A Unified Methodology for Estimating the Demand for Improved Seed at the Farm Level in Developing Agriculture

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Abstract

This paper proposes a novel approach for estimating farm level seed demand in developing countries. In principle, a farmer views an improved seed as a derived input embodying production attributes and a technology embodying consumption characteristics and 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 improved seed adoption and demand models simultaneously using data collected from 300 randomly selected farm households in the Manica, Sussundenga and Chockwé districts of Mozambique in the 2003/04 crop season.

The demand model results suggest that adoption rate, household wealth, distance to market, and input support programs (or free seed distribution) significantly influence farmers' seed purchase decisions. Wealth has a direct impact on seed demand and could be achieved through asset accumulation, credit access or competitive grain markets. To improve adoption rates and subsequently seed demand, 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 resistance to storage pests. Making seeds available to farmers at short distances will also improve adoption rate. Seed support programs, which can potentially damage rural seed market development should be implemented with care. 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 and contributes to the literature on farm level seed demand modeling.

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Introduction

Seed technological change fundamental to rural transformation sometimes by-passes some rural populations in developing countries. 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 probably inappropriate or less effective remain food insecure. In many sub-Saharan African countries where improved seed technology embodying genetic expressions for increased productivity has made less dramatic changes in agricultural productivity, incidence of rural poverty and food insecurity is pervasive (Rosegrant et al., 2001). If improved seed technology is to make a mark on the poverty of farm households in developing countries, researchers must not only concentrate on identifying determinants of adoption but also factors limiting seed demand at the farm level. In contributing to the methodological approaches to estimating seed demand within a developing country context, this study argues for the joint specification and estimation of adoption and seed demand models to account for the production and consumption attributes of seed that could cause simultaneity bias in single equation estimations.

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 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, 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 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.

In the past decades, enormous efforts have been devoted to getting an understanding of what determines the adoption of improved seed (See for example Kivlin and Fliegel, 1967; Aikens et al., 1975; Adesina and Zinnah, 1993; Smale et al., 1994; Morris et al. 1999; Doss et al., 2003; Langyintuo et al., 2003; and Moser and Barrett, 2005) but virtually no attention paid to seed demand. In contribution to the empirical methods necessary to improve farm level seed demand estimation in developing countries, this paper proposes the joint specification and estimation of improved seed adoption and demand models to account for both the input (production) and technological (consumption) aspects of seed, which was found to perform better than an ordinary least square (OLS) specification when fitted with data from Mozambique.

After all when a farmer decides to adopt an improved variety, he/she jointly decides on how much seed would be required to plant a predetermined area thereby signalling a potential simultaneity bias in a single equation estimation as demand and adoption are endogenously determined (Zepada, 1994).

The methodological approach employed in this study differs from past theoretical models and econometric methods that assumed separability in production and consumption (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). In this specific case, conditions are confounded by the intrinsic nature of the genetic attributes of seed, an inherent source of missing markets. It is usually the responsibility of the seed producer or retailer 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).

Conceptual framework

As noted above, an improved seed is a derived input for grain production and a technology as it embodies genetic expression of the plant unfamiliar to the farmer. As a derived input, seed uptake or purchase choice by farmers is influenced by government's input and output pricing policies, input support programs, etc. As a technology, on the other hand, farmer's own perceptions about the consumption attributes of the variety (such as taste), his/her socioeconomic circumstances, etc condition adoption decisions. This means that getting improved seed to farmers would require addressing both the technological and input aspects of seed simultaneously. That is, modelling farm household's production and consumption decisions in a non-separable form as being done here.

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 1966) 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:

$$U[X^g(F, a^c), Z^r, V \mid \Omega_h \Omega_l] \qquad \ldots (1)$$

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 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, seed and other inputs (e.g., fertilizer). The variety mix (local versus improved) is dependent on the farmer's perceptions of the intrinsic characteristics or attributes of the varieties.

Following Edmeades et al, 2003, define the production function Y as:

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

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 and N are household labor and fertilizer inputs, respectively, Ω_f the exogenous farm characteristics, and Ω_l as defined previously.

Farm households in semi-subsistence economies often face market imperfections such as high transactions costs of market participation. These transaction costs, which include transport costs and the consequences of imperfect and asymmetric information of market participation influence farmers' production decisions rather than exogenous market prices (de Janvry et al, 1991; Sadoulet and de Janvry, 1995). 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 entities.

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, fertilizer, 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

$$Y[Q, G^{d}(V, d^{p}), L, N \mid \Omega_{f}\Omega_{l}] \leq 0 \quad \ldots (4)$$

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

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

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

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

$$X_{i}, Q_{i}, S_{i}, all \geq 0 \ \forall i \in \tilde{S} \quad \ldots (9)$$

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:

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

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. Smallholder farmers in Mozambique plant both improved and local varieties of maize seed obtained mainly from the market, recycled from the previous harvest, and hand-outs under input support programs (Langyintuo et al., 2005). Using improved maize variety as target agricultural commodity, the model jointly estimates farm households improved variety adoption and seed demand (or purchase) decisions in Mozambique. As in most developing economies, some farmers did not plant improved varieties and therefore the dependent variable defined as the proportion of area under improved maize varieties is censored at zero. This implies a censored regression specified by a Tobit[1] model of the form:

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

Where: Y_i = proportion of area planted to an improved maize variety, i* = non-observed latent variable, 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 required to plant. Assuming that the variety is made available, the household seed purchase decision is conditioned by the traditional input market factors, as well as income and some household specific attributes that may form part of the adoption decision model. The demand model may be specified as follows:

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

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 (including seed hand-outs and recycling), 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.

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[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.

Survey locations and data used

Survey districts

The data used in this analysis were collected from the Manica, Sussundenga and Chockwé districts of Mozambique. The Manica and Sussundenga districts located in the Manica Province are in sub-humid areas while, the Chockwé district is in the semi-arid region. Annual average rainfall in the former districts ranges from 1014 – 1080 mm compared with a range of 600 – 932 mm for the latter district. The most common soils in the Manica district are brownish loamy clay while in the Sussundenga district they are yellowish-deep clay. Soils in the Chockwé district vary from 90% sandy loams along the coast to clayish with high undecomposed organic matter deposits in the wetlands.

Descriptive statistics of survey households

In each of the randomly selected districts of Manica, Sussundenga and Chockwé, 10 villages and 10 farmers per village were randomly selected. In all 300 farm households participated in the survey 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). Structured questionnaires designed to capture information on a range of potential indicators related to household livelihoods strategies were administered between August 2003 and July 2004 by trained enumerators directly supervised by research scientists from the Agrarian Research Institute of Mozambique, under the overall direction of CIMMYT scientists. The descriptive statistics of the selected farm households are presented in Table 1.

Household heads were predominantly males, constituting over 70% of household heads interviewed. Less than a third of the household heads are literate, with any formal education. Agriculture accounts for 22% and 21% of household income and expenditure, respectively. Of the estimated 3.6 ha cultivated annually, more than half was planted to maize. At the Manica, Sussundenga and Chockwé districts levels, maize accounted for 66%, 59% and 73% of the cultivated areas, respectively. Farmers planted an average of three different maize varieties on up to three different plots to reduce yield risk. Total quantity of seeds planted per maize farm of 2.4 ha was about 44 kg (22% being improved seed). Two major sources of seed were savings from the previous harvest (40%) and purchases from seed retail shops (55%). Some farmers received seed hand-outs under input support programs. The estimated improved maize variety adoption rates for the whole sample were 54% in terms of farmers and 12% in terms of cultivated area.

Choice of variables for empirical model

There is no firm economic theory that dictates the choice of independent variables for adoption studies therefore the variables in Table 2 reflecting (1) farm and farmer attributes, (2) organizational affiliation, and (3) technology specific characteristics were selected based on adoption literature. The farm and farmer characteristics in the model were used to evaluate whether human capital (age of household head, educational level, and household labor force), fixed social bias (or gender of household head) and maize farm size 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. Because extension staffs are few and predominantly male, female farmers are sometimes discriminated against in extension activities. 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 (Adesina and Zinnah, 1993). 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. 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, patronage of farmer field days on maize production, and beneficiary of an input support program, 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 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, seed availability on the local market, or consumer acceptability of the grain demonstrated by ease of sale of grain from the given seed, yield advantage, resistance to field pests, and storage pests as well as household level assessment of grain palatability. 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. Cost of seed is hypothesized to have a negative impact on adoption while the reverse is true for consumer acceptability. Given that varieties are developed in a participatory manner with farmers, household acceptability is expected to have a positive impact on farmers' adoption decisions.

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 "food deficit[2]" (Langyintuo et al., 2005). 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

[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.

including the adoption rate. 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 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. (2005) 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, they employed principal components analysis[3] method to create wealth indices for households in the selected districts. To account for seed affordability, household wealth status was included in the model as a proxy for financial status.

Distance to market 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 is hypothesized to have a negative effect on demand in line with economic theory.

Various governmental and NGO agents provide input (seed and fertilizer) support to vulnerable farmers to solve chronic food insecurity problems. Maize seeds supplied under such

[3] See Filmer and Pritchett (2001) for details of the analytical approach.

programs are improved seed either purchased from the market or through open tenders. Because beneficiary farmers are unlikely to patronize the commercial seed market, the input support program variable is hypothesized to have a negative impact on seed demand just as recycling of seed controlled by a variable "recycle". To account for district specific effects on adoption, Manica and Sussundenga district dummies were included in both demand and adoption models.

Empirical results and discussions

The estimated regression results in Table 3 showed that the simultaneous equation specification better explained seed demand in Mozambique than the OLS specification. In the former specification, the standard errors were relatively smaller and many variables were significant in explaining the variability in seed demand. Additionally, in the simultaneous equation specification, only three (gender, education and farm size) out of the more than two dozen explanatory variables had signs contrary to expectations compared with about a quarter of those in the OLS specification. Subsequent discussions on the results are restricted to the simultaneous equation specification.

Results from the seed demand estimation (lower portion of Table 3) showed that adoption rate, and wealth status of the household are statistically significant in explaining maize seed demand at 1% level of error probability, while distance to market and beneficiary of input supply program are statistically significant at 5% level. Farmers' level of liquidity plays a significant role in demand in line with economic principle. Within the Mozambican context, as in the case of most developing countries, where households are usually cash-trapped and have limited access to credit for varied reasons, their wealth is equivalent to their productive assets (Freeman et al, 2004; Ellis and Bahiigwa, 2003). The wealth status of households significantly influences quantities of seed purchased: the higher the ranking, the more seeds are purchased. Shifting a household from a lower wealth status to a higher one by a unit will increase seed purchase quantity by 0.4%. This suggests encouraging farmers to build their wealth through asset accumulation as a potential of improving their purchasing power and possibly increasing their participation in seed markets.

The significance of market access is clearly shown in the demand results. The farther away farmers are from markets, the less they consider profitability as an object of farming but rather self-sufficiency. Farmers are more likely to increase their seed demand from the market by 4% if markets are a kilometre closer to their villages. Two interpretations may be given for this result: either farmers are reluctant to travel far distances to buy seed or are concerned that if they produce excess grain and markets are not nearby they would have a problem disposing of the surpluses. Both of which are valid in the study area.

The significantly negative relationship between seed demand and input support programs suggest that seed hand-outs do not encourage farmers to participate in commercial seed markets. Once a farmer becomes a beneficiary of a government or NGO input support program, his/her investment in seed would decrease by 9%. Free seed handouts, usually in the order of 1 to 2 kg, complement farmers' own stock thereby reducing their seed demand from the market.

The results rightly point out that the quantity of seed a farmer is willing to purchase is positively influenced by maize area and the proportion planted to the improved variety (or the adoption rate). That is, increasing the proportion of land on improved seed by a percentage point would increase the quantity of seed purchased by over 27%. The relatively large capacity to expand area under the improved varieties is possibly due to the relatively low adoption rate in the study area (See Table 1). Given the simultaneity between demand and adoption, any recommendations on improving adoption rate and consequently seed demand must be derived from the corresponding adoption results presented in the upper portion of Table 3 and discussed below.

As shown in the upper portion of Table 3, exogenous variables found to be statistically significant in explaining adoption rate are household labor force, access to credit, availability of seed on the local market, seed purchase quantities, maize area, and the perceived superiority of the improved variety over the local ones in terms of yield and resistance to storage pests. Increasing labor force by a unit to cater for the extra labor required to harvest the increased yield would improve adoption rate by 4%. This might be possible through hiring of labor, which requires the mobilization of financial resources through assets accumulation. Demonstrating the superiority of improved varieties over the local ones in terms of yield and storage pests resistance could potentially increase adoption rate and area under the improved variety by 59% and 7%, respectively. Moving a farmer from lack of access to credit to access would potentially increase adoption rate and varietal use intensity by 6%. Bringing seed markets closer to farmers by a kilometre would improve adoption rate and use intensity of improved maize varieties would increase by 13%. Similar to the findings of Adesina and Zinnah (1993), but contrary to those of Edmeades et al. (2004), Langyintuo et al. (2003), and Moser and Barrett (2005), farm size negatively influenced adoption decisions. This is possibly because farmers with excess land would prefer to extensify for greater output while those with limited land intensify to maximize output and therefore willing to adopt high yielding improved varieties. As expected, if a farmer is able to purchase a kilogram of improved seed, then he/she will be able to expand the area under improved varieties by as much as 8%.

Conclusion and policy implications

This paper argues that estimating improved variety adoption and seed demand simultaneously to account for both the consumption and technological attributes of seed provides an efficient way of estimating seed demand at the farm level in developing countries. Using farm level data from Mozambique, the paper showed that input support programs can potentially damage rural seed market development. This seems to support the view that large-scale subsidized inputs often used as a vehicle to increase food security and reduce poverty following drought or civil unrest increase risk and uncertainty for emerging commercial input sector (Tripp and Rohrbach, 2000; Kelly et al., 2003). Therefore, in the interest of rural seed market development, more sustainable and cost effective ways of seed supply should replace seed hand-outs.

A strategy to improve access to markets by farmers has a potential of improving seed demand. This may require the institutionalization of the cereal banking (CB) concept known to work effectively in Western Kenya (Kelly, et al., 2003; Langyintuo, 2005). The CB concept allows farmers to learn how to bulk, store and market grains collectively at the community level. Their collective action gives them the power to bargain for better grain prices and other agricultural services. Once farmers have access to competitive markets, they have the ability to improve their overall household wealth and build assets reserves, which in the long run has a positive impact on their market participation. Another approach to improving the wealth base of farmers could be through the implementation of the so called Inventory Credit Programs (ICP) (Langyintuo, 2005) or similar rural development initiatives that allow farmers to use their collective grains in storage to source agricultural credit at harvest when grain prices collapse and farmers have the tendency to sell their marketable surpluses. As a hedge against risk, financial institutions typically limit the amount of the loan to a maximum of 75% of the value of the grains in storage. Farmers sell the grains when prices peak to pay back the loan and invest the balance as desired. Improving household wealth or credit access positively affects seed demand directly and indirectly through improving adoption rates. This might also mean that seed companies ought to consider supplying seed to farmers at locations nearer them directly, through input dealers or through the CB or ICP since farmers appear reluctant to travel long distances for seed.

The model clearly shows that increasing adoption rate would significantly improve quantities of seed demanded but how might that be achieved? An intervention strategy could be encouraging extension activities to emphasize field demonstrations that show the superiority of improved maize varieties over the local ones in terms of yield and storage pest resistance. Given the limited extension coverage by government extension services (Langyintuo et al, 2005), seed companies may consider investing in extension activities as well as demonstrations to improve their sales.

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 modeling.

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

	Manica (n=100)	Sussudenga (n=100)	Chockwé (n=100)	Whole sample (n=300)
Demographic characteristics				
Household size (number)	6.4	6.8	7.7	6.9
	(2-16)	(1-18)	(1-19)	(1-19)
Age of household head (years)	46.1	45.6	55.0	48.9
	(24-89)	(20-83)	(20-90)	(20-90)
Female headed households (%)	13	14	43	23
Membership of associations (%)	11	21	23	18
Illiterate household heads (%)	20	29	53	34
Physical assets (% of households)				
Ownership of pair of bullocks	21	20	22	21
Ownership of bicycle	47	49	42	46
Total tropical livestock units	5.34	7.64	6.16	6.38
	(0-89)	(10-113)	(0-45)	(0-113)
Crop production indices				
Total farm size (ha)	3.55	4.86	5.32	4.57
	(0.5-15)	(0.5-23)	(1-50)	(0.5-50)
Cultivated land area (ha)	3.045	3.55	4.26	3.62
	(0.5-14)	(0.1-15)	(1-22)	(0.1-22)
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)	66	59	73	66
Adoption rate (% of farmers)	83	58	22	54
Adoption rate (% of area)	23	8	5	12
Household income profile				
Total income (US$)	491.7	829.2	737.5	686.1
Agriculture (% of total)	19.7	18.2	29.4	22.4
Employment (% of total)	53.1	27.1	34	38.1
Other sources (% of total)	27.2	54.7	36.6	55.1
Household expenditure profile				
Total expenditure (US$)	254.2	225.0	591.7	356.9
Food and beverages (% total)	53.0	35.4	29.7	39.4
Farm inputs (% total)	20.4	20.1	23.0	21.2
Clothes (% total)	13.7	16.8	8.6	13.0
Miscellaneous (% total)	12.9	27.7	38.7	26.4

Note: In parenthesis are standard deviations
Source: Langyintuo et al. (2005).

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

Variable[1]	Definition	Mean (Standard deviation)
Adoption rate[2]	Proportion of cropped area under improved maize varieties	0.12 (0.19)
Male farmer	A binary variable with 1 if household head is a male and zero otherwise	0.77 (0.42)
Age of household head$^{(-/+)}$	Age of household head	48.89 (14.6)
Education	Years of formal education of household head	1.82 (0.71)
Household labor force	Household labor force estimated in man-equivalent units	4.96 (2.63)
Maize area	Cultivated area under maize (ha)	2.75 (2.15)
Association membership	A binary variable with 1 if household head belongs to a farmers' association and 0 otherwise	0.18 (0.39)
Patronage of Field days	A binary variable with 1 if household head has attended at least two field days in a year and 0 otherwise	0.16 (0.36)
Input support program	Binary variable with 1 if household is a beneficiary of NGO of government agricultural input support program and 0 otherwise	0.31 (0.46)
Access to credit	A binary variable with 1 if household head had access to credit and 0 otherwise.	0.13 (0.34)
Seed cost$^{(-)}$	A binary variable with 1 if farmer perceives that the improved maize seed is more costly than the best local variety and 0 otherwise	0.83 (0.38)
Seed availability	A binary variable with 1 if farmer perceives that the improved maize seed is more readily available than local one and 0 otherwise	0.28 (0.45)
Consumer acceptability	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	0.81 (0.39)
Yield potential	A binary variable with 1 if farmer perceives that the improved maize yields more than the best local variety and 0 otherwise	0.47 (0.50)
Field pests resistance	A binary variable with 1 if farmer perceives the improved variety is more resistant to field pests than the local variety and 0 otherwise	0.20 (0.40)
Storage pests resistance	A binary variable with 1 if farmer perceives the improved variety is more resistant to storage pests than the local variety and 0 otherwise	0.20 (0.40)

Table 2: (Cont.)

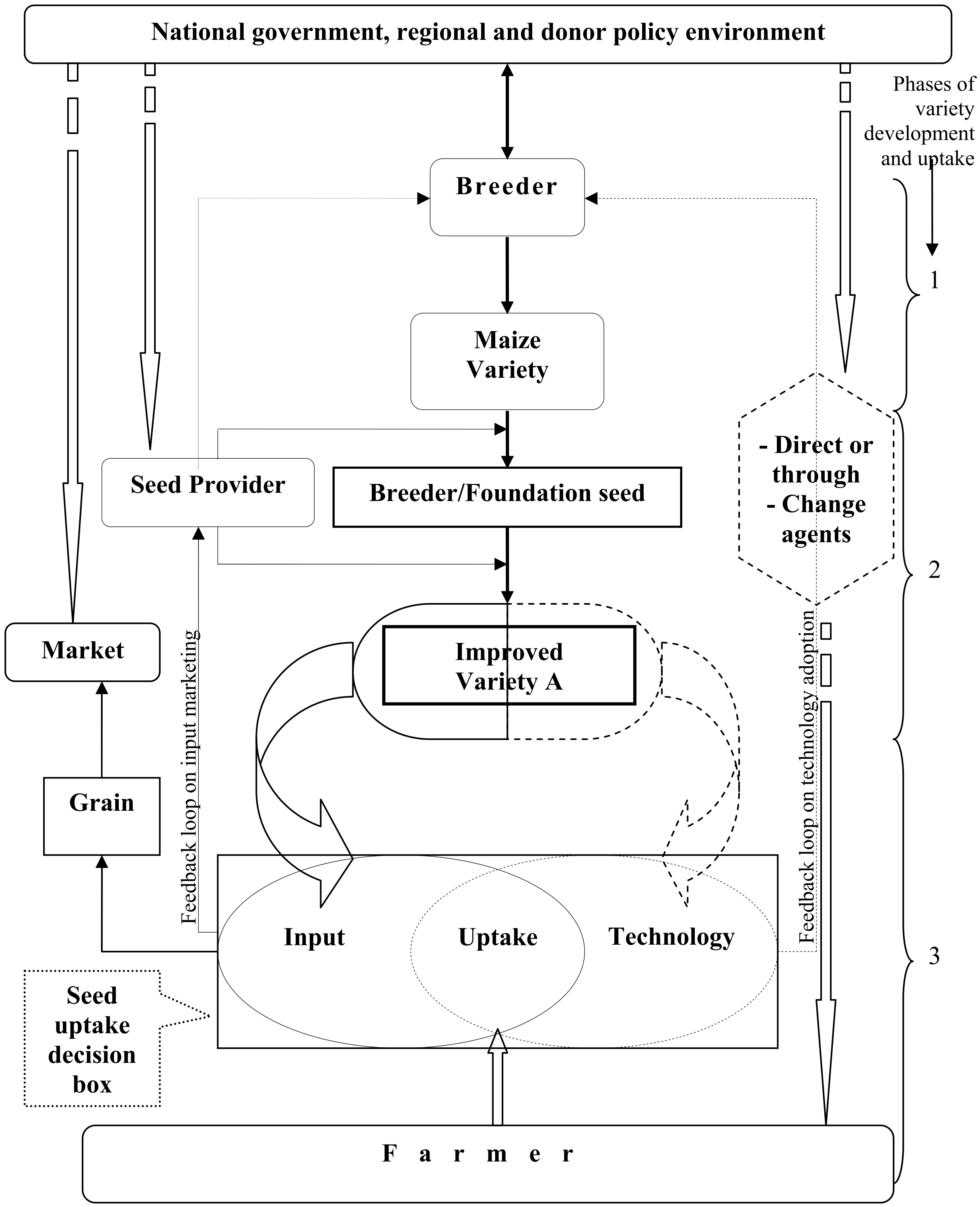
Variable1	Definition	Mean (Standard deviation)
Household acceptability	A binary variable with 1 if farmer perceives that the improved maize variety is more palatable than the local one and 0 otherwise.	0.18 (0.38)
Seed purchase[3]	Quantity of seed purchased (kg)	18.34 (35.63)
Food deficit	A binary variable with 1 if household was food self-insufficient and 0 otherwise	(-9.90 (101.36)
Household wealth	Wealth index category	1.80 (0.75)
Maize price[(-)4]	Maize price (x1000 ZK)	41.20 (111.10)
Distance to market [(-)]	Distance to output markets in physical units	14.24 (17.3)

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 Malawian currency is called Meticais (MT). The exchange rate in May 2005 was: 1US$ = 24,000 MT

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

	OLS specification		Simultaneous specification		
	Coefficient	Standard error	Coefficient	Standard error	Elasticity at the mean
			Adoption model		
Male farmer	4.8101	5.2607	-0.0026	0.0302	-
Age of household head	-0.2005	0.1534	-0.0001	0.0009	-
Educational status	-9.6729**	3.3394	-0.0060	0.0191	-
Association membership	-5.9607	5.5673	0.0430	0.0306	-
Household labor force	-0.3685	0.9287	0.0156**	0.0048	0.4305
Access to credit	-3.0336	6.1649	0.0827**	0.0352	0.0612
Patronage to field days	-4.4858	14.0424	0.1051	0.0810	-
Input support program	1.4181	5.5502	0.0326	0.0312	-
Seed cost	3.5877	5.6927	-0.0170	0.0325	-
Seed availability	3.6770	5.2303	0.0864**	0.0297	0.1341
Consumer acceptability	-0.5584	5.5167	-0.0462	0.0316	-
Yield potential	12.5326**	4.9780	0.2263**	0.0288	0.5855
Field pests resistance	0.7649	5.7587	0.0130	0.0331	-
Storage pests resistance	-4.3954	5.2931	-0.0634*	0.0305	-0.0691
Household acceptability	4.2018	5.6731	0.0350	0.0325	-
Maize area	-0.4160	1.1712	-0.0325**	0.0058	-0.4957
Seed purchase	-	-	0.0008**	0.0003	0.0862
Manica dummy	-	-	0.0779	0.0468	-
Sussundenga dummy	-	-	-0.0442	0.0384	-
Constant	-	-	0.0758	0.0823	-
			Seed demand model		
Distance to market	-0.0601	0.1494	-0.0737*	0.1446	-0.0449
Food deficit	-0.0326	0.0206	-0.0270	0.0195	-
Household wealth	13.3414**	3.1208	10.0931**	2.5791	0.0037
Adoption rate	7.9806	9.9799	27.3104**	8.2037	0.2685
Input support program	-	-	-1.9731*	5.3593	-0.0916
Maize price	0.0002	0.0008	0.0004	0.0007	-
Maize area	-	-	0.7743	1.1502	-
Manica dummy	-5.7608	21.2313	-3.4945	20.0211	-
Sussundenga dummy	-12.9404	10.6749	-9.9423	9.9864	-
Constant	33.7066	48.4578	-1.0074	44.0815	-
R-Squared	0.1947		0.4399		

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



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 et al. (2005)