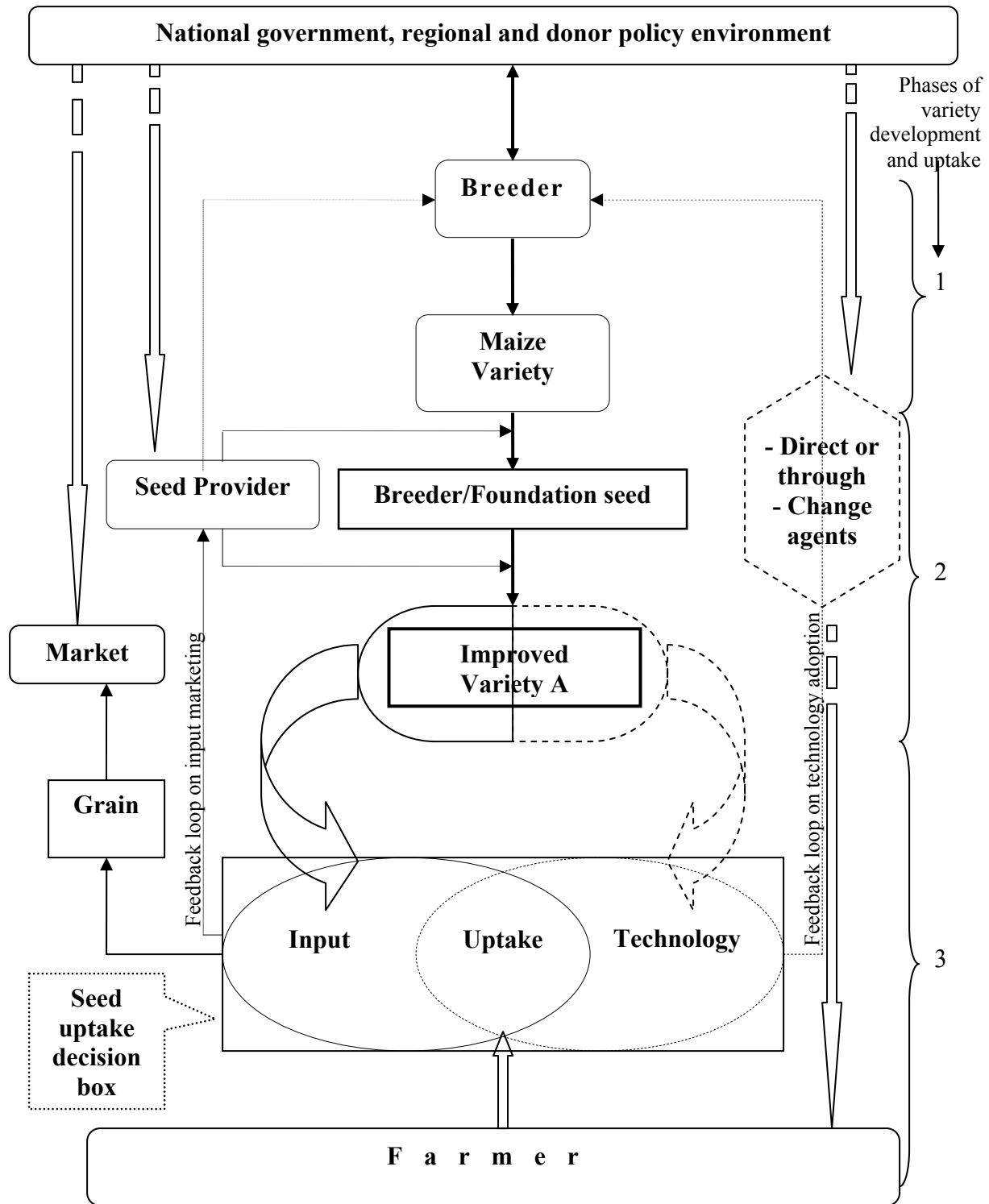
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Introduction

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.

As shown in Figure 1, an improved variety developed by a breeder goes through breeder and foundation seed production processes before being produced as certified, or "quality declared" seed for sale on the market. At the variety uptake stage, a farmer views an improved seed 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. As a derived input to the production of grain, seed uptake or purchase choice by farmers is influenced by government's input and output pricing policies, non-monetary interventions such as seed hand-outs from governments and nongovernmental organizations (NGO) and productivity attributes of the seed communicated to the farmer by the seed producer or retailer (Left hand side of Figure 1). As a technology, on the other hand, farmer's own perceptions about the consumption attributes of the variety (such as



Phases of variety development and uptake:

- 1) Variety development
- 2) Seed multiplication
- 3) Dissemination

Figure 1: Diagrammatic representation of seed uptake both as a technology and an input

Source: Langyintuo (2005)

taste or palatability), his or her socioeconomic circumstances as well as government's policies on research and development are important factors determining adoption decisions (Right hand side of Figure 1). This implies that if only the marketing problems of seed are solved but the fundamental technology adoption constraints not adequately identified and resolved, seed uptake at the farm level will remain low. Similarly, if the technology adoption problems are addressed but the marketing constraints not simultaneously tackled, improved seed uptake will not improve. In other words, the technological aspect of seed, which embodies consumption characteristics and the input aspect embodying production attributes must be addressed simultaneously if increased uptake of seed is desired.

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). Moreover, the intrinsic nature of the genetic attributes of seed is an inherent source of missing markets. The information on the genetic quality of the seed is less obvious from its appearance to the farmer. As a result the seed producer or retailer has to convince the farmer about the quality of the seed offered for sale and the farmer on his/her part has to have faith in the retailer because the true quality will not be known until it is too late (Gregg, 1983). Once faith is lost with the supplier, the farmer may not patronise the producer or retailer any longer thus driving the marginal value of seed to zero. In the developed world, competition among seed producers and fear of litigation almost completely eliminates this "faith" compared with the developing world where seed markets are less competitive and litigation uncommon. Therefore, in the latter countries, the price set does not reflect the true value of the seed offered since the market clearing price is partly determined by "faith" and not completely by marginal value product of the seed.

The above discussion justifies modelling farm household's production and consumption decisions in a non-separable form in any attempt to estimate farm level seed demand as adopted in this paper. 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. In developing countries where adoption rates for improved maize varieties are dismally low (Morris et al., 1999; Gemedda et al., 2001; Ajayi et al., 2003; Adesina and Zinnah, 1993; Langyintuo, et al., 2005a, b; Langyintuo, 2005a, b; Langyintuo and Mekuria, 2005), seed companies desperately need accurate information on the types and quantities of seed farmers need for proper planning since seed production involves an inflexible time lag between production and sales. Technical tasks are unique and must be performed at critical times (Gregg, 1983). Once the process has been initiated it is not possible to adjust the volume or variety mix. Over production of seed is undesirable not only because of high storage financing costs common in such economies, but also because most rural markets can not effectively handle seed due to the large volumes required, sensitivity of living seed to humidity and temperature, etc. On the other hand, underproduction is a recipe for over pricing. In either case, adopting farmers pay the price for inefficient planning since seed producers need to make a profit to stay in business. Furthermore, the joint identification of factors influencing both adoption and demand facilitates individual or group targeting of interventions to increase the overall uptake of improved maize seed to foster growth in the agricultural sector and improve the livelihoods of smallholder resource poor farmers in developing countries.

Conceptual framework

The conceptual basis for consumption and production goods demand is based on goods characteristics in the utility function and input attributes in the production function pioneered by

(Lancaster 1966a, b) and subsequently modified by (Ladd and Suvannunt, 1976). 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. 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:

$$U[X^g(F, a^c), Z^r, V | \Omega_h, \Omega_l] \quad \dots (1)$$

where X^g is a K -dimensional vector of consumption attributes, F an M -dimensional vector of food products consumed from each plant variety harvested, a^i an $M \times K$ 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:

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

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. Less than 40% of farms in Malawi, Mozambique and Zambia and 55% of farms in Zimbabwe are cropped to purchased improved seed and the rest to seed from various other sources without any cash exchange (Langyintuo, et al., 2005a, b; Langyintuo, 2005a, b). This means that the marginal value of seed is a shadow price. Similarly, leisure is valued by its marginal worth in household production rather than at a market wage rate given that family labor is widely used for crop production and opportunities for off-farm employment limited, etc. (ibid). Furthermore, the thinness of local grain markets suggests that quality differentials between crop varieties may be inadequately reflected in market prices.

The foregoing makes a compelling case for 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:

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

Subject to

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

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

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

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

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

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

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:

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

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 procedure. The Tobit model is derived from utility maximization underlying farmers' decision to adopt the improved technology. Consistent with Rahm and Huffman (1984), assume that $U(M_{ji}, A_{ji})$ defines the non-observable underlying utility function of a farmer facing a seed adoption decision. This utility function ranks the preference of the i th farmer for the j th variety ($j = 1, 2$: 1 = improved variety and 2 = traditional variety). Thus, the utility derivable from the new variety depends on M , a vector of farm- and farmer- specific attributes as well as information access variables of the adopter (demand side factors). This is contrasted against A , a vector of the supply-side production and processing attributes associated with the technology. Although the utility function is unobserved, the relation between the utility derivable from a j th variety is postulated to be a function of the vector of observed farm, farmer, information and variety specific characteristics (e.g. yield, taste or palatability, etc.) and a disturbance term having a zero mean:

$$U_{ji} = \alpha_j F_i(M_i, A_i) + e_{ji} \quad j = 1, 2; i = 1, 2, \dots, n \quad \dots (11)$$

As the utilities U_{ji} are random, the i th farmer will select the alternative $j = 1$ if $U_{1i} > U_{2i}$ or if the non-observable (latent) random variable $y^* = U_{1i} - U_{2i} > 0$. The probability that Y_i equal one (i.e., that the farmer adopts an improved maize variety) is a function of the independent variables:

$$\begin{aligned} P_i &= P_r(Y_i = 1) = P_r(U_{1i} > U_{2i}) \\ &= P_r[\alpha_1 F_i(M_i, A_i) + e_{1i} > \alpha_2 F_i(M_i, A_i) + e_{2i}] \\ &= P_r[e_{1i} - e_{2i} > F_i(M_i, A_i)(\alpha_2 - \alpha_1)] \\ &= P_r(\mu_i > -F_i(M_i, A_i)\beta) \\ &= F_i(M_i\alpha + A_i\psi) = F_i(X_i\beta) \quad \dots (12) \end{aligned}$$

where X is the $n \times k$ matrix of the explanatory variables (bifurcated into M demand and A supply variables) and β is a $k \times 1$ vector of parameters to be estimated (also bifurcated into subsets α and ψ), $Pr(.)$ is a probability function, μ_i is a random error term, and $F_i(X_i\beta)$ is the cumulative distribution function for μ_i evaluated at $X_i\beta$. The probability that a farmer will adopt an improved rice variety is a function of the vector of explanatory variables and of the unknown parameters and error term. Equation 12 cannot be estimated directly without knowing the distribution of μ_i that determines the distribution of F . The functional form of F is specified with a Tobit¹ model, where μ_i is a stochastic error term:

$$\begin{aligned} Y_i &= M_i\alpha + A\psi \text{ if } i^* = M_i\alpha + A\psi + \mu_i > T \text{ (Adoption)} \\ &= 0 \text{ if } i^* = M_i\alpha + A\psi + \mu_i \leq T \text{ (Non-Adoption)} \end{aligned} \quad \dots (13)$$

Where: Y_i = probability of adoption (and intensity of use) of the improved variety i^* = non-observed latent variable, and T = non-observed threshold level. The dependent variable is measured as the proportion of maize area that is planted to an improved maize variety. This transformation is useful because it measures the binary decision to adopt as well as the degree of farmer preference for a variety. The Tobit procedure maximizes a two part log-likelihood function which is discrete, for those farmers who have not adopted improved varieties, and a second part that is continuous for those that have adopted a new variety. As a result, the Tobit model, when estimated as the proportion of land under improved varieties, measures two decisions simultaneously: the decision to adopt and the intensity of usage.

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:

$$D_i = \varphi_k Z_{ik} + \gamma_j E_{ij} + \varepsilon_i \quad \dots (14)$$

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.

where D_i is the quantity of seed demanded by the i th 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 data used in this analysis were collected from 300 farm households randomly selected and interviewed in Katete, Sinazogwe and Mkushi districts in the Eastern, Central and Southern Provinces, of Zambia 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). The main agroclimatic conditions of the selected ecosystems are presented in Table 1 and Figure 2. The Mkushi district, located in the Central province has a physical coverage of 22,800 km² with Chalata, old Mkushi and Masansa as sub-districts. The main characteristics of the district are central plateau and the Luano valley with a general undulating slope and an altitude of 900 to 1,200 meters above sea level. Lusemfwa river basin forms the major drainage system in the district with Lusemfwa, Lukusashi and Mkushi as the major rivers. The district faces a fairly moderate deforestation caused mainly by farming activities and charcoal burning. The main soils are Acrisols, Lithosols, Cambisols and Fluvisols with low water holding capacity, shallow rooting depth, rapid physical deterioration, erosion hazard and poor workability. The soil chemical limitations include, low nutrient reserve and retention capacity, high acidity in some pockets, low calcium and magnesium, micronutrient deficiencies, low organic matter and low phosphorous.

Table 1: Agro-ecological description of survey regions

Characteristic	Region I	Region II
Growing season	80 – 120 days	90 – 150 days
Rainfall	Low <800mm	Medium 800 – 1000mm
Soil conditions	Zambezi-Luangwa rift valley Solonitzi soils steep slopes, difficult to manage; Semi-Arid plains; Sandy soils with low potential	Predominantly fairly fertile ferro soils with high potential
Vegetation	Kalahari, miombo & swamp vegetation	Dry miombo and acacia woodlands
Livestock	25% of Zambia’s cattle population, goats, pigs, chickens	72% of cattle population (1/3 owned by large ranchers) goats, pigs, chickens
Production constraints	Erratic rainfall; Recurrent droughts Periodic floods; Lack of improved technical packages; Poor seed availability; Low research & extension interventions; Livestock diseases; Poor marketing facilities; Poor infrastructure	Low levels of extension services Deforestation Livestock diseases Lack of credit
Risk-food insecurity	High – due to recurrent drought, floods, livestock diseases, lack of infrastructure & poor access to government services	Moderate – due to developed infrastructure & access to government services

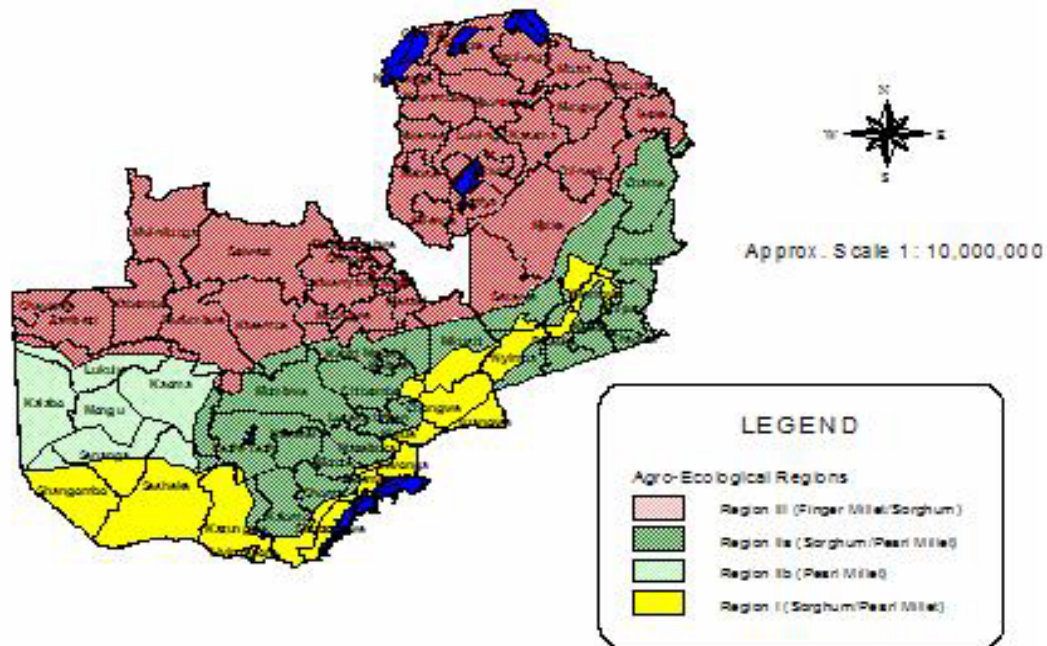


Figure 2: Map of Zambia showing the agro-ecological zones of the country

The Sinazogwe district covers 5,195 km² between latitude 17° 15' and longitude 27° 30'. Most of the district land mass lies at an altitude of 600 -1500 meters above mean sea level. The drainage system is the Zambezi river basin. The general slope is relatively flat in the valley and highly undulating on the escarpment. Deforestation is moderate but threats of erosion from runoff are real on both the valley and plateau. The main soil groups are the lithosol-cambisol on the escarpment and cambisol-luvisol in the valley floor. The main physical limitations are low water holding capacity, shallow rooting depth, rapid physical deterioration, erosion hazard and poor workability while the chemical limitations are low nutrient reserve, low nutrient retention capacity, low calcium, magnesium, phosphorous and organic matter. The soils are however quite high in potassium. The district is characterized by hot, dry spells, short rainy season of 60 - 90 days and an average annual rainfall of 600 – 700 mm. Minimum and Maximum temperatures are 14°C and 31°C, respectively.

The Katete district is situated approximately 470km East of Lusaka in the Eastern Province of Zambia with about 34,777 agricultural households of which 34,320 households are involved in maize production (approximately 15.1% of the provincial households growing maize). The district lies between 900 and 1500 meters above sea level and has a slightly longer growing

season of 135 – 140 days with 850 - 900 mm annual rainfall than the other districts. The district represents one of the most degraded places in the province. The soils, which are predominantly Alfisols with sandy topsoil, are characterised by ‘well to moderately well-drained, of light to medium acidity, and with moderate natural fertility. Major crop production limitations are low nutrient retention and reserves and tendency of topsoil capping and development of a densely packed pan at a certain soil level (VELDKAMP, 1987).

The descriptive statistics of the selected farm households extracted from Langyintuo et al, (2005a) are presented in Table 2. Maize is the predominant crop in the districts, constituting about 61%, 42% and 52% of the cultivated areas in Katete, Sinazogwe and Mkushi districts, respectively. Farmers plant about three different maize varieties on up to three different plots. Total quantity of seeds planted per maize farm of 1.4 ha was about 22 kg (27% being improved seed). The two major sources of seed were savings from the previous harvest (39%) and purchases from seed retail shops (29%). The estimated improved maize variety adoption rates for the whole sample were 66% in terms of farmers and 10% in terms of cultivated area.

There is no firm economic theory that dictates the choice of independent variables for adoption studies therefore the variables in Table 3 reflecting (1) farm and farmer attributes, (2) organizational affiliation, and (3) technology specific characteristics were selected based on literature (See for example Adesina and Zinnah, 1993; Morris et al., 1999; Gemedo et al., 2001; Ajayi et al., 2003; Langyintuo et al., 2003). The farm and farmer characteristics in the model were used to evaluate whether human capital [age of household head (AGEHH), educational level (EDUCN), household labor force (LABORF)], fixed social bias (GENDER) and land MAIAREA constraints are important in the adoption process. Farmers are risk averse and therefore are very cautious in their willingness to devote some portion of their field to an untried new variety. Consequently the proportion of area devoted to the new varieties would be positively related to maize farm size (MAIAREA). Because extension staffs are few and predominantly male, female farmers are sometimes discriminated against in extension activities.

Table 2 Descriptive statistics of household in selected districts in Zambia

	Katete (n=100)	Sinazogwe (n=100)	Mkushi (n=100)	Whole sample (n=300)
<i>Demographic characteristics</i>				
Household size (number)	6.0 (3.0)	9.8 (6.6)	8.5 (5.1)	8.1 (5.3)
Economic status index of household	0.03 (0.95)	0.32 (1.06)	-0.36 (0.89)	0.00
Age of household head	41.5 (13.9)	39.6 (13.7)	46.8 (13.4)	42.6 (14.0)
Female headed households (%)	25	23	27	25
Membership of associations (%)	33	29	60	41
Illiterate household heads (%)	30	22	10	21
<i>Physical assets (% of households)</i>				
Ownership of pair of bullocks	20	45	12	26
Ownership of bicycle	72	46	44	54
Total tropical livestock units	4.7 (6.3)	8.5 (10.6)	2.1 (4.3)	5.1 (8.0)
<i>Crop production indices</i>				
Total farm size (ha)	3.5 (2.0)	4.3 (3.7)	8.2 (10.0)	5.3 (6.6)
Cultivated land area (ha)	3.2 (1.8)	3.7 (3.5)	2.2 (1.9)	3.0 (2.6)
Improved seed purchased (kg)	3.9 (8.9)	5.6 (11.1)	9.8 (13.8)	6.4 (11.7)
Maize area (% of cropped area)	51	42	52	48
Adoption rate (% of farmers)	60	62	75	66
Adoption rate (% of area)	9	11	10	10
<i>Household income profile</i>				
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
<i>Household expenditure profile</i>				
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 ²
IMPROP	Proportion of cropped area under improved maize varieties	0.10 (0.18)
GENDER		0.75 (0.43)
AGEHH ^(+/)	A binary variable with 1 if household head is a male and zero otherwise 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)
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)
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 ⁽⁻⁾ ³	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: ¹Expected signs are positive except for those indicated; ²Din parenthesis are the standard deviations; ³The Zambian currency is called Zambian Kwacha (ZKW). The exchange rate in May 2005 was: 1US\$ = ZKW 4850

It is generally believed that as farmers grow older, they are less amenable to change and therefore may be unwilling to change from their old practices to new ones. The model will however be used to test the alternative argument that age is positively related to adoption especially prior to the consolidation period in the producer's life cycle. Educated farmers are often thought to have access to literature such as research bulletins and hence would be better informed and more willing to adopt an improved variety than otherwise. In general, improved variety is a scale neutral technology and would thus barely have an impact on labor use. However, the fact that adopting the technology may result in higher yields and consequently increased labor demand during harvesting, it is hypothesized that family labor force would positively influence adoption.

Organizational affiliations such as membership in a farmer's association (ASSOCN), patron of farmer field days on maize production (FIELDAY), and beneficiary of an NGO extension program (NGOCD), which expose farmers to new technologies and stimulate communication thereby reducing information asymmetry are hypothesized to positively influence adoption. Farmers need cash to purchase seeds and complementary inputs such as fertilizers therefore access to credit (CREDIT) is postulated to be positively related to adoption decisions.

Regarding the technology specific attributes, farmers compared the improved maize varieties with the best local variety of their choice in terms of seed cost (RCOST), seed availability on the local market (RAVAIL), or consumer acceptability of the grain (RSALE) demonstrated by ease of sale of grain from the given seed, yield advantage (RYIELD), resistance to field pests (RPESTS), and storage pests (RSTPEST) as well as household level assessment of grain palatability (RPALATA). A distinction is made here between market and household level acceptability of an improved variety because some farmers may cultivate one variety for home consumption and another strictly for the market. The perceived superiority of improved maize varieties in terms of yield, resistance to field and storage pests over the local ones is expected to be positively related to adoption. RCOST is hypothesized to have a negative impact on adoption while the reverse is true for RSALE. Given that varieties are developed in a participatory manner with farmers, RPALATA is expected to have a positive impact on farmers adoption decisions.

To account for district specific effects on adoption, Katate and Sinazogwe district dummies (KATETE and SINAZONG, respectively) were included.

Additional variables used in the demand model are FDIFICIT, IMPROPN, AGPROG, WEALTH, MAIPRICE and DISTANCE. Conditions that influence farmers' final decision on seed choice and demand levels are varied. Tripp and Rohrbach (2001) identify three of such conditions as: (1) emergency situations when environmental calamities or civil conflict results in insufficient harvest to provide seed stock, (2) poverty situation when shortage of labor or illness, etc result in poor harvest compelling farmers to consume their seed stock, and (3) demand for seed quality arising from the farmer's desire to replace old seed stock due to poor performance or when a new variety or germplasm is introduced into the community.

In a rather static analytical situation, the first two conditions could be condensed into "lack or depletion of seed stock". To capture such a scenario, 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 FDEFICIT² (Langyintuo et al., 2005a). Assuming that households deplete their food stock then they are more likely to consume their seed stock and would consequently be willing to buy seed subject to cash availability and no free seed issues. A farmer desirous of replacing his/her existing seed stock with another can be regarded as an adopter. This is captured by including the adoption rate (IMPROPN). The larger the area under improved maize variety the more seed would be required and vice versa.

Although a farmer may be aware that a given improved variety has high returns, lack of cash may prevent the farmer from investing in improved seed. As in most developing countries, farmers are often cash trapped and invariably unable to meet their financial needs. Whenever deemed appropriate, households convert liquid assets into cash implying that a household's wealth status may be judged by the assets accumulated. It is well known that ownership or access

² To calculate the minimum energy requirement per household, each household member was converted to a consumer equivalent unit (CEU) after Runge-Metzger (1988) as follows: less than 9 years: 0.4; 9 to 15 years: 0.7; males 16 to 49: 1; females 16 to 49: 0.9; over 49 years: 0.8, and the aggregated CEU normalized by the minimum energy requirement per CEU per year assumed to be 10.9 MJ (ibid). Energy equivalents of the various crop outputs were estimated based on the following Kcal per g of crop: maize, 36.2; sorghum, 35.3; millet, 33.2; rice, 35.4; cassava, 15.3; cowpea, 34.0; and groundnuts, 58.0.

to assets that can be put to productive use is the cornerstone of the capacity of poor households to chart a route out of poverty (Moser, 1998). A separate study by Langyintuo et al. (2005a) indicated that the relative wealth status of a household in the selected districts could be approximated by household ownership of labor (both family and access to non-family labor), land, physical assets such as pairs of bullock, bicycles (and sometimes motorcycles), television sets, and radio sets as well as membership of farmers' associations (since membership requires regular payment of dues), and access to social networks. Using these assets, Langyintuo et al. (2005a) employed principal components analysis³ method to create wealth indices for households in the selected districts. It was generally observed that households owning relatively larger numbers of key wealth indicators ranked higher than those with smaller numbers. To account for seed affordability, "WEALTH" was included as a proxy for financial status.

Distance to market (DISTANCE) is expected to have a negative impact on demand in that the farther away farmers are from markets, the less they consider profitability as an object of farming but rather self-sufficiency and hence less willing to purchase improved seed. Maize seed price (MAIPRICE) is hypothesized to have a negative effect on demand in line with economic theory.

Langyintuo et al., (2005a) observed that some farmers benefit from various governmental and NGO agricultural inputs (mainly seed and fertilizer) support programs (AGPROG). Because farmers who receive seed hand-outs are unlikely to patronize the commercial seed market, AGPROG is hypothesized to have a negative impact on seed demand from the market. NGOCD used in the adoption model is a subset of AGPROG in that all farmers receiving NGO extension services are captured under AGPROG. AGPROG also includes farmers benefiting from government input programs. District specific effects on seed demand are accounted for by the inclusion of Katate and Sinazogwe district dummies (KATETE and SINAZONG, respectively).

Empirical results and discussions

The estimated regression results presented in Table 3 show that the simultaneous equation specification better explains seed demand in Zambia than the OLS given the relatively smaller

³ See Fimer and Pritchett (2001) for details of the analytical approach.

Table 4: 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
<i>Equation 1: Adoption model (n=300)</i>					
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	-
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	-
<i>Equation 2: Seed demand model (n=128)</i>					
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%.

standard errors. In addition more variables in the former equation compared with the latter significantly influence seed demand at the farm level. Furthermore, in the former specification, all the explanatory variables except for GENDER and RSALE had expected signs and together explain 35% of the variability in maize seed demand at the farm level while in the latter, the explanatory variables explained 36% of the variability in farm level seed demand but six variables including NGOCD, CREDIT, and RYIELD had contradictory signs to the *a priori* expectations. Subsequent discussions are limited to the simultaneous equation results in Table 3, columns 3, 4 and 5.

The adoption model results presented in the upper portion of Table 4 suggest that membership of farmers associations (ASSOCN), seed cost (RCOST), farmer's perceptions on grain yield (RYIELD) and maize farm size (MAIAREA), significantly influence the adoption of improved maize varieties at less than 1% level of error probability while contacts with non-governmental organizations (NGOCD), access to credit (CREDIT), ease of selling grains (RSALE) and resistance of improved varieties to field pests (RPEST) significantly affect adoption rate at the 5% level. The proportion of area devoted to the new varieties is positively related to farm size as hypothesized. To maximize the benefits from adopting an improved variety, farmers need money to invest in complementary inputs such as fertilizer and the improved seed, which supports the findings that 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. Convincing farmers that a given improved variety is superior to the local ones in terms of yield and resistance to field pests by a unit would increase its adoption and use intensity by 20% and 6%, respectively. Farmers in Katete district are less likely to adopt improved varieties compared to their counterparts in the Mkushi district possibly due to the availability of alternative sources of farm income such as contract farming of cotton.

Results from the seed demand estimation show that AGPROG, IMPROPN, WEALTH and MAIAREA are statistically significant in explaining maize seed demand at 1% level of error probability, while DISTANCE and FDEFICIT at the 95% confidence level. The significantly negative relationship between AGPROG and seed demand confirms the generally held view that

seeds hand-outs encourage farmers to develop dependency syndromes. 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%. The results rightly point out that the quantity of seed a farmer is willing to purchase is positively influenced by the adoption rate. That is, increasing the proportion of land on improved seed (IMPROP) by a percentage point would increase the quantity of seed purchased by over 50%. Note that the total maize area has a significant impact on how much area could be devoted to the improved variety. The wealth status of households significantly influences quantities of seed purchased: the higher the ranking, the more seeds are purchased suggesting that moving a household from a lower wealth ranking to a higher one through wealth accumulation would nearly double the quantity of seed purchased. Farmers who fail to meet their household food requirements are willing to purchase improved seed. However, a percentage increase in their level of self-insufficiency (FDEFICIT) would result in a 7% decrease in seed demand. This seems to suggest that households in deficit lack capital assets that could be converted into cash to buy inputs. The relative impacts of MAIAREA and the Katete district dummy on seed demand are similar to the observation for adoption.

Conclusion and policy recommendations

This paper proposes a new approach for estimating the demand for seed within a developing country context where nearly all seeds purchased from the market are improved seeds but adoption rates for improved varieties in terms of area are dismally low. It is strongly argued that under such circumstances, farmers view seed first as an input and second as a technology implying that decisions on adoption (in terms of area) 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 simultaneous equation model results, which better explained seed demand compared with an OLS model, suggest that neither technological attributes nor farm and farmer specific characteristics alone can explain farmers technology adoption decisions similar to the

observations of Adesina and Zinnah (1993); Langyintuo et al. (2003). The model clearly shows that increasing adoption rate would significantly improve quantities of seed demanded but how might that be achieved? A look at the adoption model results suggests that NGOs, whose extension activities appear to have an important impact on adoption, should be encouraged to emphasize (1) farmers' group formation for information sharing to reduce information asymmetry on improved technologies, and (2) field demonstrations to show the superiority of improved maize varieties over the local ones in terms of yield and field pest resistance to boost adoption. These farmers groups should evolve into marketing cooperatives through variances of the Inventory Credit Programs (ICP) or Cereal Banking (CB) that have been demonstrated in some parts of Africa to be effective vehicles for creating critical mass of farmers to bargain for better prices and services such as credit (Langyintuo, 2005c; Okello, 2004). In the ICP concept, an NGO links the farmers' group to a financial institution for loans using their grains stored in a community warehouse as collateral. The maximum amount of the loan is up to 75% of the value of the grain as a hedge against risk. The CB, on the other hand, allows a farmers' group to bulk their grains collectively and access competitive markets. Another approach to improving adoption is providing seed to farmers at affordable prices through improvement in the efficiency of seed production. Alternatively, if farmers have access to competitive grain markets through CBs, they would be better placed to buy improved seed.

Equally important in determining seed purchases is the level of grain self-sufficiency. Farmers less secure in their food production are willing to buy seed but increased insecurity negates their intentions as they stand being driven into deprivation and want. The results also confirm the widely held view that seed handouts with all its good intentions of lifting farmers out of deprivation is detrimental to seed market development and should therefore be handled with utmost care so as not to destroy seed markets.

Quite logically, improving the wealth statuses of households as well as bringing markets closer to households has the potential of improving seed demand. But how could that be accomplished? Recently, Langyintuo and Mekuria (2005) argued for the support of farmers to form associations to better bargain for improved services through CBs and ICPs discussed above. Rural wealth

accumulation could be effected through asset trading, which should be promoted systematically among farm households.

In conclusion, it may be stated 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. Furthermore, the approach contributes significantly to the literature on farm level seed demand methodology.

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