SUPPLY RESPONSIVENESS OF MAIZE FARMERS IN KENYA: A FARM-LEVEL ANALYSIS

John Olwande[1], Margaret Ngigi[2], Wilson Nguyo[3]

[1]Egerton University, Tegemeo Institute, Kenya (olwande@tegemeo.org)

[2]Egerton University, Njoro, Kenya *(ngigim@yahoo.com)*

[3]Egerton University, Njoro, Kenya

Contributed Paper prepared for presentation at the International Association of Agricultural Economists' 2009 Conference, Beijing, China, August 16-22, 2009.

ABSTRACT

This study assessed how responsive maize output is to price and non-price factors and how sensitive fertilizer and labour demand are to prices and non-price factors using cross-sectional farm-level data for 334 maize producing households in the High Potential Maize Zone of Kenya. The study employed normalized restricted translog profit function to estimate maize supply and variable input demand elasticities. Results show that maize price support is an inadequate policy for expanding maize supply. Fertilizer use was found to be particularly important in the decisions on resource allocation in maize production. Of the fixed inputs, land area was found to be the most important factor contributing to the supply of maize. It is suggested that making fertilizer prices affordable to small holder farmers by making public investment in rural infrastructure and efficient port facilities, and promoting standards of commerce that provide the incentives for commercial agents to invest in fertilizer importation, wholesaling and retailing would be desirable. Encouraging more intensive use of other productivity enhancing inputs in addition to fertilizer is also suggested, since land consolidation to achieve economies of scale may seem untenable in the light of the existing extensive sub-division of land parcels into uneconomical units.

Key words: Maize supply response, Kenya

1. Introduction

Maize is a major staple food for over 80% of Kenya's population (Nyameino, Kagira, and Njukia, 2003) and shortage in maize supply is, to a large extent, synonymous with food insecurity. Due to the importance of maize for food security, the government of Kenya (GoK) has over the years pursued policies that influence production and marketing of maize. The policies, which have gone through several reforms, have mainly been based on the objective of self-sufficiency in maize. Currently the government intervenes in the maize market in three ways: variable import tariffs on maize imports, maize procurement at support prices by the NCPB, and non-tariff barriers on maize imports. These policies are aimed at maintaining stabilized and reasonably high maize prices as incentives for producers to produce more maize.

With respect to input delivery systems, the GoK reformed fertilizer marketing system by decontrolling fertilizer prices and leaving it entirely to the private sector and cooperatives to supply farmers.

Despite the government's pursuit of these maize pricing policies, Kenyan maize production has not kept pace with consumption. Annual maize consumption average 34 million bags while production averages 30 million bags. The emphasis on higher and stabilized maize producer prices as a means to motivate increased maize production seems not to be working. While input prices including fertilizer prices as well as non-price factors including land, access to markets, and household demographic characteristics including education often influence farm production, how Kenyan maize producers respond to these input prices and non-price factors has not been taken into consideration, and less emphasis has been put on them in the policy objective of increased maize production for food self-sufficiency and security. The objective of this paper is to provide an empirical understanding of Kenyan maize output response to price and non-price factors. It is hoped that the information revealed will complement the store of information that is already available on production in the maize sub-sector, and inform public and private researchers and policy makers seeking to understand more of the Kenyan maize sub-sector.

2. Materials and Methods

2.1 Study area, data and sampling

This study is confined to the High Potential Maize Zone (HPMZ) of Kenya. The choice of this zone was based on the region's dominance in commercialization of maize production relative to other regions. The study used cross-sectional farm household data provided by Tegemeo Institute of Egerton University. The data covers main crop season of 2003/2004 cropping year for 334 households. Multistage and systematic sampling techniques were used in selecting the sample of households.

2.2 Empirical model

This paper uses the dual (or reduced form) approach to supply analysis. In the dual (or reduced form) approach, the production technology set is not estimated directly. The approach involves estimation of a profit function from either cross-sectional data (that show inter-farm variation in effective prices) or from long run time series data that show variation in prices and fixed factors or from a combination of the two data types (Sadoulet and de Janvry, 1995). Supply and factor demand functions, from which output supply and input demand elasticities are estimated, are then derived analytically. This approach is mainly used in cases with limited information on relevant primal variables and where possible estimation problems are associated with the production function approach (Chambers, 1988; Sadoulet and de Janvry, 1995).

Using profit function, Lau (1978) has shown that the restricted profit function, defined as the excess of total value of output over the costs of variable inputs, is expressed as:

$$\pi = \pi(\mathbf{p}, \mathbf{w}; \mathbf{z}) \quad 1$$

where π, $\mathbf{p}$ and $\mathbf{w}$, respectively, represent restricted profit and vectors of output and input prices, while $\mathbf{z}$ represents quantities of fixed factors of production. This function depicts the maximum profit the farmer could obtain given prices, availability of fixed factors and the production technology. The optimization (using Hotelling's Lemma) of the profit function (1) gives the profit-maximizing level of output supply and input demand functions respectively as:

$$\mathbf{y}_m (\mathbf{p}, \mathbf{w}; \mathbf{z}) = \partial\pi(\mathbf{p}, \mathbf{w}; \mathbf{z}) / \partial\, \mathbf{p}_m, \quad 2$$

and

$$-\mathbf{x}_n (\mathbf{p}, \mathbf{w}; \mathbf{z}) = \partial\pi(\mathbf{p}, \mathbf{w}; \mathbf{z}) / \partial\, \mathbf{w}_n \quad 3$$

where *m* and *n* index the outputs and variable inputs respectively. In the case of a single output, a normalized restricted profit function (defined as the ratio of the restricted profit function to the price of the output), π^*, can be specified. It depicts the maximized value of normalized profits given normalized (relative) prices of the variable inputs, $\mathbf{w}_n^*$, and the quantities of fixed factors, i.e.,

$$\pi^* = \pi^*(\mathbf{w}^*; \mathbf{z}) \quad 4,$$

from which the factor demand equations are derived as:

$$-\mathbf{x}_n (\mathbf{w}^*; \mathbf{z}) = \partial\pi^*(\mathbf{w}^*; \mathbf{z}) / \partial\, \mathbf{w}_n^*, \quad 5$$

In the case of multi-output normalised profit function, the numéraire is the output price of the n[th] commodity (Färe, *et al.*, 1995). Normalisation has the purpose of removing any money illusion - in other words, producers respond to relative price changes. Normalisation also reduces the demand on degrees of freedom, by effectively reducing the number of equations and parameters to estimate. The system of normalized restricted profit function and factor demand equations are simultaneously estimated. Output supply and input demand elasticities are computed from the estimated parameters of the profit function and input demand equations.

This study has adopted the translog functional form of the profit function, which has a convenient property of being flexible both in the sense of allowing for theoretical restrictions to be tested and offering a second order approximation of any function.

The normalized restricted profit function in translog form is given by:

$$\begin{aligned} In\pi^* &= \alpha_o + \sum_{i=1}^{2}\alpha_i In\mathrm{P}_i^* + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2}\gamma_{ij} In\mathrm{P}_i^* In\mathrm{P}_j^* + \sum_{i=1}^{2}\sum_{k=1}^{3}\delta_{ik} In\mathrm{P}_i^* InZ_k \\ &+ \sum_{k=1}^{3}\beta_k InZ_k + \frac{1}{2}\sum_{k=1}^{3}\sum_{h=1}^{3}\psi_{kh} InZ_k InZ_h + DU \end{aligned} \qquad 6$$

where,

π^* = Restricted profit, π , normalized by the output price (P) (Ksh/kg)

P_i^* = Price of *i*th input (P_i) normalized by the output price (P) (Ksh/kg)

i =1, fertilizer price

=2, wage rate

Z_k = Quantity of fixed input, *k*.

k =1, area under maize

=2, education level of the household head

=3, distance to motorable road

$\alpha_o, \alpha_i, \gamma_{ij}, \delta_{ik}, \beta_k, \psi_{kh}$, are parameters to be estimated.

In = Natural logarithm

The corresponding share equations are expressed as,

$$S_i = \frac{\mathrm{P}_i \mathrm{X}_i}{\pi} = -\frac{\partial In\pi^*}{\partial In\mathrm{P}_i^*} = -\alpha_o - \sum_{j=1}^{2} \gamma_{ij} In\mathrm{P}_j^* - \sum_{k=1}^{3} \delta_{ik} In\mathrm{Z}_k \qquad 7$$

$$S = \frac{\mathrm{PX}}{\pi} = 1 + \frac{\partial In\pi^*}{\partial In\mathrm{P}} = 1 - \sum_{i=1}^{2} \alpha_i - \sum_{i=1}^{2}\sum_{j=1}^{2} \gamma_{ij} In\mathrm{P}_j^* - \sum_{i=1}^{2} \sum_{k=1}^{3} \delta_{ik} In\mathrm{Z}_k \qquad 8$$

where S_i is the share of *i*th input in the restricted profit, S is the share of output in the restricted profit, X_i denotes the quantity of input *i* and X is the level of maize output. The input and output shares form a singular system of equations (since by definition $S - \sum S_i = 1$). The profit and factor share equations were estimated as a simultaneous system.

It was expected that not all the households used fertilizer in the production of maize. In such a situation it requires that a correction for zero use of variable input by means of a two-step Heckman procedure is specified (Amemiya, 1984). The first step of the Heckman procedure involves the estimation of the probability of using an input by means of a probit maximum likelihood using the following binary choice model:

F^*=Hθ+u

where F^* is an unobserved latent variable determining a household's decision to buy an input, H is a set of household characteristics hypothesized to affect the input use, and u is error term. The observed binary variable will be:

F^*=1 (i.e., F^*>0, for users of the input)

=0, otherwise (i.e., F^*<0, for non-users of the input)

Then, the resulting values of the vector θ are used to compute vectors of inverse Mills ratios, $M_1 = \frac{\Theta}{\Phi}$ and $M_2 = \frac{-\Theta}{1-\Phi}$, respectively, for sub-samples of users and non-users of the input. **Θ** and **Φ** are respectively the standard normal density and cumulative distribution evaluated at the point Hθ (Savadogo, Reardon and Pietola, 1995). In the second stage, the adjusted demand function for the input in question is estimated along with the other equations in the system by including M_1 and M_2 as regressors for users and non-users respectively of the input. Once this correction is made, all observations, including observations where the input was not used in production, can be used to estimate the input demand equation. In the context of the present study the adjusted input share equation thus is of the form:

$$S_i = \frac{P_i X_i}{\pi} = -\frac{\partial In\pi^*}{\partial In P_i^*} = -\alpha_o - \sum_{j=1}^{2} \gamma_{ij} In P_j^* - \sum_{k=1}^{3} \delta_{ik} In Z_k + \mu(M_1) \quad \text{or} \tag{9}$$

$$S_i = \frac{P_i X_i}{\pi} = -\frac{\partial In\pi^*}{\partial In P_i^*} = -\alpha_o - \sum_{j=1}^{2} \gamma_{ij} In P_j^* - \sum_{k=1}^{3} \delta_{ik} In Z_k + \mu(M_2)$$ for the users and non-users respectively of the input.

Since the parameters appearing in the input and output share equations 7 and 8 also appear in the profit function 6, increased efficiency would be obtained if all these equations were estimated jointly. However, after normalization of the profit and input prices by the output price, the output share equation 8 is dropped and the estimation proceeds with the profit equation 6 and the variable input share equations 7 or 9.

The model represented by 6, 7 or 9 involves a system of seemingly unrelated regressions where contemporaneous correlations across equations are assumed. For efficient estimators, Zellner's estimation technique for seemingly unrelated regressions (Zellner, 1962) was employed.

2.3 Hypothesized Effects

A summary of the price and non-price variables that were included in the estimation of the model and the expected sign of maize supply elasticity with respect to the variables are presented in Table 1.

Table 1: Price and Non-price Variables Included in Model Estimation

Variable	Description	Measurement	Expected maize supply elasticity
nprofit	Restricted profit	Kenya shillings	
P_1	Price of fertilizer	Kenya shillings per kilogram	-
P_2	Wage rate	Kenya shillings per day	-
Z_1	Land area under maize	Acres	+
Z_2	Household head's education	Kilometres	-
Z_3	Distance to the nearest motorable road	Number of years of formal schooling	+
M	Inverse Mills Ratio		
Seeduse	Dummy variable for type of maize seed used	1=improved maize seed, 0=unimproved maize seed	
Income	Household income	Kenya shillings	

3. Results and Discussion

3.1 Socio-economic Characteristics of Maize Production in Kenya

The households were predominantly small holder maize producers, with 44 % having less than one acre under maize. Only six out of the 334 households had more than 10 acres under maize. 88% of the households used fertilizer on maize while, 91% used improved[1] maize seed. Mean fertilizer use on maize was 66 kg/acre while mean maize yield was 1433 kg/acre. Education level (number of years of formal schooling) of the household head ranged from zero to 16 years, with a mean of 6.8 years. 19 % of the households had the heads having zero

[1] Improved maize seed refers to new hybrid and new open pollinated variety (OPV).

years of formal schooling while 66 % of the households had the heads having below nine years of formal schooling.

The sample was corrected for zero fertilizer use by applying the Heckman procedure, since excluding from the sample the 12% of the households that did not use fertilizer on maize was not feasible. Since the Heckman procedure requires that at least one variable that does not enter the fertilizer share equation be included in the probit estimation, a dummy for use of improved maize seed was included in the probit estimation. This variable was not included in the fertilizer share equation. Table 2 reports the probit estimation results for fertilizer use. The goodness of fit measure (likelihood ratio chi-square of -81with a p-value of 0.0000) shows that the variables are highly significant in explaining fertilizer use and that the model as a whole is statistically significant in explaining fertilizer use, as compared to a model with no predictors. Households that used improved maize seed were more likely to use fertilizer in maize production than households that used unimproved maize seed. Level of education of household head significantly affects the probability of using fertilizer. Larger area under maize increases the probability of using fertilizer, albeit insignificantly.

Table 2: Factors influencing probability of using fertilizer on maize production

Variable	Coef.	Std. Err.	z	P>z
Z_1	0.01788	0.03032	0.59000	0.5550
Seeduse	0.81015	0.30344	2.67000	0.0080
Z_3	-0.41842	0.12878	-3.25000	0.0010
P_1	0.21808	0.03524	6.19000	0.0000
Z2	0.02128	0.02358	0.90000	0.3670
Income	0.00000	0.00000	0.29000	0.7700
Intercept	-4.75185	0.92234	-5.15000	0.0000

*Significant at 5 % level or below.
The Likelihood Ratio chi-square is -81.043223 with a p-value of 0.0000

The inverse Mill's ratio was generated for each household and additively included as a regressor in the fertilizer share equation. The parameter estimates of the profit function model are reported on Table 3. Homogeneity was automatically imposed because the normalized specification was used. For the monotonicity condition to hold in the translog model, the estimated output shares must be positive at all data points, which were found in this case.

Table 3: Parameter estimates of the profit function model

Parameter	Estimate.	Standard Error	t-statistic	p-value
α_0	6.8821***	0.0906	75.9500	0.0000
α_1	-0.0731**	0.0299	-2.4400	0.0150
α_2	-0.1377***	0.0200	-6.8800	0.0000
γ_{11}	-0.1701***	0.0285	-5.9700	0.0000
γ_{12}	0.0342**	0.0153	2.2300	0.0260
γ_{22}	-0.0853***	0.0164	-5.2100	0.0000
δ_{11}	-0.0155**	0.0076	-2.0300	0.0430
δ_{12}	0.0113	0.0077	1.4600	0.1430
δ_{13}	0.0389*	0.0215	1.8100	0.0710
δ_{21}	0.0107	0.0071	1.5000	0.1330
δ_{22}	0.0080	0.0072	1.1100	0.2680
δ_{23}	-0.0201	0.0177	-1.1400	0.2550
β_1	0.9795***	0.0596	16.4500	0.0000
β_2	-0.0055	0.0953	-0.0600	0.9540
β_3	0.0794	0.2097	0.3800	0.7050
ψ_{11}	0.1548***	0.0323	4.7900	0.0000
ψ_{12}	-0.0449*	0.0267	-1.6800	0.0930
ψ_{13}	-0.0409	0.0705	-0.5800	0.5620
ψ_{22}	0.0707	0.0672	1.0500	0.2930
ψ_{23}	-0.0546	0.0628	-0.8700	0.3850
ψ_{33}	0.1318	0.3001	0.4400	0.6610
R^2 Profit function				0.7536
R^2 Fertilizer share function				0.1904
R^2 Labour share function				0.0541

***Significant at 1%, **Significant at 5%, *Significant at 10%

The elasticity estimates are presented in Table 4. The elasticities are functions of the variable input shares, variable input prices, levels of fixed inputs, and the parameter estimates of the normalized restricted translog profit function. The elasticities were computed at mean values of the variables.

Table 4: Computed elasticities of maize supply and fertilizer and labour demand

	Elasticity of:		
	Maize output	Fertilizer Demand	Labour Demand
With respect to:			
Maize price	0.11	0.44	0.84
Fertilizer price	-0.06	-0.12	-0.46
Wage rate	-0.08	-0.33	-0.38
Land area	0.94	1.92	0.89
Distance to motorable road	0.05	-0.2	0.18
Education	0.17	0.01	0.06

Source: Authors's computation from TIAPID household survey data of 2003/2004

The own-price supply elasticity of maize is positive as expected and is consistent with theory. A 10 % increase in the price of maize would result into a 1.1% increase in the supply of maize, holding the prices of the variable inputs and the quantities of the fixed inputs constant. The inelasticity of maize supply to maize price implies that whether maize prices are favourable or not farmers will be reluctant to substantially raise or reduce their maize production. There are reasons for this. Maize is the main staple food for a large section of the population and 75 % of the total maize output is produced by the smallholder farmers. These smallholder farmers are mostly subsistence in nature and rely on maize both for own consumption and for revenue generation. The subsistence nature of maize farmers implies that maize producer price changes may not have substantial influence on the decision of the farmers on whether to produce or not to produce maize. Again, most small scale maize producers are net maize buyers, implying that maize production is not majorly a business enterprise among the small scale producers. As such, maize producer price changes are likely to have little influence on the decision of the small holder farmers to raise or reduce their production.

Variable input prices have a depressing effect on maize output. A 10 % increase in the price of fertilizer would lead to a 0.6% reduction in maize output while a 10 % increase in the price of labour would lead to a 0.8% reduction in maize output, *ceteris paribus*. It is surprising that the elasticity of maize output with respect to fertilizer price is less than the elasticity of maize output with respect to wage rate in absolute terms. This is likely to reflect the lower usage of chemical fertilizer compared to labour usage, partly because the effective price of fertilizer is too high for most of the small holder maize farmers.

The most important fixed input in terms of maize output response is land (elasticity of 0.94). This suggests that maize output would expand by about 9% if land area under maize were to increase by 10%. This, however, need not imply support for a general policy of increasing the size of holdings so that more land can be allocated to maize production. It may be that there are many small-holding maize farms that are smaller than the minimum efficient size, so the objective would be to expand area under maize to be above the minimum efficient size.

Maize output is least responsive to market access (distance to motorable road) (elasticity of -0.05). Market access has equally low influence on demand for fertilizer and labour, with elasticity for labour having an unexpected sign. Education of the household head (the main decision maker of the household) is not important, though it positively influences maize supply (elasticity of 0.17). This again emphasizes the dominance of maize production among the Kenyan rural households, irrespective of education level.

The own-price elasticity of demand for fertilizer is negative as suggested by theory. Fertilizer demand is, however, price inelastic. A 10 % decrease in the price of fertilizer would result into a 1.2 % increase in the demand for fertilizer, *ceteris paribus.* This suggests that policies targeting fertilizer price would be reasonable for encouraging fertilizer use on maize to improve productivity and production. Maize price and land area are also important factors affecting fertilizer use, with elasticities of 0.44 and 1.92 respectively. These elasticity estimates imply that fertilizer demand would increase more with an increase in maize prices than with a decrease in fertilizer prices. It is, however, noteworthy that raising maize prices would hurt the welfare of urban maize and maize products consumers and the welfare of small holder maize farmers most of whom are net maize buyers. The suggestion would be to focus policy on fertilizer prices with the aim of making fertilizer more affordable and available to the majority of small holder maize farmers. The elasticity of fertilizer demand with respect to land area indicates that increased acreage under maize is associated with higher use of fertilizer.

Labour demand is inelastic to changes in the wage rate, having an own-price elasticity of 0.38 in absolute terms, though the negative sign of the elasticity estimate is consistent with economic theory. If this is a general phenomenon in all agricultural areas and across all agricultural enterprises in Kenya, then 'surplus' labour in the agricultural areas will only be absorbed, if it is, by large reductions in wage rates. By the same token, out-migration will have a substantial effect on the rural wage rates. Increases in maize price would encourage the expansion in demand for labour just as it would for fertilizer demand. However, a 10 % increase in maize price would raise the demand for labour by 8.4 % compared to 4.4 % by which such an increase in maize prices would raise fertilizer demand. This implies that labour demand is more sensitive to maize price incentives than fertilizer demand. As expected, land area was found to have an expansionary effect on the demand for labour with estimated elasticity close to unity (0.89). Market access (distance to motorable road) had an expansionary effect on labour demand (elasticity of 0.18) against expectation, though the magnitude of the effect was low. Labour demand would also increase with the expansion of the level of education of the household head (elasticity of 0.06). The negative cross-price elasticities of fertilizer and labour demand suggest that fertilizer and labour are more of complementary inputs than substitutes in maize production.

4. Conclusion and Recommendations

To increase aggregate production of maize in Kenya, a support price policy appears to be inadequate and unattractive. This is because most of the maize producers are small holders who also double as net maize buyers. A higher maize price support would result into hurting the welfare of the small holder maize farmers, who happen to be the majority. A higher maize price support would favour only the few larger and commercial maize farmers who are net maize sellers, but in the overall reduce the welfare of a larger section of the population, including the urban population.

More focus should be on reducing fertilizer price since it assumes a key significance in influencing the fundamentals of maize production. The options that could be exploited to reduce fertilizer price include making public investment in rural infrastructure and efficient port facilities and promoting standards of commerce that provide the incentives for commercial agents to invest in fertilizer importation, wholesaling and retailing. These developments would not only increase fertilizer use on maize but also would lead to more use of fertilizer on other crops. This would result into a sector-wide increase in agricultural productivity and production.

Finally, land size is found to be far more important in affecting production of and resource use in maize than price incentives. Increasing the size of land holdings through consolidation may be desirable as maize output is responsive to land area, suggesting scale economies. However, in Kenya where population pressure has resulted into extensive sub-division of parcels of land into uneconomical units, the process of consolidation may seem untenable. A more appropriate option may be to encourage more intensive use of productivity enhancing inputs. A part from fertilizer discussed above, high yielding maize seed varieties are another input whose adoption and use could be encouraged. This could be done through intensification of extension services' provision and shifting focus to avenues that could make credit more accessible to especially small holder maize farmers.

References

Amemiya, T. (1984), Tobit Models: A Survey, *Journal of Econometrics,* 24: 3-61.

Chambers, R.G. (1991), *Applied Production Analysis: A Dual Approach*, Cambridge University Press, Cambridge.

Färe, R. and Primont, D. (1995), *Multi-output Production and Duality: Theory and Applications*, Kluwer Academic Publishers, Massachusetts.

Lau, J. L. (1978), Applications of Profit Functions, in Jorgenson, D. W. and Waelbroeck, J. (eds), *Production Economics*: *A dual Approach to Theory and Applications. Volume 1*, North-Holland.

Nyameino, D., Kagira, B. and Njukia, S. (2003), Maize market Assessment and Baseline Study for Kenya, Regional Agricultural Trade expansion Support Program (RATES), Nairobi, Kenya.

Sadoulet, E, and de Janvry, A. (1995), *Quantitative Development Policy Analysis*. Johns Hopkins University Press , Baltimore, Maryland.

Savadogo, K., Reardon, T. and Pietola, K. (1995), Mechanization and Agricultural Supply Response in the Sahel: a Farm-level Profit Function Analysis, *Journal of African Economies,* 4:337-77.

Zellner, A. (1962), An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias, *Journal of the American Statistical Association,* 57: 348-68.