The effectiveness of agricultural extension with respect to farm size: The case of Uganda

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2009
AAEA & ACCI Joint Annual Meeting, Milwaukee, Wisconsin, July 26-29, 2009

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Because over 80% of the Ugandan labor force is employed in the agricultural sector, modernization of Ugandan agriculture is central in fighting poverty (Government of the Republic of Uganda 2000). In 1997 the Ugandan government launched its Plan for the Modernization of Agriculture (PMA) as a strategic framework to eliminate poverty through agricultural development. The PMA is comprised of seven components, each of which addresses a particular objective of the plan. The National Agricultural Advisory Services (NAADS) is one of the seven components and is responsible for broad range of activities, including the provision of education and advisory services to farmers, expansion of farmer institutions, and development of agribusiness and improving market linkages, aimed at raising the productivity of Uganda farmers. However, recent analysis show that for a majority of staple crops agricultural productivity is decreasing and any output gains are attributed primarily to the expansion of cultivated land (Kraybill, Bashsaasha, and Betz 2009). These practices have contributed to Uganda to having one of the highest rates of soil depletion in all of Sub-Saharan Africa (Pender et al. 2004; Wortmann and Kaizzi 1998).

Improved farming technologies such as high yield crop varieties, chemical fertilizers, and irrigation techniques have been central in raising yields in other parts of the world; however, African farmers have been much slower in adopting these new methods. One reason that farmers cite for not adopting the new technologies is a lack of information regarding how to apply the improved inputs (Morris, Kelly, Kopicki, and Byerlee 2007). In many cases if the improved inputs are not applied correctly yields will be lower than traditional crop varieties, leading farmers to abandon the new technologies. Consequently, access to reliable information is an integral part in any farmer’s ability to raise productivity. Information about improved methods or new technologies come through a variety of mechanisms such as formal government extension, mass media such as radio, and as often is the case, through other farmers.

Agricultural extension is the primary mechanism that developing country governments use to assist farmers in expanding their ability to adopt and implement new methods and to relay information concerning new technologies. Throughout Africa extension programs have the reputation of being largely ineffective (Dejene 1989; Gautam 2000), adding very little to the productivity of farmers. This reputation is no exception in Uganda as evidenced by the Ugandan government's suspension of NAADS in September 2007 on the grounds of implementation failures. In February of 2008 NAADS was reinstated as a part of President Yoweri Museveni's "Prosperity For All" program. Following its reinstatement NAADS has been charged with the task of designing and implementing effective agricultural extension services aimed at increasing the productivity of Ugandan farmers, creating an opportunity for research on what conditions allow extension service to be successful.

Previous studies have investigated the relationship between agricultural extension and productivity with varying results. Birkhaeuser, Evenson, and Feder (1991) review 26 studies that use linear regression to determine the relationship between extension contact and farm productivity, with only 11 statistically significant at the 90% level. Evenson (1997) points out that because of large variation in program design and field worker skill it is not feasible to make broad generalizations about the economic contribution of agricultural extension. Birkhaeuser, Evenson, and Feder also point out two major difficulties of including extension variables in the estimation of agricultural production functions. First, most studies use a farm-level extension contact variable that does not account for knowledge spillovers occurring when farmers talk to each other and exchange information. In this case a farmer that has not been visited by an extension agent, but has obtained the same potentially output increasing information from a neighbor, has received the treatment without any statistical accounting of it, biasing the results upward. The second difficulty with using a farm-level extension variable is that there is possible endogeneity within the farmer-extension worker interactions. That is, more productive farmers may have some unobservable quality, such as a desire for the best farming methods, which would also lead them to seek out extension agents. Owens, Hoddinott, and Kinsey (2003) control for the endogeneity of the extension variable by including farm plot characteristics, location dummies, and a variable representing farmer ability into the regression equation. This study attempts to correct for both the endogeneity and spillover effects by including control variables for farmer ability and information exchange between farmers.

Another relevant question with respect to agricultural extension in Uganda is whether the farmer-extension worker interaction has differential effects on farms of different size. As is the case in most developing countries, the Ugandan government can only devote limited resources to agricultural extension programs and so most programs are only administered to a limited proportion of the population. Because there is significant variation of farm size throughout Uganda, and likely significant variation in the determinants of output for different sized farms, it is critical for NAADS to understand which extension policies will benefit farms of different sizes.

Past research has found relationships between farm size and factors of production and also farm size and output. Larger farms are more likely to use advanced farming inputs such as fertilizer, irrigation, and improved seed varieties (Feder, Just, and Zilberman 1985) when compared to smaller farms. This has lead many agricultural programs to solely target larger, more sophisticated farms that are viewed as better equipped to make use of additional resources. Conversely, a vast literature exists showing an inverse relationship between land productivity and farm size (Sen 1962; Berry and Cline 1979; Rosenzweig and Binswanger 1993) suggesting that smaller farms are more productive and would be better targets of available resources. It may prove advantageous for NAADS to provide assistance to farms of all sizes simultaneously, in which case it is important to understand how extension enters the production technology of various farm sizes differently. This study further examines the relationship between farm size and productive inputs, with particular attention given to extension services.

I find that the number of extension visits a household receives has a positive effect on the value of output of the smallest and largest farms, but does not have a significant effect on medium sized farms. Also, the number of extension visits has almost twice the affect on large farmers as it does on small farmers. The rest of the paper is structured as follows: Section II presents the data and analyzes the summary statistics. Section III delivers a review of the theory behind the empirical model and justification the model itself. Section IV presents the empirical results and their interpretation. Section V concludes.

Data

The data that is used throughout this study comes from the 2005/2006 Ugandan National Household Survey (UNHS). The survey is administered by the Ugandan Bureau of Statistics (UBOS) and has historically had two main components: a socio-economic survey and a community survey. The socio-economic survey records important household indicators such as health, education, assets and consumption activities, whereas the community survey includes information on community characteristics, such as infrastructure, utilities, and nearby institutions. Recognizing the importance of agriculture in the Ugandan economy, UBOS included an agricultural survey in the 2005/2006 National Household Survey.

The agricultural survey includes detailed information concerning agricultural inputs, crop selection, land characteristics, and market access, along with many other factors relevant to farming. A key component of the agricultural survey is a quiz that was administered to farmers, assessing their knowledge of specific agricultural practices. A major difficulty in estimating agricultural production functions is controlling for heterogeneity that exists across farms as a result of individual farmer ability and knowledge. This quiz provides an opportunity to control for farmer ability, which in the past has been a possible source of error. The agricultural survey also includes several questions that are central to this study concerning agricultural extension and specifically NAADS.

The 2005/2006 UNHS contains data from both the long growing season (January-June) and short growing season (July-December). Only the data from the long growing season is considered because of the short growing season's irregular weather patterns, and thus lower probability of producing consistent results. Additionally the average value of household agricultural output for the short growing season is only approximately 10% of that of the longer growing season. The 2005/2006 UNHS was conducted in all four regions of Uganda: Northern, Eastern, Western, and Central. It was administered using a stratified two-stage sampling design, where 750 villages were selected across the four regions. Ten households were selected at random from each village, resulting in 7,500 total observations. Of the 7,500 households 5,405 produced some positive agricultural output in the long growing season, of which 5,200 had data complete enough to be included in the study.

The means of variables of particular interest are presented in Table 1. Overall trends follow farm size pretty closely for most variables. The data show that large farms have larger households, use more productive inputs, such as fertilizer, pesticides, and improved seeds, and have higher quality land. As farm size increases we see more adults per household, greater average distances to parcels and more visits from agricultural extension workers. The last point is of particular interest from a policy standpoint. The stated focus of NAADS is “to develop a demand driven, farmer-led agricultural service delivery system targeting the poor subsistence farmers, with emphasis on women, youth and people with disabilities” (NAADS). In this sample large farms (more than 13 acres) received extension visits at almost four times the rate of medium farms (between 2 and 13 acres) and nine times the rate at which small farms (less than 2 acres) received them. Furthermore, large farms have a lower incidence of female headed households than either medium or small farms, yet receive significantly more visits from extension workers.

Modest levels of improved agricultural inputs in Uganda are evident. The average farm owns only US $10 worth of agricultural assets. This includes simple tools such as hoes, rakes, machetes, and wheelbarrows, but also includes any larger assets like plows or even tractors. In real terms US $10 worth of agricultural assets means that the average household owns several machetes, a couple of hoes, and a wheel barrow, at most. Small farms, which comprise almost half of the sample, own even less, possessing only US $5 worth of agricultural assets. Though large farms have significantly more agricultural assets, their levels are still relatively low compared to other parts of the world.

Fertilizer and pesticide use in Uganda is very modest as well, with the average household spending only US $0.58 on fertilizer and US $0.73 on pesticides, herbicides, and fungicides for the entire long cropping season. This is consistent with other findings that fertilizer use throughout Sub-Saharan Africa remains much lower than the rest of the world (Morris, Kelly, Kopicki, and Byerlee 2007). The percentage of farms using improved seeds and mulching also remain low at 13.9% and 6.7%, respectively.

The data shows evidence of an inverse relationship between land size and productivity. Small farms produce over twice the value per acre compared to medium sized farms and almost 5.5 times the value per acre of large farms. Van der Veen (1975) proposes that this is the result of smaller farmers' more efficient use of family labor, while also working the land more intensively to meet subsistence needs. This is very likely the case in Uganda as well.

The data show some interesting features with respect to crop choice. In principle, larger farms do not typically operate near subsistence so they are able to take on more risk and can devote a higher percentage of their land to cash crops (Rosenzweig and Binswanger 1993), which in Uganda have traditionally been coffee and bananas. However, the data show large farms are planting higher percentages of beans, maize, and cassava (traditional staple crops) than one would expect if this were the case. Both small and medium farms are planting higher proportions of bananas than large farms. Small farms do plant higher percentages of beans and lower percentages of coffee; however, large farms are planting more cassava than small and medium farmers. This reflects the trend that in recent years traditional staple crops are being harvested for sale rather than consumption on many farms. This has resulted in larger farmers increasing the diversity of their crop choice to include maize and beans as well as coffee and bananas.

Methods

The model that is used is a Cobb-Douglas production function of the form:

$$Y = AL^{\alpha}K^{\beta} \quad (1)$$

where Y is the value of agricultural production, K is the farm's capital inputs and L is the farm's labor inputs. A is the total factor of productivity, otherwise known as technology, and increases the effect of both capital and labor simultaneously. All observable household, community, and land characteristics are included in A. α represents the output elasticity of capital and β represents the output elasticity of labor, where $\alpha + \beta$ greater than one, equal to one, and less than one imply increasing, constant, and decreasing returns to scale, respectively.

There are several problems that have historically plagued econometric estimations of agricultural production functions. In past studies, the heterogeneity of farmer ability or knowledge has been difficult to control for resulting in correlation between the output produced and the error term. Models that fail to control for farmer ability will produce biased results and thus potentially flawed results. For this study farmer heterogeneity is controlled for by including a variable in the regression that represents a farmer's knowledge of specific farming practices in general and also specific to Uganda. The farmer knowledge variable was constructed using a quiz that was administered to each farmer as part of the agricultural section of the UNHS. The quiz consists of seven multiple choice questions covering the topics of fertilizer use, planting methods, pest and disease control, and soil fertility. The scores followed a normal distribution with a mean of 3.4 and a standard deviation of 1.4, suggesting that the quiz was able to capture a fairly complete range of farmer knowledge and is a relatively accurate measure of farmer specific ability.

There are two major concerns in trying to empirically estimate the effect of agricultural extension on output. The first is that there is a strong possibility of an endogenous relationship between output and extension visits. This simultaneous relationship runs both ways, from the farmer to the extension worker and vice versa. For example, farmers who seek out extension workers and other extension programs are likely seeking out other opportunities that improve their productive capabilities and increase their output. This makes farmers involved in extension more likely to have higher outputs even before they interact with any extension personnel. Likewise, extension workers often gravitate towards more capable and motivated farmers. The farmer ability variable discussed about will serve as a control for both of the situations.

The second issue in estimating the impact of extension on output is information spillovers between farmers. Farmers receive information on new technologies and approaches to cultivation through a variety of different sources including formal extension, mass media outlets such as radio or newspaper, private companies, and other farmers. Table 2. is a summary of the data concerning different sources from which farmers had access to information about various improved farming methods and inputs such as soil fertility management, crop protection, farm management, improved varieties, on farm storage, and improved individual and group marketing. Clearly many farmers do not have access to information for any of the above categories through any of these sources. What is also evident is that farmers with more land generally have more information available to them. Government extension and NAADS account for modest amounts of information transfer for small and medium size farms, while both mass media and other farmers are the main sources on new information for all farm sizes. It appears that farmers still rely heavily on each other for finding ways to improve their harvest. This creates some difficulty in measuring the effect of extension if a farmer who did not receive an extension visit had access to the same information as a farmer who did receive an extension visit through the transmission of information between neighboring farmers. To control for this a variable recording whether or not each farmer had received any information on improved inputs or techniques from other farmers was included in the regression equation.

Formally, letting i denote households, the estimation equation is

(2) $$y_i = \alpha k_i + \beta l_i + \gamma a_i + \mu_i$$

where the dependant variable y_i is the log of the total value of household $i's$ agricultural output. k_i, l_i ,

and a_i are the log values of household $i's$ capital, labor, and technology, respectively. Capital includes the household's land and agricultural assets, while the labor variable includes labor performed by household family members and hired labor. The household's technology includes variables like the household head's education, the amount of fertilizer applied, and percentage of the land under improved seeds. μ_i is a stochastic, normally distributed error term with a mean of zero. Robust regression was used to control for heteroskedasticity. In testing for multicollinearity the variance inflation factor did not indicate that any potentially damaging multicollinearity exists.

Empirical results

Robust regression results of the Cobb-Douglas production model are presented in Table 3. The three models estimated are for households that own less than 2 acres (small), between 2 and 13 acres (medium), and more than 13 acres (large). Most of the important variables are significant and are of the expected sign, although there are some interesting variations between the models. The variables representing the household's head's age, days of household labor, days of hired labor, use of mulch, and use of fertilizer are all positive and significant. These results are rather intuitive as more experience, labor, and advanced inputs generally lead to greater output.

Geographically, farms in the north experienced lower values of total output across all farm sizes. This is most likely attributed to the civil unrest that was occurring in some parts of the northern regions at the time of the survey. Conversely, farms in the Western region were positively correlated with value of total output. This can be in part attributed to the lower population densities and better soil fertility in the Western region. Also, the percentage of land devoted to cassava, banana, and coffee are all positively correlated with total value of output. This result is intuitive for banana and coffee as they are both cash crops, but the connection with cassava is not quite as obvious.

There are several other variables that show variation across farm size that are noteworthy. Being located in the Western region has less than half of the effect on the value of output for small farms and less than two-thirds of the effect on the value of output for medium farms as it does on the largest farms. This may be from the elevated government investment into the region, of which much goes to the largest, most politically connected households.

Although the value of output is affected more negatively by conflict in the north for small farmers, the difference over farm sizes in this region is much less than differences in farm size in the western region. Small farms have fewer safety nets available when civil conflict does arise and experience a disproportionate negative effect on output when conflict does arise.

Land size is significant and positively correlated with value of output for small and medium farms, but insignificant for large farms. This may be because the scale is much greater for large farms. The standard deviation of land size in the large farm sample is 74 acres, compared to 0.5 and 2.5 acres respectively for small and medium farms. The marginal benefit of adding another acre of land decreases significantly as scale increases.

Effectiveness of extension

Of most interest to this study is the variable measuring the number of extension visits over the past twelve months. Extension visits are positive and significant for small farms and large farms, but are not significant for medium sized farms. Explanations for this may lie in the scale of production and available opportunities for each farm size. Although the magnitude of the coefficient on the extension variable is fairly small, extension visits have a significant impact on the value of production. For small farms doubling the number of extension visits will yield less than a two percent increase in the value of output produced. For large farms a doubling of the number of extension visits will yield just over a three percent increase in the value of output produced. However, the typical small farmer only received 0.11 extension visits, so a doubling of extension visits is not adding significantly to the each farmer’s production technology. However, if the average household received one extension visit the value of output would increase by 19.9%, raising the average small farm income from US $70 to US $84 per season. Furthermore, extension visits have a lasting effect. Knowledge is retained from season to season and it is likely that each subsequent growing season will see an increase in output as well.

The extension variable for medium sized farms is insignificant implying that extension visits did not have an effect on the value of output produced by farms that cultivated between 2 and 13 acres. Households in this range typically have more opportunities available to them than small farms and may not invest so intensively in agriculture. In Table 4 we see that households with medium farms are not only more likely than small farm households to have a member that participates in off-farm work, but their the average monthly income from off farm work is more than double that of small farmers. Because households with medium sized farms have more diversified sources of income they are not as intensely tied to agricultural as a means of survival as small farms. This may explain why extension visits are not having a significant effect on their output. The opportunity cost is much higher for medium sized farms to invest labor in modifying aspects of their farms than it is for smaller farms.

There is a positive relationship between extension visits and output value for large farms as well. Large farmers have even more diversified incomes, having double the monthly off-farm income of households with medium sized farms and almost five times that of households with small farms. However, the opportunity costs of investing time in improving farm output tend to be different for these larger farmers. Many farms of this size have the resources to hire a farm manager, whose job it is to oversee the production activities of the farm. The farm managers then bear the time and labor costs of implementing any of the extension agent's recommendations, while household members are free to pursue other off-farm activities. Also, large farms have greater financial resources available enabling them to invest in any inputs that require up-front costs, maximizing the effectiveness of the information they have received from the extension service.

A typical extension visit consists of the extension worker examining the crops, farming techniques, and other aspects of cultivation that the farmer is currently applying. Recommendations are made concerning how the farmer can improve his production, which the farmer considers and decides to enact or not. These changes usually do not require investment or accumulated capital, but are rather changes in methods. It is not surprising that such extension visits benefit the smallest farms. These are households that have less than 2 acres of land and are typically involved in subsistence agriculture. Any information that improves output will be helpful to this segment of the population. These small farmers usually cannot save much from one season to the next and most likely cannot afford fertilizer, complex irrigation, or other productive inputs that require an initial monetary investment. As a result, for small farmers marginal increases in output come from more and better knowledge concerning all aspects of production.

Information transfers can have a large effect over time, as evidenced by the quiz score variable. Increasing the farmers' knowledge by one correct question will raise output by 3%. Because broad agricultural knowledge has little, if any, depreciation from one season to the next improving the quality and availability of information available to farmers will have a cumulative effect and raise output every year thereafter. Such information delivery is an attractive intervention relative to investments in physical assets that are regressive in their effect on output or seasonal inputs that only improve that season's crop. Also, small, poorer farmers have few livelihood options outside of agriculture. Most do not have access to the required capital to engage in some small off-farm business or to migrate to the city and have little choice but to farm and invest their time in increasing their agricultural output. Consequently, improving agricultural output is seen as central to improve living standards and improving access to better farming techniques and methods can have a significant role in increasing incomes.

Conclusion

Because the agriculture sector is such a large and important part of the Ugandan economy it becomes gravely important that policies regarding this sector be designed efficiently and implemented effectively. This study estimated a Cobb-Douglas agricultural production function, controlling for heterogeneity in farmer ability and knowledge spillovers. The empirical analysis yields a positive relationship between agricultural extension and value of output for small and large farms, but finds no statistically significant relationship between extension and value of output for farms between 2 and 13 acres. This result has important policy implications for the Ugandan government's administration of agricultural extension services. Targeting small and large farms with agricultural extension may be the best use of limited resources, where other policy initiatives may be more suitable for medium farms.

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Table 1. Means of Household Characteristics by Farm Size

	Full sample	Small Farms	Mid-size farms	Large farms
Basic household characteristics				
Household size	6.0	5.1	6.5	8.4
Number of adults	2.5	2.2	2.7	3.7
Number of children under 15	3.0	2.6	3.4	3.9
Percent of female headed households	25.9%	33.1%	20.3%	14.3%
Household head's age	44.0	42.3	45.1	48.6
Agricultural Inputs				
Acres of land cultivated by the household	4.9	1.0	4.8	43.0
Days of labor performed by household members	90.8	55.7	117.1	151.5
Days of labor performed by hired members	14.0	5.3	18.0	55.2
Value of household's agricultural assets (US$)	10	5	10	53
Value of fertilizer applied (US$)	0.58	0.19	0.78	2.30
Value of pesticides, herbicides and fungicides applied (US$)	0.73	0.26	1.00	2.41
Percent land mulched	13.9%	13.3%	14.0%	17.1%
Percent land under improved seed	6.7%	6.1%	7.0%	9.6%
Farm and farmer characteristics				
Percent land good soil	42.1%	35.7%	46.0%	61.6%
Percent land steep	3.1%	3.4%	2.8%	2.4%
Percent of land devoted to cassava	12.8%	11.9%	13.5%	14.3%
Percent of land devoted to beans	8.1%	10.0%	6.8%	3.6%
Percent of land devoted to maize	17.2%	17.4%	17.1%	15.7%
Percent of land devoted to coffee	5.6%	4.5%	6.5%	5.5%
Percent of land devoted to banana	22.8%	25.1%	20.9%	19.7%
Average parcel distance from the homestead (km)	1.5	1.2	1.6	2.7
Score on the farmer knowledge quiz (out of 7)	3.4	3.3	3.5	3.8
Number of extension visits in the past 12 months	0.22	0.11	0.24	0.92
Value of household's agricultural output (US$)	137	70	175	368
Average value of output per acre (US$)	61	87	41	16
Number of observations	5200	2373	2575	252

Table 2. Percentage of Farmers Who Got Information About Improved Inputs or Methods from Various Sources

	Small	Medium	Large
No access	41	32	23
Government extension	6	9	17
NAADS	5	8	14
Mass media	25	34	39
Other farmers	38	40	38

Table 3. Cobb-Douglas Model Regression Results

	Small	Medium	Large
Eastern	-0.100	-0.053	0.054
Northern	-0.779***	-0.561***	-0.646**
Western	0.153**	0.192***	0.360*
Female head dummy	-0.080	-0.063	-0.057
Log of head's Age	0.093	0.030	-0.141
Log of head's school	0.021***	0.017***	0.033*
Log of household's total land	0.308***	0.290***	0.173
Log of household's total labor	0.284***	0.308***	0.227***
Log of total hired labor	0.029***	0.030***	0.043***
Log of household's agricultural asset value	0.009	0.014	0.118*
Log of percentage of land mulched	0.016***	0.015***	0.024*
Log of percentage of land with good soil	0.013***	0.007*	0.012
Log of percentage of land that is steep	0.005	0.011*	0.014
Log of the value of fertilizer applied	0.042***	0.021***	0.030**
Log of the value of agricultural chemicals applied	0.004	0.012***	0.009
Log of the percentage of land with improved seed	0.007	0.016**	0.000
Log of the percentage of land devoted to cassava	0.021***	0.009*	0.036**
Log of the percentage of land devoted to beans	0.006	0.009*	0.012
Log of the percentage of land devoted to maize	0.004	0.005	0.018
Log of the percentage of land devoted to banana	0.027***	0.021***	0.040**
Log of the percentage of land devoted to coffee	0.018**	0.012**	0.044**
Log of the farmer's quiz score	0.033***	0.044***	0.045
Knowledge received from other farmers dummy	0.021	0.037	0.046
Log of the number of extension visits	0.018**	0.006	0.032**
Constant	12.42***	12.14***	13.73***
R squared	0.425	0.375	0.514
N	2373	2575	252

* for p<.05, ** for p<.01, and *** for p<.001

Table 4. Off-farm Employment and Distance to Agricultural Land by Farm Size

	Small	Medium	Large
Percentage of households who participated in off-farm employment	39%	42%	51%
Average monthly household income from off-farm employment (US$)	50	116	231
Average farm income as a percentage of total income	10%	11%	12%