The Role of Income Diversification, Transaction Cost and Production Risk in Fertilizer Market Participation

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Abstract
Past agricultural input market participation studies have generally ignored the joint influence of income diversification, transaction cost and production risk on input market participation decisions. This study develops an analytical framework that jointly incorporates the three factors and other household factors in farmer-fertilizer market participation decisions. The framework is then tested by analyzing the entry and intensity decisions of fertilizer market participation in semi-arid eastern Kenya, at the farm level. Transaction costs and production risk negatively influence both the entry and intensity decisions, while income diversification positively influences the entry decisions. These results are confirmed by nested likelihood ratio tests which show that inclusion of each of the three factors improve the explanatory power of both the entry and intensity decision models except in one case: inclusion of income diversification in the intensity decision model. Inclusion of all three factors is therefore strongly recommended in future agricultural input market participation studies.

Keywords: Income diversification, transaction cost, production risk

1. Introduction

Improved access and participation in both input and output markets is necessary for better economic performance of farmers and in reducing poverty in many regions in the world (Wiggins, 2000; McCuloch and Ota, 2002; Shyamal, 2006, Barrett, 2008). In addressing the issue of "linking farmers to markets," more attention has generally been given to participation in output markets than input markets (see Jaffee, 1990; Gilg and Battershill, 1999; McCuloch and Ota, 2002; Govereh and Jayne, 2003; Fafchamps and Hill, 2005; Kan *et al.,* 2006). However, access and participation in input markets (like the fertilizer market) has the potential of raising farmer incomes just as participation in high value output markets.

Fertilizer has two striking attributes: it supplies readily available nutrients for increased soil fertility and productivity; it is labour saving as opposed to manure and the excess labour can be re-deployed on the farm, sold off-farm, allocated to leisure or the savings used to purchase other inputs (Wakimoto, 2004). All these attributes have the potential of increasing farmer well-being. However, current evidence reveals that fertilizer consumption in Sub-Saharan Africa (SSA) is only 9 kg of nutrients per ha per year, compared to 73 in Latin America and 100-135 in Asia, where as much as 50 percent of the Green Revolution yield growth is attributed to fertilizer use (Kelly, 2006). Additionally, nutrient degradation in SSA is estimated at 30-60 kg of nutrients per ha per year (Oluoch-Kosura, 2007), indicating declining soil fertility, a threat to SSA agriculture.

This paper contributes to the literature on input market participation by evaluating the joint role of income diversification, transaction costs and production risk. Income diversification (on-farm/off-farm) may relax a farmer's financial constraint and hence improve the capacity to participate in an input market. Additionally, income diversification may mitigate the effects of production risk, leading to more optimal production choices (Lamb, 2003). Transaction costs include both physical and non-physical costs involved in exchange. High transaction costs in inputs markets may discourage farmer participation. Production risk is considered as the effect of weather crop production, which may increase or reduce farmer input market participation.

Recent studies on farmer-fertilizer market participation in Sub-Saharan Africa include Green and Ng'ong'ola (1993), Negassa *et al.* (1995), Nkonya *et al.* (1997), Adugna (1997), Croppenstedt (2003), Ade and Omiti (2003), Kelly (2006), Marenya and Barrett (2007) and Alene *et al.* (2008). The major limitation of these studies is that they seem to generally ignore the joint influence of the three factors discussed above (the role of income diversification, transaction costs and production risk). In a departure from these studies, an analytical framework that jointly incorporates the three factors is developed and tested, with an application in Kenyan fertilizer market. Kenya is chosen for the test because of data availability.

The paper is organized into six sections. The present section gives the introduction. The second and third sections present the theoretical and empirical frameworks, respectively. The fourth section describes the data used, while the fifth section presents the results and discussion. Conclusion and suggestions for further research are given in the sixth section.

2. Theoretical Framework

A farmer needs to decide whether or not to buy fertilizer as an input for producing an agricultural commodity q and the amount to buy. However, she faces transaction costs which includes market information search (for example which fertilizers to buy and the places to buy them), and the cost of travelling to the fertilizer market. In order to model the fertilizer market participation decision making process, it is assumed the farmer is risk averse, with a constant risk aversion coefficient of r. The degree of risk aversion is assumed to be homogenous for all farmers. As well, the possibility of production risk is allowed but without price risk. The farmer can also diversify income by engaging in off-farm employment. The objective of the farmer is to maximize expected utility of income. For simplicity, fertilizer and labour are taken as the only variable inputs in producing output q and expenditure on other inputs is fixed.

Using the mean-variance utility function, the farmer's objective to maximize expected utility of income [$EU(M)$] can be specified as:

$$Max\ EU(M) = \overline{\pi} - TC + NFI - \frac{1}{2} r \sigma_m{}^2 \tag{1}$$

In equation (1), M is total income, $\overline{\pi}$ is expected farm profit, TC is transaction cost in the fertilizer market and NFI off-farm income. $TC = PTC + FTC$, where PTC is proportional transaction cost and FTC is fixed transaction cost. $\frac{1}{2} r \sigma_m{}^2$ is the risk premium, where $\sigma_m{}^2$ represents the variance of income. According to Key *et al.* (2000), and Goetz and Debertin (2001), PTC includes per-unit costs of accessing markets associated with transportation and imperfect information. FTC includes: search for a market; negotiation and bargaining; and screening, enforcement and supervision.

Assuming risk in farming, equation (1) can be expanded to:

$$\underset{x,l}{Max} \quad EU(M) = p_q\bar{q} - p_x x - k - t_p x - FTC + w(f-l) - \frac{1}{2}r\sigma_\pi^{\ 2} \tag{2}$$
$$x \geq 0$$

Where x is amount of fertilizer purchased, p_q is price of the agricultural commodity q, $\bar{q} = Eq$ is the expected value of agricultural output q, p_x is the price of fertilizer, k is fixed expenditure on other inputs, t_p is per unit proportional transaction cost for fertilizer, w is wage rate (income diversification incentive), f is family labour available for work (fixed), l is the labour requirement in the farm and $\sigma_\pi^{\ 2}$ is the variance of farm income. It is assumed that family labour and hired labour are perfect substitutes and labour is sold or hired in the same market at price w. The production function which includes production risk is specified as follows:

$$q = f(x,l;z_q) + h(x,l;z_q)\theta \tag{3}$$

Where q is output, z_q is a vector of production shifters (which include farm household characteristics), θ is a random variable which measures the effect of weather, where $E\theta = 0$ and $Var(\theta) = \sigma_\theta^2$. θ is considered not known to the farmer at the time input decisions are made.

Substituting (3) in (2) and simplifying gives the following:

$$U(M) = p_q f(x,l;z_q) - (p_x + t_p)x - k - FTC + w(f-l) - \frac{1}{2}rp_q^2 h^2(x,l;z_q)\sigma_\theta^{\ 2} \tag{4}$$

Let $U(M)_{wp}$ be expected utility of income *without* participating in the fertilizer market and $U(M)_p$ be expected utility of income *with* participating in the fertilizer market. It is assumed that a rational farmer would maximize equation (4), obtain the optimum amount of fertilizer (x^*) and substitute back into the utility function. If $U(M)_p > U(M)_{wp}$, the farmer will go ahead and use fertilizer (entry decision). However, If $U(M)_p \leq U(M)_{wp}$ she does not purchase fertilizer. The first order condition for maximizing equation (4) is given as:

$$\frac{\partial U(M)}{\partial x} = p_q f_x(x,l;z_q) - (p_x + t_p) - rp_q^2 h(x,l;z_q)h_x \sigma_\theta{}^2 - \lambda = 0 \tag{5a}$$

$$\lambda x = 0 \quad x \geq 0; \ \lambda \leq 0$$

$$\frac{\partial U(M)}{\partial l} = p_q f_l(x,l;z_q) - w - rp_q^2 h(x,l;z_q)h_l \sigma_\theta{}^2 = 0 \tag{5b}$$

Solving equations (5a) and (5b) simultaneously gives for the optimal amounts of fertilizer (x^*) and labour (l^*) demanded as follows.

$$x^* = g_1(p_q, p_x, z_q, w, t_p, r, \bar{\theta}, \sigma_\theta{}^2) \tag{6a}$$

$$l^* = g_2(p_q, p_x, z_q, w, t_p, r, \bar{\theta}, \sigma_\theta{}^2) \tag{6b}$$

Substituting x^* and l^* into the expected utility function, the fertilizer market entry decision (D) can be specified as:

$$D = g_3(p_q, p_x, z_q, w, t_p, r, \sigma_\theta{}^2) \tag{7}$$

3. Empirical Framework

Because of lack of data on farm labour demand, the study only considers fertilizer demand. For empirical purposes, q is taken as expected aggregate crop output and p_q an aggregate price measure. Since the technical relationship between fertilizer and labour in aggregate crop production is unknown, a linear fertilizer demand equation is assumed. Because of the unavailability of fertilizer prices, fertilizer price perception (or unaffordability) is used as a proxy for price of fertilizer.

Incorporating the assumption of homogeneity in risk preferences, the farmer demand equation for fertilizer is linearly specified as follows:

$$x^* = \alpha_o + \alpha_1 p_x + \alpha_2 p_q + \alpha_3 z_q + \alpha_4 t_p + \alpha_5 DIV + \alpha_6 \sigma_\theta^{\ 2} + e \qquad e \sim N(0, \sigma_e^{\ 2}) \qquad (8)$$

Where DIV is the incentive to diversify income and e is the error term. The incentive to diversify includes possibilities of the farmer diversifying income from one crop to many crops, to livestock production and to off-farm employment. It can therefore be specified as follows:

$$DIV = \delta_0 + \delta_1 z_d + \mu_1 \quad \mu_1 \sim N(0, \sigma_{\mu_1}^{\ 2}) \qquad (9)$$

Where z_d is a vector of factors including wage rate off-farm, value of livestock and number of crops grown. On the other hand, proportional transaction cost (t_p) and the variance of weather effect (σ_θ^2) are un-observable. t_p and σ_θ^2 are therefore expressed as functions of other variables z_t and z_w as follows:

$$t_p = \gamma_0 + \gamma_1 z_t + \mu_2 \qquad \mu_2 \sim N(0, \sigma_{\mu_2}^2) \tag{10}$$

$$\sigma_\theta^2 = \phi_0 + \phi_1 z_w + \mu_3 \quad \mu_3 \sim N(0, \sigma_{\mu_3}^2) \tag{11}$$

Where z_t include years of education, distance to the nearest fertilizer market, access to agricultural extension and agricultural group membership, while z_w includes use of drought resistant crop varieties, access to permanent water source and agro-climatic zone. Production shifters or farm household characteristics (z_q) include age of the farmer, gender, family size, crop farm size and access to production credit. Substituting equations (9), (10) and (11) in equation (8) gives:

$$x^* = \beta_0 + \alpha_1 p_x + \alpha_2 p_q + \alpha_3 z_q + \alpha_4 \gamma_1 z_t + \alpha_5 \delta_1 z_d + \alpha_6 \phi_1 z_w + v \tag{12}$$

Where $\beta_0 = \alpha_0 + \alpha_4 \gamma_0 + \alpha_5 \delta_0 + \alpha_6 \phi_0$, $v = e + u_1 + u_2 + u_3$ and $v \sim N(0, \sigma_v^2)$. Equation (12) can be simplified as follows:

$$x^* = \beta_0 + \beta_1 p_x + \beta_2 p_q + \beta_3 z_q + \beta_4 z_t + \beta_5 z_d + \beta_6 z_w + v \tag{13}$$

The models capturing fertilizer market participation decisions are specified as follows:

Entry decision to participate in fertilizer market

$$D = \begin{cases} 1 & if U(M)_p > U(M)_{wp},\ x^* > 0 \\ 0 & otherwise \end{cases} \tag{14}$$

Intensity decision of participation in the fertilizer market

$$x = \begin{cases} x^* & if\ D = 1 \\ 0 & if\ D = 0 \end{cases} \tag{15}$$

And x^* is as specified in equation (13)

The entry decision is estimated by the *probit* model while the intensity decision is estimated by the *Tobit* model. Since the income diversification (DIV) variables (i.e. off-farm wage rate and value of livestock) are endogenous, predicted values are used instead of real values. Predictions are made following the *Heckman's two step procedure*, to cater for the possibility of sample selection. Age, age squared, family size, education and inverse mills ratio are used to obtain predicted off-farm wage rate. The same variables in the off-farm wage-rate equation, in addition to value of farm implements are used to obtain predicted value of livestock.

It is expected that the more a farmer is informed (through education, extension and group membership) coupled with a shorter distance to the fertilizer market, the lesser transactions costs become and hence increased participation in the fertilizer market. In addition, income diversification is hypothesized to positively influence fertilizer market participation, if fertilizer use is labour saving, if the farmer is financially constrained or if income risk is mitigated. Production risk is hypothesized to negatively influence fertilizer market participation.

4. Data Sources

The data was collected from 228 farmers in the semi-arid areas of Eastern Kenya, by means of semi-structured questionnaires. The survey was undertaken jointly by the Kenya Agricultural Research Institute (KARI-Katumani) and the University of Nairobi, under the Collaboration on Agricultural/Resource Modeling and Applications in Semi-Arid Kenya (CAMASAK) project. The area covered was a catchment of about 5000 Km^2, comprising three districts (i.e. Machakos, Makueni and Kitui). Geographical Information System (GIS) guided random sampling procedure was used to select farmers to be interviewed. Using this procedure, 30 blocks (1 km^2 each) were randomly selected from the catchment. Farmers were then randomly interviewed in these blocks. The survey was based on long-rain and short-rain seasons of the year 2003. Questions asked include: farm household characteristics; farm enterprise(s); soil fertility management/soil and water conservation technologies; and marketing and institutional support. However, price of fertilizer and on-farm wage rate was not reported. A summary of descriptive statistics of the variables is included in the appendix (Table 1).

5. Results and Discussion

The results presented in Table 2 show that, the perception that fertilizer is unaffordable, value of crop products, family size, distance to the nearest fertilizer market and being in a favourable agro-climatic zone influence both the entry and intensity decisions of fertilizer market participation, at the ten percent significance level or better. Out of these factors, the perception that fertilizer is unaffordable, family size and distance to the nearest fertilizer market negatively influence fertilizer market participation. On the other hand, value of crop products and being in a favourable agro-climatic zone positively influence fertilizer market participation. This means that farmers in a favourable agro-climatic zone, who perceive that fertilizer is affordable, have small family sizes, live near a fertilizer market and receive higher product prices have a higher likelihood and intensity of participating in the fertilizer market. The negative influence of the distance to the nearest fertilizer market shows that *transaction costs* discourage both the entry and intensity decisions of farmers into fertilizer markets. Alene *et al.* (2008) also find the same result. In addition, the positive influence of a favourable agro-climatic zone (or negative influence of unfavourable agro-climatic zone) shows that *production risk* also discourages the entry and intensity decisions of fertilizer use; hence the farmers are *risk averse*. The negative influence of family size may be related to the *labour saving property* of fertilizer. Farmers with small family sizes may want to save labour, hence purchase more fertilizer. In addition, farmers with small family sizes may have more income available to them, improving their ability to purchase fertilizer.

Variables which influence only the entry decisions are gender (male), access to credit, access to a permanent water source, number of crops grown and off-farm wage rate. All these variables have a positively influence. The positive influence of the number of crops grown and off-farm wage rate is a sign that *income diversification (Div)* positively influences *only* the entry decisions to participate in fertilizer market. The use of drought resistant varieties only influences the intensity decisions. This is further evidence that production risk discourages the intensity decisions.

The observed positive influence of income diversification on the fertilizer market entry decisions can be explained by three reasons: (1) Fertilizer is a labour saving input (compared to manure for example) and hence is more preferred if farmers have to diversify income sources (2) Income diversification relaxes the financial constraints of farmers and hence their ability of buy fertilizer (3) Income diversification mitigates the effects of production risk, leading to more optimal production choices, such as greater use of fertilizer.

Likelihood ratio tests at the bottom of Table 2 indicate that, all the variables included in the two models are jointly able to explain both the entry and intensity decisions of fertilizer market participation, at one percent significance level. Nested likelihood ratio tests for income diversification, transaction costs and production risk are summarized in Table 3. Joint inclusion of income diversification, transaction cost and production risk variables significantly improve the explanatory power of both the entry and intensity decision models of fertilizer market participation. Inclusion of each of the three factors also improves the explanatory power of the two models except in one case: inclusion of income diversification in the intensity decision model. In other words, inclusion of income diversification improves the explanatory power of the entry decision model but not the intensity decision model. This confirms the earlier finding that transaction costs and production risk influence both the entry and intensity decisions of fertilizer market participation, while income diversification influences only the entry decisions.

6. Conclusion and Suggestions for Further Research

This study develops an analytical framework that incorporates the possible effects of income diversification, transaction costs and production risk on the entry and intensity decisions of fertilizer market participation. The framework is then tested in the fertilizer market in Kenya.

According to the results, the perception that fertilizer is unaffordable, value of crop products, family size, distance to the nearest fertilizer market and being in a favourable agro-climatic zone influence both the entry and intensity decisions fertilizer market participation. The perception that fertilizer is unaffordable, family size and the distance to the nearest fertilizer market negatively influence fertilizer market participation. Value of crop products and being in a favourable agro-climatic zone positively influence fertilizer market participation. Gender (male), access to credit, access to a permanent water source, number of crops grown and off-farm wage rate only influence the entry decisions, while the use of drought resistant varieties only influences the intensity decisions.

The study concludes that both transaction costs and production risk discourage the entry and intensity decisions of fertilizer market participation, while income diversification encourages the entry decisions. These results are confirmed by likelihood ratio tests which show that inclusion of each of the three factors improve the explanatory power of both the entry and intensity decision models of fertilizer market participation except in one case: inclusion of income diversification in the intensity decision model. Inclusion of income diversification, transaction costs and production risk is therefore strongly recommended in future input market participation studies. Future studies may also consider joint estimation of fertilizer and labour demand functions, under heterogeneous risk preferences.

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Appendix

Table 1. Descriptive Statistics

Variable	Description	Mean	Std.Dev.
Dependent Variables			
Fertilizer use (Decision)	Dummy variable; 1=a farmer buys fertilizer, 0 otherwise	0.39	0.49
Amount of fertilizer purchased (Intensity)	Continuous variables; measured in kg purchased per year	47.39	124.45
Independent Variables			
Prices			
Fertilizer price perception (p_x)	Dummy variable; 1=fertilizer is unaffordable, 0 otherwise	0.87	0.33
Value of crop products (p_q)	Continuous variable; measured in thousand Kshs	13.25	17.82
Production shifters (z_q)			
Age of the farmer	Continuous variable; measured in years	48.39	14.75
Gender (male)	Dummy variable; 1 = Male, 0 = Female	0.70	0.46
Family size	Continuous variable; number of children in a family	5.45	3.12
Crop farm size	Continuous variable; measured in acres	3.95	3.28
Access to production credit	Dummy variable; 1=Farmer received credit, 0 otherwise	0.18	0.38
Transaction cost (z_t)			
Years of education	Continuous variable; measured in years	6.43	3.96
Distance to nearest fertilizer market	Continuous ; measured in km	4.89	4.74
Access to agricultural extension	Dummy Variable; 1=Farmer received extension, 0 otherwise	0.19	0.39
Agricultural group membership	Dummy variable; 1=Group member, 0 otherwise	0.39	0.49
Income diversification (z_d)			
Number of crops grown	Continuous variable	3.78	0.93
Value of livestock	Continuous variable; measured in thousand Kshs	33.90	46.74
Off-farm wage rate	Continuous variable; measured in thousand Kshs per month	2.02	4.83
Production risk (z_w)			
Use of drought resistant varieties	Dummy variable; 1=use drought resistant varieties, 0 otherwise	0.18	0.39
Access to permanent water source	Dummy variable; 1= Near a permanent water source, 0 otherwise	0.39	0.49
Agro-climatic zone (good climate)	Dummy variable; 1= Higher agro-climatic zone, 0 other wise	0.47	0.50

Sample size = 228 for all variables

Table 2. Summary of Regression Results for Fertilizer Market Participation Models

Variable	Entry Decision Model (Probit)					Intensity Decision Model (Tobit)				
	Coefficient	t-value	Marginal effect	t-value	Elasticity (at mean)	Coefficient	t-value	Marginal effect	t-value	Elasticity (at mean)
Constant	-1.685*	-1.688	-0.586*	-1.703		-216.537	-1.466	-56.060	-1.492	
Prices										
Fertilizer price perception (p_x)	-1.011***	-2.613	-0.383***	-2.679	-0.970	-111.353***	-2.457	-28.828***	-2.310	-0.608
Value of crop products (p_q)	0.013*	1.707	0.004*	1.714	0.147	2.021*	1.931	0.523*	1.918	0.146
Production shifters (z_q)										
Age of the farmer	0.008	0.640	0.003	0.641	0.335	2.765	1.479	0.716	1.471	0.731
Gender (male)	0.568**	2.241	0.184***	2.453	0.465	35.948	0.920	9.307	0.921	0.196
Family size	-0.146**	-2.294	-0.051**	-2.291	-0.703	-18.919**	-2.051	-4.898**	-2.017	-0.563
Crop farm size	-0.053	-1.078	-0.019	-1.084	-0.186	-1.759	-0.247	-0.456	-0.247	-0.038
Access to production credit	0.833***	2.746	0.313***	2.719	0.143	34.542	0.843	8.943	0.850	0.189
Transaction cost (z_t)										
Years of education	0.022	0.506	0.008	0.507	0.122	3.820	0.567	0.989	0.568	0.134
Distance to nearest fertilizer market	-0.171***	-4.104	-0.059***	-4.571	-0.736	-22.316***	-3.685	-5.777***	-4.314	-0.596
Access to agricultural extension	0.230	0.716	0.083	0.696	0.210	18.772	0.429	4.860	0.428	0.103
Agricultural group membership	0.081	0.340	0.028	0.339	0.072	49.993	1.390	12.943	1.381	0.273
Income diversification (z_d)										
Number of crops grown	0.285**	1.953	0.099**	1.930	0.950	3.554	0.178	0.920	0.178	0.073
Predicted value of livestock	0.006	1.108	0.002	1.111	0.172	0.844	1.110	0.218	1.112	0.156
Predicted off-farm wage rate	0.172*	1.821	0.060*	1.819	0.307	10.464	0.744	2.709	0.744	0.116
Production risk (z_w)										
Use of drought resistant varieties	0.475	1.644	0.175	1.577	0.444	97.328**	2.463	25.197**	2.388	0.532
Access to permanent water source	0.440*	1.798	0.156*	1.799	0.395	25.663	0.717	6.644	0.723	0.140
Agro-climatic zone (favourable climate)	1.482*	5.207	0.491*	6.012	1.244	174.894***	4.107	45.279***	4.190	0.955
Log likelihood function	-93.078					-643.816				
Restricted log likelihood	-152.947					-694.508				
Chi squared	119.738***					101.383***				
Sample size	228					228				

* Significant at 10 percent or better; ** significant at 1percent, *** significant at 1 percent

Table 3. Likelihood Ratio Test Results for the Fertilizer Market Participation Models

Entry Decision Model (Probit)					
Tests	*Log L* (Ω_0)	*Likelihood ratio statistic* (ψ)	*Number of restrictions (R)*	*P-value*	*Decision*
Ho: $\beta_4 = \beta_5 = \beta_6 = 0$	-133.283	80.409	10	0.000	Reject Ho
Ho: $\beta_4 = 0$	-105.440	24.725	4	0.000	Reject Ho
Ho: $\beta_5 = 0$	-97.204	8.252	3	0.041	Reject Ho
Ho: $\beta_6 = 0$	-110.050	33.945	3	0.000	Reject Ho
Intensity Decision Model (Tobit)					
Tests					
Ho: $\beta_4 = \beta_5 = \beta_6 = 0$	-675.100	62.568	10	0.000	Reject Ho
Ho: $\beta_4 = 0$	-655.066	22.499	4	0.000	Reject Ho
Ho: $\beta_5 = 0$	-644.740	1.847	3	0.605	Accept Ho
Ho: $\beta_6 = 0$	-656.214	24.796	3	0.000	Reject Ho

Note: β_4, β_5 and β_6 represent the coefficients of transaction cost, income diversification and production risk variables respectively as specified in equation (13).

$\psi = -2[\log L(\hat{\Omega}_0) - \log L(\hat{\Omega})]$, where log L $(\hat{\Omega})$ = - 93.078 and - 643.816 for entry and intensity models respectively; the P-value is $1 - prob[\chi^2(\psi, R) > 0]$