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Supply Response of Ethiopian Farmers to Price and Non-Price Factors

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SUPPLY RESPONSE OF ETHIOPIAN FARMERS TO PRICE AND NON-PRICE FACTORS: A Micro-economic Analysis

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Abstract: *The main purpose of this study is to examine the responsiveness of peasant farmers to changes in price and non-price factors. To this end, quadratic production and restricted profit functions are fitted to farm-level survey data from Ethiopia. The results indicate that farmers respond significantly to price incentives, but the effect of prices on output supply and fertilizer demand is negligible. The most important finding is that non-price factors are far more important in affecting production and resource use than price incentives. The results underscore the need to strengthen market incentives through effective policies that will improve farmers' access to land and credit, public investment in roads and irrigation. The results are robust to whether primal or dual approach is used to estimate elasticities.*

Introduction

Agriculture in Ethiopia contributes about 45% of GDP, 90% of total exports, and 80% of employment[1]. The peasant sector, which produces more than 90% of crop output, is characterised by poor and outdated farming technology, acute shortage of purchased inputs particularly fertilizer, poor infrastructure and marketing facilities. Added to these are the ever-increasing population and bad weather conditions. Superimposed on these mainly structural bottlenecks are institutional rigidities and policy constraints. Policies have always been biased against the peasant sector, more so during the 70s and 80s due to the complex mix of administrative control on markets and prices ranging from compulsory delivery of output to controlling the movement of output by setting road blocks.

Since 1992, the present government has been undertaking reform measures that affect the incentive structure and productivity of the peasant sector. The most important economy-wide policies are devaluation of the domestic currency and credit policies that withdrew previleged access to state farms and co-operatives. In addition, more direct agricultural policies have been taken that include, among others, early and rapid move towards deregulating food grains markets[2], as well as price support for export crops. This was further strengthened by subsequent reforms in agricultural input markets, with much emphasis on fertilizer. The reform measures of the 1990s have mostly focused, directly or indirectly, on getting prices right.

With little or no room for area expansion, growth in the agricultural sector largely depends, at least in the foreseeable future, on the effectiveness of yield-increasing measures, particularly use of fertilizer. Having recognized this, the government has, from the outset, put fertilizer at the centre of its development strategy. Beginning with the issuance of National Fertilizer Policy in 1993, the government has been taking several measures including gradual liberalization and deregulation of fertilizer markets and prices which was completed in 1998, and elimination of fertilizer

[1] Unless otherwise specified, national figures are from various statistical documents of Central Statistical Authority (CSA) and Ministry of Economic Development and Co-operation (MeDAC).
[2] Note that deregulation of food grains markets has started as early as 1989 by the previous government.

subsidies in 1997. Most importantly, a new system of extension program was launched in 1994/95.

Following the favourable environment created by these policies, agricultural output has increased. Nevertheless, how much of this recovery is due to price incentives and how much due to non-price factors is not all too clear. The official assessment of the on-going reform program is that recovery in agricultural production is mainly due to peasant supply response to price incentives[3]. However, the growth rate of agricultural output is relatively higher in those years (for example, 1992/93 and 1994/95) of more favourable weather conditions than drought years, for example 1993/94, when the growth rate was even negative. Further, Dercon and Lulseged (1994) conclude that the increase in official exports would come from devaluation of the *Birr* because of reduced smuggling rather than from production response to increased incentives. Alem (1996) also found low and insignificant price elasticity of export supply following changes in effective exchange rate.

It was also reported that fertilizer use has increased in recent years mainly in response to incentive measures, particularly lower retail prices, and also due to the recent extension program (Techane, 1999). The question however remains as to whether or not sustainable use of fertilizer is being hampered by rising prices in recent years as a result of the devaluation of the Birr, high local transport tariff, and elimination of subsidies. Above all, the response of output to increased use of fertilizer has not been carefully examined. On the other hand, there are indications that the full benefit of the drive to increase fertilizer use has not been realized as it is reflected by the sizeable stock of unsold fertilizer every year. For instance, only about 59 and 64 per cent of the fertilizer made available for sale are actually sold in 1996 and 1997 respectively (Mulat and Techane, 1999).

In general, ambiguities abound about the precise role and impact of agricultural policies. Partly this is attributed to lack of farm-level study of the impact of policies (particularly producer prices) on the supply response of peasant farmers. The few

[3] For more details on the recent reform programs and impacts, see Abrar (2000).

supply response studies that have been carried out are based on aggregate time series data (see for e.g., Dercon and Lulseged 1994; Alem 1995; Zerihun, 1996), and nearly all of these studies emphasise on impacts of economy-wide policies on export supply response, particularly coffee[4]. Micro-economic studies of supply response are generally few in Sub-Saharan Africa where lack of farm level data is more acute, but there are recent examples (see for e.g., Savadogo, *et al*, 1995; Hattink, *et al*, 1998).

In Ethiopia, several micro-economic studies of resource use efficiency have shown that the potential for efficiency and productivity gains in peasant agriculture is immense (e.g., Abrar, 1996; Abbay and Assefa, 1996; Croppenstedt and Mulat, 1997). These studies used only Cobb-Douglas production functions to estimate the extent of efficiency, and they only provide supply elasticities in response to changes in physical input levels, ignoring the role of prices on production and input allocation decisions of farmers. Finally, key non-price factors that condition farmers' response, such as rainfall and infrastructure, are not usually included in the analysis.

Against this stark, this study primarily aims at examining peasant responsiveness to price and non-price factors in Ethiopia using farm-level survey data. As a secondary objective, the paper assesses the extent to which estimates and inferences are sensitive to whether primal or dual approaches are used. To this end, both production and profit functions are estimated and elasticities derived using the quadratic functional form.

Data and Estimation Procedure.

The data we use is the Ethiopian Rural Household Survey (ERHS) which is a nation wide survey of rural households that has been conducted during 1994-2000. The survey was undertaken in 15 villages across the country (which include the four largest regions where well over two-thirds of the population live) from which nearly 1500 households are selected randomly[5]. It is believed to account for the diversity of

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[4] The only exception is Zerihun (1996) who, also using aggregate time series data, investigated relationships between producer prices of foodgrains and size of cultivated land, and has forecasted that little change in aggregate food grain production occurs following incentive measures.

[5] The final sample consists of smaller observations (1154 households) than the original (1477) as farmers with either lower cultivated land than 0.1 or zero labour or zero output or zero and negative profit are excluded, a procedure which has excluded one of the villages (Harasaw) altogether as

the farming system in the country. Large geographic dispersion of the sampled villages on the one hand and big differences in accessibility of the same to input and output markets on the other means that there is large variation in effective prices.

Two variable inputs, fertilizer and labour, and three fixed inputs, total area under crops adjusted for quality, animal power, and farm capital are used to estimate supply response of aggregate crop output. We have also included other three structural and conditioning factors namely land access, infrastructure, and rainfall. The definition of and summary statistics on the variables used are given in Appendices A and B. For empirical estimation, we use the quadratic functional form. The normalized restricted profit function is given by[6]:

$$\Pi^* = \alpha_\circ + \sum_i^2 \alpha_i W_i^* + \sum_k^7 \beta_k Z_k + \frac{1}{2}\left(\sum_i^2 \sum_j^2 \gamma_{ij} W_i^* W_j^* + \sum_k^7 \sum_h^7 \delta_{kh} Z_k Z_h \right)$$
$$+ \sum_i^2 \sum_h^7 \phi_{ih} W_i^* Z_h + D + \varepsilon \quad \text{..........} (1)$$

where,

Π^* = normalized restricted profit,

W^*_i = price of input i, normalized by output price (P)

= 1, fertilizer price,

= 2, wage rate,

Z_k = quantity of fixed input or other exogenous variable k,

k =1, area cultivated ,

=2, animal power,

=3, farm capital,

=4, land quality,

=5, land access,

=6, road density,

=7, rainfall,

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virtually all the farmers did not produce anything. More observations are excluded due to a preliminary analysis of outliers based on the examination of residuals.

[6] Restricted profit function is defined as the excess of total value of output over the costs of variable inputs Lau (1976), and depicts the maximum profit the farmer could obtain given prices, availability of fixed factors and the production technology. In the case of a single (aggregate) output, we can specify a normalized restricted profit function which is defined as the ratio of the restricted profit function to the

D = dummy for farming system. α_0, α_i, β_k, γ_{ij}, δ_{kh}, and ϕ_{ih} are parameters to be estimated. ε is error term with the usual properties. Using Hotelling's Lemma, the corresponding input demand equations are derived as:

$$-X_i = \alpha_i + \sum_j^2 \gamma_{ij} W_j^* + \sum_h^7 \phi_{ih} Z_h + \upsilon_i, i = 1,2 \qquad (2)$$

where X_i denotes the quantities of variable inputs, and ν is the error term. For maximum efficiency, the system of input demand equations and the profit function are estimated simultaneously. The output supply equation is not included in estimation as it becomes redundant under normalized specification, and its parameters are recovered residually from:

$$Y = \Pi^* + \sum_i^2 W_i^* X_i \qquad (3)$$

where Y is the aggregate output index. The cross-equation (symmetry) restrictions and the possibility of error correlation among the system of equations could make OLS estimator inefficient. For efficient estimation we used iterative Seemingly Unrelated Regression. Parameter estimates of the normalized restricted profit function, with symmetry imposed, are presented in Table 1. Linear homogeniety is automatically maintained because we are using the normalized specification as we should in the case of aggregate output.

We conducted a Wald test for symmetry subject to homogeniety. The null hypothesis is that the parameters of the input demand equations are equal to the corresponding same parameters of the profit function. This is a joint hypothesis on the validity of imposing 20 restrictions in estimating the input demand and the profit functions jointly. A joint test of symmetry was rejected. The majority of dual studies which reported tests for symmetry also rejected the hypothesis (for e.g., see Shumway, 1983; Wall and Fisher, 1987; Savadogo *et al*, 1995). However, since symmetry is a necessary condition for deriving the input demand equations from the profit function, we imposed it in our estimation.

(aggregate) price of the output.

Table 1. Parameter Estimates[1]

Parameter	Dual	Primal	Parameter	Dual	Primal	Parameter	Dual	Primal
α_o	126.033	146.230	δ_{77}	0.000	0.000	δ_{56}	0.000	0.000
	(0.61)	(0.72)		(1.09)	(1.25)		(4.56)***	(4.65)***
α_1	-6.77	0.868	δ_{12}	-12.148	-11.584	δ_{57}	0.000	0.000
	(0.88)	(11.23)***		(1.68)*	(1.61)		(1.42)	(1.61)
α_2	-5.49	1.873	δ_{13}	0.914	0.920	δ_{67}	0.000	0.000
	(0.59)	(14.40)***		(2.01)**	(2.03)**		(8.28)***	(8.18)***
β_1	154.58	130.038	δ_{14}	-16.580	-15.902	ϕ_{11}	1.998	-0.011
	(2.56)**	(2.16)**		(0.53)	(0.51)		(1.51)	(0.73)
β_2	122.560	80.78	δ_{15}	-0.015	-0.016	ϕ_{12}	-15.059	0.010
	(2.94)***	(1.95)*		(0.27)	(0.29)		(14.72)***	(0.79)
β_3	0.662	0.776	δ_{16}	0.013	0.015	ϕ_{13}	-0.313	0.000
	(0.27)	(0.32)		(3.56)***	(4.19)***		(5.69)***	(0.74)
β_4	-8.505	17.943	δ_{17}	0.105	0.125	ϕ_{14}	5.756	-0.096
	(0.04)	(0.08)		(3.82)***	(4.55)***		(1.53)	(2.33)**
β_5	0.923	0.93	δ_{23}	0.016	0.012	ϕ_{15}	-0.006	0.000
	(2.93)***	(2.96)***		(0.08)	(0.06)		(1.47)	(1.21)
β_6	-0.105	-0.095	δ_{24}	-50.113	-49.097	ϕ_{16}	-0.005	0.000
	(4.46)***	(4.03)***		(2.18)**	(2.14)**		(10.07)***	(6.87)***
β_7	-0.14	0.25	δ_{25}	-0.109	-0.110	ϕ_{17}	-0.003	0.000
	(1.04)	(1.90)*		(2.00)**	(2.02)**		(1.07)	(3.85)***
γ_{11}	7.761	-0.320	δ_{26}	0.020	0.020	ϕ_{21}	-5.047	-0.022
	(3.38)***	(1.06)		(7.31)***	(7.54)***		(3.16)***	(0.92)
γ_{22}	15.618	-0.400	δ_{27}	0.064	0.073	ϕ_{22}	-4.969	0.023
	(8.61)***	(9.85)***		(3.32)***	(3.78)***		(4.03)***	(1.17)
γ_{12}	3.140	0.100	δ_{34}	0.449	0.015	ϕ_{23}	-0.237	0.000
	(2.20)**	(2.95)***		(0.39)	(0.01)		(3.59)***	(0.26)
δ_{11}	-34.867	-35.086	δ_{35}	0.005	0.005	ϕ_{24}	-6.473	-0.138
	(3.77)***	(3.80)***		(1.68)*	(1.90)*		(1.44)	(2.00)**
δ_{22}	-7.779	-6.639	δ_{36}	0.000	0.000	ϕ_{25}	-0.009	0.000
	(1.37)	(1.17)		(2.63)***	(2.69)***		(1.74)*	(0.25)
δ_{33}	-0.017	-0.026	δ_{37}	0.000	0.001	ϕ_{26}	-0.001	0.000
	(0.97)	(1.47)		(0.43)	(1.12)		(2.51)**	(6.18)***
δ_{44}	12.064	-7.936	δ_{45}	-0.203	-0.194	ϕ_{27}	-0.023	0.000
	(0.10)	(0.07)		(1.26)	(1.21)		(6.75)***	(7.81)***
δ_{55}	0.000	0.000	δ_{46}	-0.003	-0.005	D	55.960	46.989
	(5.09)***	(5.71)***		(0.27)	(0.44)		(1.20)	(1.01)
δ_{66}	0.000	0.000	δ_{47}	-0.055	-0.015	Adj. R^2	0.71	0.74
	(3.92)***	(2.68)***		(1.06)	(0.30)		(52.74)	(59.62)
						Wald Stat[2]	35.78	62.36

1. Absolute value of z-statistics in parentheses. *significant at 10%; ** significant at 5%; *** significant at 1%.
2. chi-squared statistics (three degrees of freedom) of the Breusch-Pagan test of independence among the equations in the system.

We also checked for monotonicity and convexity after estimation. Monotonicity requires that the fitted values of the input demand equations are negative. We checked for monotonicity at data mean points, and cannot be rejected. Convexity is checked by looking at the signs of the estimated input demand equations and the Hessian of the profit function. The necessary condition for convexity is that all terms on leading diagonal of the Hessian of normalized prices be positive, or alternatively the own-price elasticities should have the expected signs. The sufficient condition is that this Hessian must be positive definite. Both conditions are satisfied. The model has not only generated correct signs for fertilizer and labour demand own prices, they are also significant at 1%. This is so even before the symmetry restrictions are imposed. In addition, the high significance of the own-price parameters is an indication of sufficient variation in prices. Besides, just over half (about 53%) and about 40% of the parameters are significant at 5% and 1% respectively.

In our estimation of the production function, we used a similar structure to the normalized restricted profit function. The outstanding feature of the quadratic form is its self-duality[7]. The quadratic functional form is self-dual if there is only one production function and profits are maximized (Lau, 1976; Jegasothy et al, 1990). Thus, the production function consistent with the restricted profit function is also quadratic. For brevity, similar notations are used for the parameters. The only difference is that we have variable input quantities instead of normalized variable input prices and aggregate output index instead of normalized restricted profit. The quadratic production function is expressed as:

$$Y = \alpha_{\circ} + \sum_{i}^{2} \alpha_i X_i + \sum_{k}^{7} \beta_k Z_k + \frac{1}{2}\left(\sum_{i}^{2} \sum_{j}^{2} \gamma_{ij} X_i X_j + \sum_{k}^{7} \sum_{h}^{7} \delta_{kh} Z_k Z_h \right) + \sum_{i}^{2} \sum_{h}^{7} \phi_{ih} X_i Z_h + D + \varepsilon \ldots\ldots (4)$$

Following Just *et al* (1983) and Jegasothy *et al* (1990), we estimated the production function simultaneously with the first order conditions[8]. Assuming that second order conditions are satisfied for the relevant constrained profit maximization and also assuming efficiency in production (full allocation of fixed inputs), we derive the system of first order equations (inverse demand functions) of the variable inputs for estimation along with the production function. Rearranging these equations in linear form to facilitate simultaneous solution for the variable input allocations, we have[9]:

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[7] We have compared other two commonly used flexible forms (generalized Leontief and translog), as well as Cobb-Douglas form with the quadratic form based on various statistical criteria and consistency with theory, the quadratic and the Cobb-Douglas forms are found to be better approximations of the underlying data. We are not reporting the Cobb-Douglas estimates because of the highly restrictive nature of the model. However, the elasticities and their policy implications are very much similar to the quadratic case. For details, see Abrar (2001).

[8]Hausman (2SLS) endogeniety test was carried out to determine the extent of simultaniety in the production function using predicted values. *A priori* we assumed labour and fertilizer to be endogeneous, and cannot be rejected. Thus predicted values are accordingly used in these models. The instruments used include: expenditure on other inputs, non-farm income, total number of crops intercropped, age, non-food expenditure, real prices of fertilizer and labour, and some of the exogenous variables included in the production function.

[9]The maximization problem is essentially a short-run constrained maximization, but since we are assuming that fixed inputs are fully allocated, the lambda equations in the Lagrangian and thus the first order conditions for the fixed inputs will be identities. If some equations do not have stochastic

$$W_i^* = \alpha_i + \sum_j^2 \gamma_{ij} X_j + \sum_h^7 \phi_{ih} Z_h + \upsilon_i, i = 1,2 \ldots\ldots (5)$$

Theoretically, the primal and dual results from estimation of such systems are equivalent, although in practice they differ in stochastic specification and functional forms. Few studies actually estimate the production function along with first-order conditions (e.g., Burgess, 1975; Jegasothy *et al*, 1990), and very few compare these results with estimates from the dual approach (e.g., Burgess, 1975 using translog cost function). We are not aware of any non-experimental study of production relationships which compares estimates from primal and dual approaches using quadratic functional form.

The results of the technology tests are similar to the dual side, i.e., except for symmetry, the model satisfies all the others[10]. The parameter estimates of the primal model, with symmetry imposed, are reported in Table 1. The model has generated expected signs for own-price parameters which are highly significant. The only exception is the parameter for own price of fertilizer which, though having the right sign, is statistically insignificant. Nearly half of the parameters are significant at 5%.

Elasticities and Policy Implications

Price Elascticities

The elasticities estimated from the normalized quadratic profit function (at mean values of prices and fixed factors) are reported in Table 2. All elasticities have expected signs (positive for output supply and negative for input demands), and are all less than unity. The responsiveness of output to price variables is negligible. The own-price elasticity of output, though significant, is very low. Elasticities of output to variable input prices are even lower, and are also insignificant. Particularly, the magnitude of output elasticity to fertilizer price is extremely low, implying little or no response of output to increased fertilizer use.

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disturbances, they may be treated as identity equations and not be incorporated in the ultimate estimation procedure (Just *et al*, 1983).

[10] Monotonicity requires that the fitted values of the inverse demand functions be positive. The necessary condition for concavity is that the leading diagonal terms be negative, the sufficient condition being the Hessian of the production function be negative semi-definite.

Table 2. Estimated Elasticities.

	Dual[1]			**Primal[2]**		
	Output	Fertilizer	Labor	Output	Fertilizer	Labor
with respect to:						
Output price	0.013*	0.16*	0.48*	0.08	0.24	0.78
Fertilizer Price	-0.002	-0.09*	-0.05	-0.03	-0.13	-0.10
Wage rate	-0.01	-0.07	-0.43*	-0.05	-0.11	-0.68
Area cultivated	0.43*	-0.09	0.27*	0.83	-0.54	0.42
Animal power	0.29*	0.68*	0.28*	0.45	1.30	0.05
Farm capital	0.16*	0.19	0.18	0.23	0.61	-0.36
Land quality[3]	0.31*	0.22*	-0.31	0.72	0.47	-0.16
Land access	0.07*	0.01	0.02*	0.12	0.30	0.08
Infrastructure	0.27*	0.49*	0.18*	0.56	1.82	0.41
Rain	0.39*	0.04*	0.39*	0.67	-0.16	-0.02

1. The asterics show that the corresponding derivatives from which these elasticities are derived are significant at 5%.
2. Since monotonicity and curvature conditions are satisfied for the system of first-order conditions (13), following Jegasothy *et al* (1990), we derived the profit maximizing fertilizer and labour demand equations by simultaneously solving the system using Cramer's Rule. The output supply equation was obtained by substituting these input demand equations for the exogenous factors back into the production function. Then conditional input demand and output supply elasticities are calculated at mean values of prices and fixed inputs.
3. For brevity, the sign of elasticities of land quality is adjusted to take opposite signs from the parameter estimates of Table 1 related to this variable.

Although the main reason for this could be the low level of fertilizer application on a per hectare basis, misuse and inefficiency arising from lack of knowledge, institutional and infrastructural impediments, and the state of nature are also factors contributing to this. First, in spite of faster growth rate of fertilizer use at national level, farmers still use considerably lower amount of fertilizer than the recommended rate. Total amount of fertilizer used by peasant farmers increased by about 200 per cent during 1991-1996. But, the amount of fertilizer use per hectare has increased by only 50 per cent during the same period[11]. On the other hand, the number of farmers using fertilizer has increased from about 10 per cent in the 1980s to about 35 per cent in recent years.

The loss of output due to nutrient imbalance is also significant as farmers' application is biased towards DAP instead of using it with Urea in equal proportions in line with

[11] Average fertilizer application range from as low as 10 to 50 Kg per hectare, considerably lower than the recommended rate of 150 to 200 kg.

the recommendation. Croppenstedt and Mulat (1997) found a very high degree of inefficiency of fertilizer use among cereal farmers in Ethiopia. They estimated mean efficiencies of 40 per cent for fertilizer, which compares to 76 per cent and 55 per cent respectively for land and labour. Second, bad timing in application and lack of experience and knowledge is another reason. Partly, this is due to the inability of farmers to acquire fertilizer and fertilizer credits at the right time. Fertilizer is mostly scheduled to be delivered in June and July, not taking into account the different planting calanders for different regions and different crops. Finally, we can see from the significant elasticities of fertilizer demand with respect to land quality and rain that fertilizer use and its yield-increasing effect crucially depend on the soil quality and prevailing weather conditions.

Although own-price elasticities of input demands are significant, the own-price elasticity of fertilizer is low, suggesting that fertilizer prices would have to decrease substantially to increase the low level of fertilizer use in rural Ethiopia. Quantitatively, to increase the current adoption rate of about 50 kg per hectare to at least 100 (which is the average for low income economies), that means to increase it by about 100 per cent, fertilizer prices would have to fall by about 1111 per cent. However, fertilizer prices seem to have increased over the last few years, and very likely to be so for some time to come. This will make it even more expensive for farmers who are already too poor to buy fertilizer as over 80 percent of them buy fertilizer through credit.

There are many reasons for this but the most important are devaluation of the Birr, high local transport cost, and the elimination of fertilizer subsidies. In spite of significant decreasing trend in the international prices of fertilizer, the farm-gate prices have not decreased proportionately due to continuous devaluation of the *Birr* and high local transport tariff (partly owing to high fuel prices and high transport costs during rainy season). For instance, international prices of Urea and DAP have decreased by 62.42 and 18.99 per cent respectively between 1996 and 1999. But retail prices of DAP have increased over the same period (Techane, 1999). Further, prices of fertilizer in Ethiopia are relatively higher compared to other developing countries

(Mulat, 1995)[12]. In addition, fertilizer prices are more expensive than the prices quoted, as a great deal of farmers finance their purchase through informal credit market with very high interest rates. Another reason is that fertilizer markets, especially retail markets, are not sufficiently deregulated as only few companies are still monopolizing the supply and distribution even at local market (Mulat and Techane, 1999).

Therefore, in light of the evidence here and given the central role fertilizer plays in the drive for sustainable growth in the agricultural sector, the removal of fertilizer subsidies can be put into question. In other words, the evidence here calls for the need to consider some price support mechanism for fertilizer prices.

Labour has the highest own-price elasticity (i.e., 0.43) compared to output (0.013) and fertilizer (0.09). This coupled with its relatively high elasticity with respect to output price suggest a higher labour response to price incentives compared to fertilizer. The results show that, unlike fertilizer, price incentives are at least as important as non-price factors are for labour allocation decision of the farmers. Thus, due consideration should be given to enhancing more labour-intensive off-farm activities and food-for-work programs that absorb the prevailing rural surplus labour during off-peak seasons. However, lower productivity of labour is evident from the low elasticity of output with respect to the wage rate. Yao (1996) found declining elasticity of labour over time, suggesting that stagnation of yield and increasing population growth gradually depressed labour productivity.

The lower own-price elasticities of the variable inputs as compared to their elasticities with respect to output price suggest that incentives affecting the price of output are much more important in the input allocation of peasant farmers than those affecting input prices. This is particularly the case for fertilizer where the difference between the two elasticities is relatively bigger. Hence, the results of this study indicate that increased use of fertilizer is not so much from policy measures affecting fertilizer

[12] For instance, in 1993 (well before the removal of subsidies), farm-gate price of fertilizer was US$300 per ton compared to unsubsidized prices of 205, 226, and 257 in Pakistan, Bangladesh and India respectively.

prices as it is from the overall liberalization of the economy, particularly from the deregulation of agricultural output markets which started as early as 1989.

Non-Price Elasticities

On the whole, the effects of non-price factors on production and input use are highly significant and strong. Output responds significantly to all fixed inputs and structural variables. What is more, it is far more responsive to these non-price factors than price variables, which is demonstrated by the uniformly higher magnitudes of these elasticities. Of the fixed inputs, output responds primarily to size of cultivated land (with elasticity of 0.43), followed by animal power (with elasticity of 0.29) indicating the critical nature of these inputs. Though production is least responsive to farm capital, the results indicate that the availability of this input significantly increases output supply without generating much additional demand for variable inputs. The three conditioning factors that affect output most are rain, land quality and market access with elasticities of 0.39, 0.31, and 0.27 respectively. The combined effect of more land of better quality on output supply are therefore substantial.

In most cases (with the exception of fertilizer demand with respect to size of land, farm capital and infrastructure, and labour demand with respect to farm capital and land quality), variable input demands also respond significantly to non-price factors. The largest impact for labour comes from rain, followed by animal power and land size. Fertilizer demand is more elastic to animal power (with the highest elasticity estimate of 0.68), followed by infrastructure and land quality with elasticities of 0.49 and 0.22 respectively. Since cattle in rural Ethiopia are major stores of wealth, animal power is likely to be positively correlated with credit availability, and in turn usage of purchased inputs.

The high elasticity of fertilizer demand to infrastructure is very much expected. Given uniform prices within a village, the road density variable may capture the largest component of transport cost differences and stand for an additional dimension of the fertilizer elasticity with respect to the delivered price (Bapna *et al*, 1984). Land quality has also strong and positive impact on fertilizer demand, which can be attributed to the fact that better quality land is usually closer to roads and market. Further, hill side farmers with slope higher than 5 per cent are not eligible to benefit from government support of modern input packages (Zerihun, 1996).

The negative and insignificant elasticity of fertilizer demand to size of cultivated land is not entirely unexpected in light of the extremely low intensity of fertilizer use of Ethiopian farmers. Most farmers in Ethiopia apply substantially lower amount of fertilizer than the recommended rate. This result, together with the relatively low and insignificant elasticity of fertilizer to land access, indicate that land is not as sever constraint for fertilizer as it is, for instance, for labour.

Primal Elasticities

The elasticity estimates from the primal model are also reported in Table 2. The output (production) elasticities are in general consistent with previous works on peasant production in Ethiopia (see for e.g., Croppenstedt and Mulat, 1997; Abrar, 1996; Yao, 1996). Croppenstedt and Mulat (1997), using the same data set, in their study of technical efficiency reported land and fertilizer elasticities in the range of 0.46 to 0.58 and 0.03 to 0.09 respectively. Yao (1996), using aggregate time series data, reported elasticities in the range of 0.20 to 0.45, 0.05 to 0.10 and 0.35 to 0.97 for land, fertilizer and rainfall respectively.

These conditional elasticites reinforce the major result of the dual elasticities namely fixed inputs and other non-price variables are more important factors affecting output and input use. The relative importance of these variables is somewhat similar. The only difference comes from the relative importance of the effects of rain and land quality on output, and of animal power and infrastructure on fertilizer. With the exception of elasticities of fertilizer demand with respect to animal power and infrastructure, all primal elasticities are less than unity. These elasticities also produced similar signs except in three cases, all of which are elasticities of input demands. The weak response of output to fertilizer is particularly evident.

However, in nearly all cases, the production elasticities calculated from the primal model are larger in magnitude than those derived from the profit function. These elasticities are generally found to be larger in absolute magnitude than their dual counterparts (Jegasothy *et al*, 1990; Applebaum, 1978). On the basis of estimates of translog production and cost functions, Burgess (1975) reported markedly different inferences concerning elasticities of substitution while Applebaum (1978) found that magnitudes of price elasticities are sensitive to primal-dual specifications. On the other hand, studies by Dixon *et al* (1985) and Haughton (1986), using production and profit functions, indicate that parameter estimates and elasticities are more sensitive to functional forms than to primal-dual representation of the technology. In our case, despite differences in magnitudes, the inferences made from the primal and dual elasticities are not quite different from each other.

Conclusions

The results suggest that peasant farmers in Ethiopia respond (albeit modestly) to price incentives. Output price significantly affects output supply and resource utilization although its effect on output is not strong. While changes in variable input prices significantly affect the demand for these inputs, the influence of input prices, particularly fertilizer prices, on output is insignificant and very negligible. The price elasticities taken together imply that small adjustments in prices may not be effective especially for fertilzer. Even taking the relatively larger primal elasticity estimates into account, to increase the rate of fertilizer application by 100 per cent fertilizer prices would have to fall by 769.23 per cent. This reflects the need to consider some form of price support mechanism. The results also indicate that policy incentives affecting output prices are more effective in influencing input allocation decisions of the farmers than those designed directly to affect input prices. The response of labour to price incentives is found to be strong compared to that of fertilizer and output supply.

The most important finding is that non-price factors are far more important in affecting production and resource use than price incentives. This is demonstrated by the substantially higher magnitudes of the elasticities of output and input demands with respect to these factors. This shows that the weak response of output and fertilizer demand to improved price incentives is mainly due to the relatively more important role of non-price factors. This means getting prices right is not enough. In addition to price incentives, effective policies that improve farmer’s access to land, credit, public investment in roads and irrigation are required. In light of the limited room for area expansion and the existing land policy which does not allow land transfer, it seems probable that price incentives only affect the crop mix shift, making aggregate response following these incentives to be small. While this is the case or not should be rectified through an in-depth study of crop-level supply response, the urgent need for institutional change for access to land is all too obvious.

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Appendix A. Definition of Variables.

Aggregate output is defined as implicit aggregate quantity index derived by dividing total value of output by the price index. The output and price indices correspond to that used by Croppenstedt and Mulat (1997) on their study of cereal farmers using the same data. We are grateful to Dr. Croppenstedt for providing his set of variables from the first round of the survey. The aggregate price index is defined as the Laspeyer's price index calculated from the major crops using the value share of each crop as a weight. We used the prices collected by an independent price survey simultaneously with the main survey. In very few cases where the price of a crop is not reported, we used unit values.

Fertilizer is measured as total amount of chemical fertilizer applied in kilograms. Labour is defined as the number of person-days of traditional (share) and hired labour used in ploughing and harvesting. Labour used in weeding is also given in the data, but we have not included it for two reasons. First, as weeding is predominantly carried out by women and children, it is not traded or it has very low opportunity cost in terms of off-farm employment as women and children rarely participate in off-farm work. The data also shows that weeding constitute a very low component of hired labour. Thus, excluding it makes sense particularly in light of the fact that we are using off-farm and hired wage bills to derive the wage rate. Second, weeding is least important in tree crop areas. Family labour is not included as it is treated as fixed. Also, share labour is adjusted for quality using average product as a weight. The implicit assumption here is that hired labour is more productive than share and family labour, an assumption justified by the data.

The price of fertilizer is calculated by dividing total expenditure on the amount applied. For those farmers who do not use fertilizer, the mean of those who applied is used. In two villages where there is no any farmer applying fertilizer, the mean of the nearest villages is used. The wage rate per person-days is calculated from the wage bill of hired labour. For those farmers (villages) with no hired labour, we imputed the wage rate from the off-farm income of farm-related employment.

Land is total area of land cultivated in hectares. Animal power is defined as total number of oxen owned. Farm capital is measured by value of hoe and plough owned. Land quality is defined as an index of quality of cultivated land (1 being best, 2 mediocre, and 3 worst). We combined the two indices of land quality given in the data (one for fertility and another for steepness) into one index using total area cultivated as a weight. Other inputs used in the preliminary analysis include: proxy for manure use, and expenditure on all other inputs, the former avoided due to multicollinearity, and the latter due to statistical insignificance.

A proxy for access to land is measured by the amount of harvest paid in the form of rent for land. Following Bapna *et al* (1984), infrastructure (and/or market access) is measured by dividing the total population of the nearest town (or big market) to the road distance between the town and the village. The level of rainfall is measured by multiplying amount of rain in mm by the dummy for rain included in the questionnaire, where the farmer is asked if rain was enough or on time. We also included a dummy variable to capture the two most important cereal and tree cropping systems (1 if household is in cereal growing zone, 0 otherwise). Other alternative dummies were initially used for this purpose that split the sample into villages or regions or sub-farming systems. Village level dummies were excluded due to extreme multicollinearity with rain and market access which are also village level measures whereas region dummies avoided as they performed no better than the one currently used. Some other variables such as education, age, household size, number of crops inter-cropped, number of plots, access to credit, and non-farm income included in the preliminary estimation are left out due to multicollinearity.

Appendix B. Describtive Statistics of Variables Used.

Variables	Mean	Standard deviation
Output (Birr)	710.30	889.85
Fertilizer (Kg)	39.87	70.43
Labour (person-days)	32.14	75.10
Output Price (Birr/Kg)	3.19	3.00
Fertilizer Price (Birr/Kg)	1.52	0.37
Wage rate (Birr/person-days)	2.83	1.62
Area Cultivated (hectares)	1.74	1.56
Animal Power (numbers)	1.80	2.00
Farm Capital (Birr)	24.31	32.43
Land Quality (index)	1.53	0.44

Land Access (Kg)	72.43	384.30
Infrastructure (road density)	3880.45	3817.45
Rain (mm)	548.16	677.21