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THE EFFECTS OF AGRICULTURAL EXTENSION ON FARM YIELDS IN KENYA

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ABSTRACT

The paper examines effects of agricultural extension on crop yields in Kenya controlling for other determinants of yields, notably the schooling of farmers and agro-ecological characteristics of arable land. The data we use were collected by the Government of Kenya in 1982 and 1990, but the estimation results reported in the paper are based primarily on the 1982 data set. The sample used for estimation contains information about crop production, agricultural extension workers (exogenously supplied to farms), educational attainment of farmers, usage of farm inputs, among others. A quantile regression technique was used to investigate productivity effects of agricultural extension and other farm inputs over the entire conditional distribution of farm yield residuals.

We find that productivity effect of agricultural extension is highest at the extreme ends of distribution of yield residuals. Complementarity of unobserved farmer ability with extension service at higher yield residuals and the diminishing returns to the extension input, which are uncompensated for by ability at the lower tail of the distribution, are hypothesized to account for this U-shaped pattern of the productivity effect of extension across yield quantiles. This finding suggests that for a given level of extension input, unobserved factors such as farm management abilities affect crop yields differently. Effects of schooling on farm yields are positive but statistically insignificant. Other determinants of farm yields that we analyze include labour input, farmer experience, agro-ecological characteristics of farms, fallow acreage, and types of crops grown.

Key words: agricultural extension, economic effects

JEL Classification: O13 and Q16

1. INTRODUCTION

Strengthening of national agricultural support system has been advocated as a strategy for increasing agricultural production in Sub-Saharan Africa by governments in the region and by international development agencies (see e.g., World Bank, 1983, 1990; Bindlish and Evenson, 1997). The T & V system (training and visit) system of agricultural extension has been central to this strategy. The World Bank-supported agricultural extension programs, based on the T&V system have been implemented in some thirty Sub-Saharan countries or in about three-fifths of African countries. A substantial amount of resources has been committed to this system, both by national governments and international development agencies (Bindlish and Evenson, 1993). There is however an emerging controversy as to cost-effectiveness and productivity of a national system of agricultural extension, particularly in Sub-Saharan Africa where governments' ability to meet a large recurrent cost that the system entails is limited (see Purcell and Anderson, 1997 and Gautam, 1998). The analysis presented in this paper suggests that a national system of agricultural extension can play an important role in increasing farm yields but its effect on yields is not uniform across farmers.

The paper assesses farm-level economic effects of T & V and traditional systems of agricultural extension in Kenya as of 1982 controlling for other determinants of farm productivity. The T &V system was introduced in Kenya in 1982 as a supplement to the old system which had been implemented before Independence in 1963. The new system spread rapidly and by 1985 it covered some 30 districts, despite having been started on a pilot basis in only two districts. An important and salient feature of T &V extension system is a regular pattern of visits by frontline extension workers to contact-farmers (see e.g., Benor et al. 1984). A fortunate aspect of the T &V system in Kenya, with respect to visitation by extension workers, is that in many areas, farmers in Kenya have organized themselves in groups to facilitate such ventures as the marketing of agricultural output, mutual help assistance and acquisition of agricultural credit. Extension workers seek out these existing groups as their contacts. The original design of T & V whereby extension workers were to reach out for individual farmers proved hard to implement.

Extension workers focus on imparting key messages to farmers on each visit, with the complexity of these messages being increased in subsequent visits. Initial messages aim at improving basic production techniques, with attention being focused on land preparation, the timeliness of operations, crop spacing, plant population sizes, the use of better seed varieties and on weeding. After the simple messages, attention shifts to more complex messages such as those relating to fertilizer use and pest control measures. Implementation of the latter set of messages typically requires higher investment expenditure in purchased inputs by farmers. Other key features of the T &V system include the existence of a permanent cadre of subject matter specialists and regular supervision and training of extension workers and regular meetings between the frontline extension workers and the subject matter specialists. These meetings serve as a feedback mechanism between the supervisors, frontline extension workers and farmers. The primary duties of the frontline extension agents under the T & V system is to transfer agricultural information to farmers and to report farmers' problems to higher levels of the system, especially to supervisors and the subject matter specialists.

The features of T & V described above refer to a well functioning national system of agricultural extension. In Kenya both the T & V system and the traditional system of technology extension have suffered from poor supervision. Moreover, frontline extension staff are often unable to cover the required number of households because of lack of transport and because of impassable roads in the rainy season. However, even though Bindlish and Evenson (1993) show that annual government budget allocations to agricultural extension services in some districts declined substantially between 1981 and 1991, the budgetary constraint was not as binding in 1982 because of support and enthusiasm that existed for the new system at the time of its implementation. Thus, in the early days, lack of funds was probably not a major constraint on proper functioning of the national extension system, especially its Training and Visit component. However, the nature of linkage of the extension system with research stations (Purcell and Anderson, 1997), may have affected the availability of relevant farming technology that could be passed to farmers. At least in design, the T & V system is a substantial improvement over the traditional system despite *weaknesses* of public extension systems (Umali-Deininger, 1997; Purcell and Anderson, 1997). The identified weaknesses here, and over which there is no agreement (see Purcell and Anderson, 1997, pp. 98-101), concern cost-ineffectiveness of national extension systems and non-availability of agricultural technology of the magnitude that merits a uniform machinery of transmission to farmers. A further discussion of these issues is outside the scope of this paper.

We summarize and quantify the agricultural extension package, which includes changes in technical knowledge and farm practices by a variable that we call *number of extension workers per farm* in a given cluster. By the design of the extension system, this variable embodies what might be termed farm-specific human capital of extension workers, as measured by the level of training they receive prior to commencing extension activities. Moreover, to the extent that the knowledge possessed by extension workers is successfully transmitted to farmers via contact visits or through inter-farmer communications, the specific human capital of farmers is positively correlated with that of the extension workers. The variable *number of extension workers per farm* therefore captures both agriculture-specific human capital embodied in extension workers as well as the amount of it that the extension workers transmit to farm people. As Schultz (1975) has argued, agriculture-specific human capital is important in improving farm yields in a changing environment because it enhances resource allocation abilities of farmers.

We assume that the larger the number of extension workers per farm, the greater the intensity and effectiveness of the agricultural extension service delivered to farmers over a specific time period. Thus, for a *fixed* number of farms, the larger the number of extension staff, the higher the farm yield.

The extension variable as defined here is "exogenous to individual households and internalizes inter-farmer communications" (Brikhaeuser *et al*, 1991, p. 613). It is a *supply* variable, which ideally, should be independent of farmer behaviour with regard to use of the extension input. That is, it does not reflect choice decisions of farmers in the sample, as its size is determined by staffing and budgetary decisions of the central government. Bindlish and Evenson (1997) note that the geographic expansion of T & V system in Kenya at the aggregate level appeared to be random after the pilot phase. Even so, the ratio of the extension staff per farm would actually *not* be exogenous if, as is normally the case, the size of the number of farms at the level of sample cluster reflects farmer decisions. We avoided this difficulty to some degree by dividing the number of extension staff in a sample cluster by the number of farms in a cluster in 1982. The staff ratio is sufficiently exogenous because the number of extension workers in a cluster (the numerator) is determined by the government and the number of farms in the same cluster (the denominator) is primarily a result of past behaviour of farmers. Still, the extension variable may not be truly exogenous because farmers and extension workers may seek out one another over the duration of crop cycle. However, in similar previous work (Bindlish and Evenson, 1993, 1997) tested and found no support for endogeneity of the extension variable as defined here.

The paper has five sections following this introduction. The second and third sections describe the model and the data. The fourth and fifth sections contain presentation and discussion of results. Section six concludes with a summary and a conclusion.

2. ANALYTIC MODEL

Previous studies on economic effects of extension service have used two types of statistical frameworks to measure the effect of agricultural extension on farm productivity, namely, the meta production function and the total productivity index (see e.g. Bindlish and Evenson, 1993, 1997. See also Feder and Slade, 1984 for an evaluation of the effect of extension on knowledge acquisition. In contrast to the conventional agricultural production function, where technological options, farmer information sets and public infrastructure are taken as *background* or fixed variables, and are thus not included in the estimated equations, in a meta specification of the production effects of extension, the background variables are incorporated directly in the estimated equation. In the case of the total factor productivity approach, an aggregate input index whose value depends on quantities of variable and fixed inputs is first constructed. The observed agricultural output is then divided by this aggregate index to obtain total factor productivity which is then conditioned on extension service and the background variables (see in particular, Bindlish and Evenson, 1993, pp. 114 -115). Choice of one or the other of these approaches is normally dictated by the nature of the available data.

In our case, we adopt a meta production function of the form shown in Equation (1). A complete description of the variables included in Equation (1) is in Table 1.

$$\mathbf{y_i = G\,(a, h, f, w, l, s, x, r, q) + u_i} \qquad (1)$$

Where

G(.) = deterministic component of the farm yield;

y_i = logarithm of farm yield (i.e, log of crop yield in kilograms per acre of crop land) for farmer i; suppressing the i subscript for the right-hand side covariates we have:

a = logarithm of acres of cropped area;

h = logarithm of the number of hours worked by hired and family labour on a plot;

f = logarithm of expenditure on fertilizer and sprays per acre of cropped area;

w = logarithm of number of extension workers per farm;

l = logarithm of the acreage under fallow;

s = personal and social attributes (education, age and sex of the farmer);

x = crop type dummies;

r = agro-ecological dummies;

q = interaction terms;

$\mathbf{u_i}$ **=** stochastic component of the farm yield for farmer i.

Adopting a simple Cobb-Douglas form for the farm productivity function, we estimated Equation (1) using a quantile regression technique (see Koenker and Basset, 1978). The mean effects of productivity determinants (the average effects of these determinants at all levels of the farm yield) are also estimated with ordinary least squares (OLS) and reported along with the quantile estimates for comparison purposes. If focus were on the extension variable, the OLS results would show how the farm yield for the average farmer would respond to agricultural extension controlling for the effects of the other right-hand side covariates in Equation (1).

However, results obtained via the OLS and other parametric methods cannot be used to examine, for example, how farmers in an extreme distribution of the farm yield residuals would be affected by investments in agricultural extension. Makers of policy, are typically interested in this issue as farmers may be affected differently by extension service due to their unobserved personal endowments such as cognitive and physical abilities. Previous studies on extension effects of farm yields have ignored this issue (see e.g Birkhaeuser *et al*, 1991 and Feder and Slade, 1986 for reviews).

To remedy this situation we focus attention on the behavior of the entire conditional density of the farm yield residuals, and examine agricultural extension effects at any arbitrary point on that density, controlling for the effects of other covariates. The econometric problem involves estimation of the parameters of the entire distribution of the residuals of farm yields given the set of regressors specified in Equation (1). We use quantile regression [(see e.g, Buchinsky (1994, 1998), Chamberlain (1994), Koenker and Bassett (1978, 1982)] to estimate economic effects of extension at three points of the distribution of the yield residual: the first quartile (25th percentile), the second quartile (50th percentile) and the third quartile (75th percentile). See Buchinsky (1994) for a different characterization of the conditional distribution of wage residuals.

In the case of the extension variable, regression estimates at the first quartile show the extension effects for the sample farmers at the lowest 25 per cent of yield residuals, whereas estimates at the second quartile depict effects for farmers at the median residual. Similarly, estimates at the third quartile are for farmers at the 75th percentile of the distribution of yield residuals. Thus, the quantile regression technique permits a comparison of how the yield of the median farmer responds to changes in its determinants relative to the response in the yield of any other farmer below or above the median residual.

Using notation in Buchinsky (1994, 1998), a quantile regression model of the farm yield function shown in Equation (1) can be expressed as

$$y_i = \mathbf{z}_i\beta_\theta + \mu_{\theta i} \qquad (2a)$$

$$\text{Quant}_\theta\,(y_i|\mathbf{z}) = \mathbf{z}_i\beta_\theta \quad \text{and Quant}_\theta\,(\mu_\theta|\mathbf{z}) = 0 \qquad (2b)$$

Where

β_θ and $\mathbf{z}_i$ are K x 1 vectors, and $\mathbf{z}_{i1} \equiv 1$;

$\mathbf{z}$ is a vector of the right-hand side covariates in Equation (1);

$\text{Quant}_\theta\,(y|\mathbf{z})$ is the θth conditional quantile of y given $\mathbf{z}$, and y is an N x 1 vector of farm yields with the constraint that $0 < \theta < 1$.

The parameter vector, β_θ is obtained by minimizing the sum of absolute deviations from an arbitrarily chosen quantile of a farm yield across farmers. In the case of Equation (2) this sum can be expressed as:

$$\text{Minimize } \Sigma_i|y_{\theta i} - \Sigma_j\beta_{\theta j}\mathbf{z}_{ij}| \qquad (3)$$

where

$y_{\theta i}$ = Farm yield for farmer i at quantile θ (i =1, ...n);

$\mathbf{z}_{ij}$ = Covariate j (e.g, education) for farmer i (j = 1,....K);

$\beta_{\theta j}$ = Effect of covariate j on farm yield at quantile θ.

The solution to Equation (3) is found by rewriting the expression as a linear programming problem of the *entire* sample (see Chamberlain, 1994) and applying linear programming computation algorithms, one of which is now available in STATA (see Deaton, 1995). Incorporation of LP algorithms into commonly available statistical packages, makes quantile regression, which is otherwise computationally burdensome, a simple tool to use. See for example, Deaton (1997), Buchinsky (1998) and Schultz and Mwabu (1998) for a description of properties of the quantile regression.

Production effects of extension may vary across yield quantiles, if for example, unobserved ability of farmers is omitted from the productivity equation. If high ability farmers happen to be the contact farmers of the field extension workers or are treated preferentially by the extension staff, the estimated extension effects on yields would be higher at the upper segment of the distribution of yield residuals. Briefly, omission from the yield equation of intangible variables such as managerial abilities of farmers, which essentially is a measurement error, is likely to be the main source of variation in the productivity effects of extension services across quantiles.

3. DATA

This section draws heavily from Bindlish and Evenson (1993) and Evenson and Mwabu (1996). The data for this study were gathered by Kenya's Central Bureau of Statistics from farm households in seven Kenyan districts and from government records on agricultural extension. We begin with a general description of the study districts. The seven districts are located in six of eight provinces and are thus representative of much of Kenya. The excluded provinces are Nairobi and Northeastern. The sample districts are Bungoma, Kericho, Kisumu, Machakos, Murang'a, Taita Taveta, and Trans-

Nzoia. The districts cover three ecological zones; a “high-potential” zone that generally receives rainfall of 3 inches annually and has no climatic or drainage problems; a “medium-potential” zone that receives 25-35 inches of rainfall annually or has some climatic or drainage problems; and a “low-potential” zone that generally receives a rainfall of 25 inches per annum.

Reflecting their agricultural importance, the seven study districts account for only 8 percent of total land in Kenya, but for 19 percent of arable land. Moreover, the proportion of arable land for the study districts amounts to 61 percent in comparison to 26 percent for the whole of Kenya. Except for Taita Taveta, all the other six districts have very high population densities (Republic of Kenya, 1981).

The data used for empirical analysis was obtained by combining crop and other relevant data from 1981-82 survey by CBS with data on extension staff for 1982 derived from the data collected in 1990, also by the Central Bureau of Statistics. The 1981-82 data are from a nationally representative Rural Household Budget Survey conducted in all the seven districts. The survey contains detailed information on agricultural production and household characteristics but has no information on agricultural extension services. However, the 1990 data were obtained by interviewing farmers re-sampled from those surveyed in 1981-82 sample. The 1990 data set consists of survey data (see Bindlish and Evenson, 1993) plus secondary information on extension staff derived from government records. In particular, for each survey cluster, information was collected on extension staff in that cluster for 1990 (the period when the T & V system was firmly in place) and for 1982 (when the T & V system was introduced as a national system of agricultural extension alongside the traditional system). The present paper uses extension information for 1982 only. As already noted, the information was collected from government records and not from farmers.

To obtain the analytic sample for this study, the 1981-82 data set was first linked to the extension data for 1982 by enumeration cluster. The extension variable for 1982 was part of the 1990 data set, with enumeration clusters being the same in both data sets. The enumeration cluster comprises a group of villages in a geographic area, usually the smallest administrative unit within a district known as a location. The second and final step in the creation of the analytic sample was the pooling of information on thirteen crops grown by 676 farmers re-sampled from the 1981-82 households for the 1990 survey. Of these farmers, 362 were in enumeration clusters containing information about extension staff in 1982. Farmers in the original sample (1982 survey) for whom information on extension staff was not available in the 1990 data were assigned the average extension staff in their district. This assignment procedure is consistent with the fact that extension services in locations within a district are managed at the district level. Thus, in contrast to Bindlish and Evenson (1993, 1997) who analyze the effect of extension on crop yields for 1990, we analyze this effect on yields in 1982. Since all farmers grew more than one crop, the pooled sample by crop consists of 3682 observations. The pooled data set contains information on crop yield measured in kilograms (our dependent variable), socioeconomic attributes of farmers, number of extension staff per farm, quantity of fertilizer applied at the level of the farm (rather than at the plot on which specific crops are grown), agro-ecological zones in which farmers operated, among others (see Table 1). All farm inputs in Table 1 (except labour which is at the crop level) are measured at the level of the cropped area, i.e., excluding acreage under fallow. In order to control for effects of crop-specific factors on farm yields, thirteen crop dummies were constructed, with maize being the comparison crop. In other words, estimation proceeds under the assumption that the marginal effect of extension is constant across crops.

4. RESULTS

Tables 1-3 below show results from the analysis of survey data. Tables 1 and 2 present sample statistics and correlations of crop yields with selected variables respectively, while Table 3 reports results from a quantile regression analysis of yields. The three sets of results are discussed in detail in Section 5, following the order in which they are presented. We will now provide a preview of these results.

The sample statistics in Table 1 show that nearly 70 percent of the family farms sampled were headed by men, and that maize was the main crop grown. The extension input per farm has a very high variance across farms, which is a reflection of uneven distribution of agricultural extension across districts. The sample farmers have an average of only lower primary schooling, but they seem to have considerable farming experience. Results from the correlation analysis (Table 2) indicate strong co-movements between farm yields with plot-level inputs such as extension staff, farm labour, and fertilizers and sprays. As to the extension input, the regression analysis leads to the same qualitative conclusion as that implicit in Table 2, namely, farm yields rise as the number of extension staff per farm increases. However, as the results reported in Table 3 show, the response of yields to the extension input varies considerably across regression quantiles. Even though the economic returns associated with the estimated extension coefficient are substantial (see Bindish and Evenson,

1997) the coefficient is not statistically significant at the low end of the distribution of yield residuals. That is, the economic effects of extension are uneven among farmers.

A. Sample statistics and correlations

Table 1
Sample Means

Variables	Means	Standard Deviation
Natural logarithm of kilograms of crop produced on an acre of land in 1982	2.129	1.43
Log of the total number of hours worked by family and hired labour on a plot of crop		
Log of total acreage under all crops	1.495	1.29
Log of total expenditure on fertilizers and sprays per acre of crop land (log fertilizer expenditure)	.542	1.13
Log of the number of field extension workers per farm	1.361	2.90
Log of uncultivated (fallow) acreage	-5.323	.87
Log of fallow acreage x log of fertilizer expenditure	-.207	1.65
Log of fallow x Log of the number of extension workers per farm	-1.219	5.31
Maize	1.043	8.78
Beans	.294	.46
Potatoes	.192	.39
Sorghum	.060	.24
Peas and grams	.041	.20
Bananas	.056	.23
Millet	.069	.25
Cabbage	.029	.17
Other vegetables	.022	.15
Coffee	.161	.37
Tea	.026	.16
Other cash crops	.006	.08
Other crops	.023	.15
Sex of household head (1=male)	.019	.14
Log of years of schooling	.688	.46
Log of age of household head	.922	.93
Log of age squared	3.757	.33
Log of age x log of years of schooling	14.227	2.48
Log of distance in kilometres to the market centre	3.307	3.31
Hill (= 1 if sublocation is hilly and zero otherwise)	1.119	1.20
Lower highland zone 1 (tea and dairy area (= 1 if cluster is in this zone)	.241	.43
Lower highland zone 3 (wheat and barley area)	.087	.28
Upper midland zone 1 (coffee and tea area)	.131	.34
Upper midland zone 2 (main coffee area)	.074	.26
Upper midland zone 3 (marginal main coffee area)	.077	.27
Lower midland zone 2 (marginal sugar area)	.163	.37
Lower midland zone 3 (cotton area)	.079	.27
Lower midland zone 4 (marginal cotton area)	.123	.33
Lower midland zone 5 (livestock and millet area)	.014	.12
	.161	.37
Sample size	3682	

Table 2

Correlation of productivity (crop yield per acre) with selected variables

Variables	Correlation with log of crop yield	p-value
Log of the total number of hours worked by family and hired labour on a plot of crop	.363	.000
Log of total acreage under all crops	.166	.000
Log of total expenditure on fertilizers and sprays per acre of crop land	.115	.000
Log of the number of field extension workers per farm	.037	.026
Log of uncultivated (fallow) acreage	.122	.000
Log of fallow acreage x Log of expenditure on fertilizer and sprays per acre of crop land	-.002	.910
Log of fallow x Log of the number of extension workers per farm	-.114	.000
Log of years of schooling	.029	.083
Sex of household head (1=male)	.082	.000
Log of age of household head	-.020	.218
Log of distance to the market centre	-.079	.000
Sample size	3682	

B. Regression Results

Table 3
Quantile Regression Estimates of the Farm Yield Function
(absolute bootstrap t-ratios in parentheses)

Explanatory Variables	Quantile Parameter Estimates			Mean (OLS)
	.25	.50	.75	
A. Labour and nonlabour inputs				
Logarithm (log) of the total number of hours worked by family and hired labour on a plot of crop land	.209 (4.68)	.191 (7.50)	.190 (8.53)	.196 (10.08)
Log of total acreage under all crops	.274 (7.79)	.300 (8.94)	.280 (10.09)	.262 (12.50)
Log of total expenditure on fertilizers and sprays per acre of crop area	.077 (4.82)	.081 (6.72)	.088 (9.11)	.075 (8.60)
Log of the number of field extension workers per farm	.091 (1.86)	.052 (1.24)	.094 (3.62)	.130 (4.72)
Log of uncultivated (fallow) acreage	.219 (1.43)	.332 (3.12)	.278 (3.28)	.288 (3.53)
Log of fallow acreage x Log of expenditure on fertilizer and sprays per acre of crop area	-.026 (3.38)	-.019 (3.77)	-.016 (4.20)	-.022 (5.11)
Log of fallow x Log of the number of extension workers per farm	.022 (.77)	.049 (2.42)	.042 (2.90)	0.040 (2.58)
Log of years of schooling	.466 (.95)	.357 (.85)	.293 (1.33)	.039 (.52)
Log of age of household head	2.821 (2.13)	2.219 (1.17)	1.833 (1.25)	.637 (.51)
Log of age squared	-.400 (1.47)	-.310 (1.28)	-.260 (1.31)	-.110 (.66)

Log of household age x log of years of schooling	-.155 (1.17)	-.099 (.88)	-.082 (1.40)	-.000 (.21)
B. Crop Types [Maize is the omitted category]				
Beans	-1.087 (8.42)	-1.141 (20.30)	-1.239 (17.76)	-1.999 (19.73)
Potatoes	-.471 (2.50)	-.526 (6.02)	-.186 (2.53)	-.475 (4.96)
Sorghum	-.561 (4.07)	-.723 (6.17)	-.781 (5.67)	-.746 (6.65)
Peas and grams	-.864 (6.03)	-.804 (7.94)	-1.078 (15.17)	-1.085 (11.03)
Bananas	-1.134 (7.14)	-.969 (6.13)	-.995 (8.51)	-1.056 (11.23)
Millet	-1.089 (6.32)	-1.309 (10.32)	-1.496 (10.82)	-1.239 (9.82)
Cabbage	-1.371 (6.53)	-788 (3.65)	-.208 (1.62)	-.894 (6.22)
Other vegetables	-.969 (6.94)	-.910 (10.43)	-.899 (12.21)	-.970 (13.70)
Coffee	-.237 (1.06)	.151 (.77)	.533 (2.21)	.093 (0.71)
Tea	-.439 (.94)	-.836 (9.37)	-1.032 (4.47)	-1.030 (3.98)
Other Cash Crops	-1.582 (5.98)	-1.472 (6.35)	-1.309 (7.32)	-1.428 (10.52)
Other crops	-1.664 (6.01)	-1.657 (6.65)	-1.491 (9.88)	-1.478 (9.92)
C. Gender, access to markets, and agro-ecological zones				
Sex of household head (1=male)	.157 (1.97)	.072 (1.19)	.119 (2.02)	.092 (2.00)
Log of distance in kilometres to the market centre	-.068 (1.92)	-.050 (2.19)	-.062 (3.11)	-.057 (3.05)

Hill (=1 if sample cluster is hilly and zero otherwise)	.035 (.33)	.155 (2.77)	.114 (1.90)	.050 (.90)
Lower highland zone 1 (tea and dairy area (= 1 if sample cluster is in this zone and zero otherwise)	.284 (1.57)	.274 (2.63)	.187 (3.12)	.184 (2.35)
Lower highland zone 3 (wheat and barley areas)	.326 (2.38)	.523 (6.65)	.356 (4.42)	.291 (4.09)
Upper midland zone 1 (coffee and tea area)	-.665 (5.69)	-.825 (5.76)	-.798 (7.45)	-.659 (6.71)
Upper midland zone 2 (main coffee area)	.111 (.63)	.166 (.91)	.095 (.84)	.151 (1.26)
Upper midland zone 3 (marginal coffee area)	.065 (.42)	-.091 (.68)	-.355 (3.74)	-.185 (2.07)
Lower midland zone 2 (marginal sugar area)	.048 (.31)	.075 (.74)	.144 (1.94)	.131 (1.50)
Lower midland zone 3 (cotton area)	-.232 (1.58)	-.112 (.35)	-.077 (.79)	-.150 (2.12)
Lower midland zone 4 (marginal cotton area)	-.005 (.02)	-091 (0.26)	.083 (.38)	.104 (0.57)
Lower midland zone 5 (livestock and millet area)	-.378 (3.22)	-.268 (2.51)	-.150 (2.17)	-.202 (2.88)
Constant Term	2.813 (.69)	-1.349 (.36)	.362 (1.34)	2.213 (.93)
(Pseudo) R-squared	.158	.195	.228	.325
Dependent Variable Mean (Log of farm yield)	1.179	2.120	3.101	2.129
Sample size	3682			

5. DISCUSSION OF RESULTS

A. Sample statistics

From the top panel of Table 1, which contains the sample statistics for the study districts, it can be seen that there is a large variation in farm yields and inputs across households as the standard deviations of these variables from their mean values are quite large. The observed variation in farm yields across households can be linked to differences in input usage across farms. It should be noted that the cross-sectional variation in farm yields is smaller than the variation in farm inputs. The less than proportional association between changes in yields and variation in farm inputs across households suggests that accumulation of inputs may not be the critical determinant of farm production in study areas. As can be seen from Table 3, differences in soil types could also be important determinants of the observed variation in yields.

The middle panel of Table 1 shows the relative importance of the various crops grown in the sample districts. Maize and beans, the staple foods in Kenya, constitute respectively 29.4 and 19.2 percent of all crops grown in the seven districts studied. The cash crops (tea, coffee, cotton and other cash crops) comprise only about 4.8 percent of all crops, indicating that nearly 95 of crops grown are on average for meeting food needs.

The lower panel of the Table shows socioeconomic attributes of farmers and the agro-ecological conditions of study areas. About 69 percent of respondents in sample districts are males and the average level of education for all farmers is 3-4 years (antilog of .922) while the average age is 45 years. On average, a farmer in the sample district lived about 5 kilometres from the nearest market centre (the geometric mean). A relatively large proportion of arable land (24.1 percent) is hilly, with the remainder of cultivable area being classified either as highlands or midland zones of various gradations. Tea, coffee, wheat and dairy farming take place in the highlands and in the upper midland zones. A substantial portion of both maize and beans is also grown in the upper midland zones. The lower zones are used primarily for livestock grazing and for growing dryland maize, and various types of millet.

B. Correlation results

Table 2 shows the degree of association between crop yield and selected variables from Table 1. These are variables that production theory suggests might be important in influencing farm productivity. As can be seen from Table 2, crop yield is positively and significantly correlated with labour, crop area and with the expenditure on fertilizers & sprays. The correlation is strongest with respect to the labour input. Farm productivity is also positively correlated with the extension staff and with farmer's education, but its association with the latter covariate is statistically significant only at about 8 percent level. The results in Table 2 provide evidence of co-movement of crop yields with key covariates in equation (2). Except for a few cases the correlation coefficients shown in Table 2 are largely consistent with results from the regression analysis reported in the ensuing section in Table 3.

C. Regression Results

Table 3 shows regression results at the first quartile (25th percentile), the median (50th percentile) and the third quartile (75th percentile) of the farm yield residuals. We begin by considering both the magnitude and the pattern of regression coefficients across the yield quantiles. Looking at the top panel of Table 3 (Section A), it can be seen that the elasticities of the farm yields with respect to the labour input are roughly the same over the three quantiles, ranging from a value of .205 at the first quartile to .190 at the third. In particular, a ten percent increase in the labour input would increase farm yields by about 2.0 percent for farmers at the 25th percentile of the distribution of the yield residuals but by 1.9 percent for farmers at the 75th percentile. It should be noted that the mean elasticity (the OLS estimate of .196) is of the same order of magnitude as the labour elasticity of output at the three quantiles. This elasticity is also within the range of the labour elasticity of .174 obtained by Aguilar (1988) for one Kenyan province using a different data set collected in 1982. As is evident from the bootstrap t-ratios, the labour elasticities are statistically significant at all the quantiles.

The productivity response to acreage is statistically significant across all quantiles and has a concave shape, as it first rises and then falls. In contrast, its response to agricultural extension is convex, displaying a U-shape across the quantiles. However, the extension elasticities at the first and the second quartiles are not significant at conventional levels.

Focusing attention on the extension case, it can be seen that farmers at the middle points of the yield residuals gain less from the extension service than farmers at the two ends of the distribution. In particular, productivity effects of extension service for farmers at the lower and upper ends of the yield residuals are higher than can be explained when account is also taken of other determinants of productivity. This result could be due to the effect of unobserved ability of farmers on diminishing returns to the extension input. Assuming that high-ability farmers are leaders in the use of extension service, they would have a greater quantity of this input than low-ability farmers. Hence, other things being equal, the marginal productivity effect of extension service would be lower among farmers of high ability than among farmers of low ability who lag behind in extension adoption. However, if high ability farmers happen to use extension service more productively than *low* or *average* ability farmers (i.e., ability and extension are complementary), high ability farmers may *not* experience diminishing returns to agricultural extension. Hence their marginal gain from extension service may not differ from that of low ability farmers. In contrast, diminishing returns to extension service would be experienced among farmers of average ability (because they have a higher quantity of the extension input than farmers of low ability). Thus, as the results show, it is conceivable for productivity or economic effects of extension to be lower for average ability farmers at the median residual than for farmers above or below it, thereby generating a U-shaped yield response across quantiles. This result, which could also be generated by errors in the measurement of the extension input rests on the assumption that extension and ability become complementary only when a certain threshold level of ability is attained.

It is worth noting that the U-shaped pattern of extension effect on farm yields across quantiles persists even when the effects are estimated using separate samples for males and females. Moreover, consistent with what the coefficient on the sex dummy shows (see below), productivity effects of extension are higher for males than for females. These results, which are not reported here are available on request. In another set of results, which we also do not report due to space limitation, the extension effect on maize yield (the dominant food crop in Kenya) is around .29, that is, more than twice the OLS elasticity of .13 for all crops. Economic effects of agricultural extension in Kenya from previous studies are not clear-cut. Evenson and Bindlish (1993) report large, positive productivity effects, while Aguilar (1988) and Aguilar and Bigsten (1993) report negative effects. A more recent paper (Gautam, 1998) shows that the earlier, large positive extension effects reported by Bindlish and Evenson (1993, 1997) are reversed by inclusion of district dummies in the productivity equation, but these new results are hard to interpret because it is not clear what is being controlled for by district dummies. However, the issue of non-robustness of extension effects raised by Gautam (1998) deserves further study.

The yield effects of fallow land and fertilizers differ in pattern and magnitude across quantiles. Both sets of effects are positive but the effect of fertilizer is 3-4 times larger than that of fallow land. Moreover, the effect of fertilizer rises throughout, while that of the fallow land falls after the median decile.

Productivity effects of fallow acreage were investigated further by interacting it with fertilizers and with extension staff. On farms with more fallow land, productivity effect of fertilizers is smaller than on farms with less fallow but the effect of the extension staff is greater. These two results respectively suggest that fallow land is a substitute for fertilizers and that extension enhances productivity on farms with more fallow land perhaps because farmers get advice on how best to rotate crops between cultivated and fallow acreage.

The schooling elasticities of yields are positive but decline steadily over the quantiles. A 10% increase in the education of farmers (measured in years of schooling) improves yields by 4.7% for farmers at the first quartile of the yield distribution but by only about 3% for farmers at the third quartile (75th percentile). However, the elasticities are not statistically significant. The effect of age of farmers, which is a proxy for experience, exhibits a concave shape at each quantile (the coefficients on age and age squared are positive and negative respectively), a result that indicates diminishing returns to experience. Despite the weak statistical significance of the age coefficients, the foregoing finding is important as it reveals very large experience elasticities of yields in all quantiles. Further, the coefficient on interaction of age with schooling shows that the yield effect of an extra year of schooling is smaller on farms managed by older farmers.

The middle panel of Tables 3 (section B) shows effects of crop-specific factors on yields. The common pattern in both tables is that farm yields are higher for maize than for any other crop in all quantiles except in the case of coffee. In the case of coffee, the farm yield is greater than the yield for maize at the median and higher quantiles. Relative to kilograms of maize yield, coffee production per acre is greater at higher quantiles of yield residuals.

The bottom panel of Tables 3 (section C) presents effects of demographic and geographic factors on farm productivities. Yields are higher for male farmers in all quantiles, especially at the 25th percentile. This finding may not be interpreted to mean that being a male enhances productivity because it could be reflecting differences in family structures among families. For example, male headed families may have more workers than female headed families. Distance from the market centre is negatively correlated with farm yields across all quantiles. The negative effect on yield of distance from market centres has no particular pattern across quantiles. As to agro-ecological zones, crop yields are generally higher in highland zones than in midland zones in all quantiles.

In summary, a key finding of this study is that agricultural extension has favourable effects on farm production but this finding is difficult to compare with results from previous studies (see Birkhaeuser *et al*., 1991) because measurement of agricultural extension varies across studies. Nonetheless, the finding is consistent with Schultz (1975) hypothesis that human capital acquired through schooling or via extension advice enhances productivity of farmers especially in a changing environment.

6. SUMMARY AND CONCLUSION

This study has examined the effect of agricultural extension on farm productivity in Kenya controlling for other determinants of crop yields, such as schooling of farmers, labour and fertilizer inputs and soil quality, proxied by agro-ecological conditions. There are five main findings of the study. To start with, productivity gains from agricultural extension are highest at the top end of the distribution of yield residuals, suggesting that agricultural extension may be enhancing unobserved productive attributes of farmers such as managerial abilities. The U-shaped response of farm yields to extension services across quantiles that has been noted is probably due to a positive association between extension service with unobserved factors such farm management skills and possibly to errors in the measurement of extension.

The second noteworthy finding of this work is that increases in farm yields due to schooling generally rise with quantiles but these increments are not significant. Aguilar (1988) obtained negative productivity effects of schooling among Kenyan smallholders in Nyanza province but found positive effects in Central province. Evenson and Bindlish (1993) and Appleton and Balihuta, 1996) report mixed effects of schooling on farm productivity.

The third result is that public investment that makes market centres broadly available to farmers would improve farm productivity because distance from market centres reduces farm yields at all quantiles. This is so because there are large costs of transacting at distant markets. In addition to reducing farm profits, transactions costs weaken a farmer's ability to obtain purchased inputs such as fertilizers and sprays which complement other farm inputs, notably labour and land. The fourth finding of the paper is that extension services are more productive in farms with more fallow land than in farms with less fallow acreage. Periodic crop rotation, which is one activity initiated by extension agents at the farm level may be the process through which extension reinforces productivity of fallow land. Lastly, agro-ecological factors, which include soil quality and rainfall variability *do* influence farm yields. If these factors are not taken into account in assessing production effects of extension services, their effects would be incorrectly measured.

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