Farm productivity in Burkina Faso: effects of animal traction and nonfarm income

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The purpose of this invited paper session is to stimulate, at the micro, meso, and macro levels, debate on positive analytical approaches to agricultural productivity. The session focuses on Africa because it is the only developing region where crop output and yield growth is lagging seriously behind population growth.

The present paper treats the micro (farm-household) level. Macro and meso analyses are useful for tracing productivity effects of policy and infrastructure change employing broad samples over long periods. Micro analyses tend to track smaller samples over shorter periods, but dig below the aggregate surface to discern and explain productivity differences over crops, zones, and farmer groups. Micro analysis is useful for policy and technology formulation and for infrastructure and commodity promotion strategies. Further, many aggregate studies are limited to only a few composite product categories because of lack of more detailed data on labor, land, and capital allocations over crops. To obtain finer distinctions among crops, one needs detailed farm management surveys.

Since the spate of African farm management studies in the 1960's and 1970s, soils have rapidly degraded, access to land has become increasingly constrained, factor and credit markets have changed structurally, and nonfarm activity by farm households has apparently increased. These changes should affect productivity across farm types, suggesting the need to revive attention to farm-level analysis.

Past farm-level productivity work in Africa, which largely used positive analysis, tended

to stratify the sample exogenously based on farm characteristics, generally by farm size, use of animal traction, access to credit, use of new seed varieties, land tenure status, or income. We follow these earlier studies by stratifying the farm household data by a factor we expect to affect technical parameters, namely farm capital. In the Guinean zone of Burkina Faso in particular, we stratify according to whether the household owns animal traction equipment (following Barrett et al. and Jaeger and Matlon).

Besides adding to empirical evidence on the productivity effects of animal traction, we endogenously stratify the sample with a selectivity model, an approach too rarely taken (with a few recent exceptions such as Carter) in productivity research. We then estimate production functions, controlling for selectivity bias.

Such an approach also allows us to test the (indirect) effect of nonfarm income on productivity through its effect on technology adoption as embodied in farm capital acquisition. Studies of nonfarm income effects on capital acquisition are not absent in the literature (e.g. Barrett et al. in eastern Burkina), but they have been somewhat neglected in farm-level work, and neglected even more in aggregate-level research because of the rarity of rural nonfarm income data.

Yet nonfarm income is an important part of total rural household income in semi-arid West Africa. Reardon et al., for example, show for the Guinean zone of Burkina, that half the income and three-quarters of the cash of the typical farm household are from nonfarm sources. Narrowly focusing farm productivity research on the farm sector means ignoring the context in which farm activities are inserted: rural households, which are multisectoral firms, husband

resources over the year to produce a vector of farm and nonfarm outputs so as to maximize food security and income and to manage risk. Off-farm uses of household resources can compete with crop uses. Nonfarm income can also increase farm productivity by providing liquidity in cases where access to input credit is limited (such as in the West African semi-arid tropics). We hypothesize that nonfarm income has a positive effect on animal traction investment in Burkina. Modeling this effect in a selectivity framework allows nonfarm liquidity to enter the analysis without appearing directly in the production function. It makes more sense that nonfarm liquidity should affect the choice of fixed inputs that in turn determine technology, than that it directly influence output.

Illustration from Burkina Faso

The data are from the ICRISAT survey of the five cropping seasons of 1981-1985 in Burkina Faso. The survey covered crop input/output, household nonfarm income, and other household characteristics, in three zones, employing a sample of 150 households in total. Due to space constraints, we report results only for the subsample of 50 farm households in the southerly, Guinean zone. We thus use 250 observations of the panel variables, and 50 observations of the cross-section variables. In the Guinean zone, animal traction and cash cropping are more common, and cropping is more diverse and dynamic than elsewhere in Burkina.

Four principal crops are produced in this zone: cotton and maize (cash crops), and millet and sorghum (subsistence grains). Table 1 shows that production of maize and cotton are twice

as labor intensive as that of millet and sorghum. Land is fairly equally distributed, so we did not stratify by farm size. There is no irrigation or tractorization. Half the sample households own traction equipment; the rest use hand tools and seldom hire traction services.

Table 1 shows that labor use does not differ greatly between groups, but traction is labor-saving per hectare. Fertilizer use is similar between groups; most fertilizer is used on cotton and maize (averaging 111 and 43 kgs./ha. respectively, with millet and sorghum averaging only 3 kgs.). Most manure is used on cotton and maize. Traction households use much more manure than do non-traction households because of their greater capacity for transport and application, and because they have the animals to produce the manure.

We first model adoption (ownership) of traction equipment in a probit function (equation 1), then endogenously partition the sample. Finally, we estimate the production and input demand functions (equations 2 and 3), correcting for the resulting sampling bias by including as a regressor the Mills ratios calculated from the estimated parameters of equation (1). The traction adoption model is:

$$(1) \qquad AT_{ht} = \theta_0 + \theta_1 SIZE_{ht} + \theta_2 ROAD + \theta_3 AGE_{ht} + \theta_4 NONFARM_{ht} + \theta_5 LIV_{ht} + u_{ht},$$
$$(h=1,\ldots,N; \quad t=1,\ldots,5)$$

where AT is zero or one. SIZE is size of household in adult equivalents. ROAD is a dummy for good access to a road. AGE is age of the household head. NONFARM refers to income from nonfarm (neither cropping nor livestock) sources, measured as a cross-section variable (a

household observation is an average over the period). LIV is livestock income measured as a cross-section variable.

The production function is specified as quadratic and estimated without imposing concavity:

$$(2) \qquad Q_i = a_{i0} + \sum_{k=1}^{m} a_{ik}X_{ik} + \sum_{l=1}^{q} c_{il}Z_{il} + \frac{1}{2}\sum_{j}^{m}\sum_{k}^{m} b_{ijk}X_{ij}X_{ik}$$

$$+ \frac{1}{2}\sum_{k}^{m}\sum_{l}^{q} g_{ikl}X_{ik}Z_{il} + \frac{1}{2}\sum_{l}^{q}\sum_{r}^{q} d_{ilr}Z_{il}Z_{ir},$$

$$i = 1,\ldots,4;\ j = 1,\ldots,m$$

where: Q_i is the quantity harvested of the ith crop; X_{ij} is the quantity of the jth variable input allocated to the ith crop; and Z_{il} is the quantity of the lth fixed or conditioning factor allocated to crop i. Equation (2) was estimated together with the input allocation functions:

$$(3) \quad X_{ij} = X_{ij}(r_1/p_i,\ldots,r_m/p_i,\ Z_{i1},\ \ldots,\ Z_{iq}), \quad (i=1,..,4;\ j=1,..,m)$$

where p_i is the price of output i and r_j the market price of variable input j. Equations (2) and (3) together give technical parameters that are free of simultaneity bias. The maintained hypothesis is that farmers attempt to maximize returns to the fixed factors. Products in this study are the four principal crops discussed above. The variable input is total labor (family labor plus hired labor). Fixed factors are land, chemical fertilizer, manure, rainfall, and toposequence, a proxy for land quality. Prices are for crops and the farm labor wage. The fertilizer price was

excluded because it did not vary over the sample period; the manure price was excluded as there is no market for it.

Results for all three zones and further discussion of methods used are in Savadogo et al.). Here we give a brief synopsis. Table 1 shows that the coefficient of nonfarm income in equation (1) is highly significant and positive, suggesting credit market constraints. Household size is also positive and significant. As this variable is correlated with farm size, the significance may imply that only larger farmers find it worthwhile to invest in traction, or it may mean there is a critical minimum level of family labor needed to operate traction equipment and care for animals. Age of household head is negative and significant.

Marginal productivities (MPs) and average productivities (APs) were calculated from the estimated own and cross product parameters of the production function. Table 2 shows MPs and APs in terms of francs CFA at the mean input usage. Labor MPs in the traction group do not differ much among crops. Approximate constancy across products of a given factor's marginal value product suggests that the farm households allocate labor in an economically rational fashion. This rationality may be aided by the greater resource-allocation flexibility that traction affords. But in the manual group, labor MPs are not close to one another in the manual group (millet's is close to cotton's, and maize's is close to sorghum's, but the labor MPs of cotton and maize are together twice those of maize and sorghum). The average MP in the traction group (33 francs/hour) is above that in the manual group (20), as traction is labor-augmenting. Manual households also use less manure than do traction households.

Labor APs are higher than labor MPs (twice as high in traction households, thrice as high

in manual households), a result not imposed by model specification because concavity was not imposed. Excess of AP over MP suggests a labor surplus or possibly a land or capital constraint. But the average AP in the traction group (71 francs/hour) exceeds that in the manual group (61), implying as expected a higher overall labor efficiency in the traction group. The gap between MP and AP is higher among traction households than among manual households, again because traction is crop-labor saving.

MPs of land vary by labor intensity of crop. In traction households, the land MP of cotton is close to that of maize, and the land MP of millet is close to that of sorghum. But the average MP of cotton and maize is nearly five times that of sorghum and millet. This might reflect: (a) the practice of growing millet and sorghum on lower quality land, (b) much lower use of fertilizer, manure, and hired labor on millet and sorghum than on cotton and maize, or (c) possibly greater effort and management in cash crops than in millet and sorghum cropping. Millet and sorghum, that is, appear to be treated as subsistence or "safety first" crops. Among manual households, MPs of land in cotton, maize, and sorghum are close to one another, but millet's land MP is far below the other crops' land MPs, probably because millet is allocated poorer land and fewer inputs than are the other crops.

In the traction group, the MP of land in labor-intensive crops (cotton and maize) is nearly twice that in the manual group. Given that labor and fertilizer use in these two crops is virtually the same in the traction and in the manual group, the fact that traction households have a higher land MP than do the manual households may be because the traction group employs more manure and is better able to crop more fertile (but heavier) clay-loam soils.

Land APs again vary roughly according to labor intensity of crop. In traction households, cotton and maize APs are similar to each other, and together are higher than sorghum and millet APs. In manual households, the land AP of maize is the highest, followed by that of cotton, sorghum, and millet.

Moreover, in the traction group, land APs are close to land MPs (ratio of 1.7) in cotton and maize. In the manual group, land APs are further apart from MPs (ratio of 2.5). The implication is that the traction group has, at the margin, easier access to land of sufficient quality for cotton and maize, which usually are allocated the higher quality land. Either traction households are endowed with better land reserves or traction allows households to crop fertile land with heavy soils.

Table 2 shows MPs of fertilizer in cotton and maize only, as little fertilizer is used on other crops. Marginal value products are, as expected, positive, but unfortunately the standard errors are so high that results not statistically significant. Nonsignificance could be a result of our estimation at the household rather than plot level.

Two conclusions stand out. First, nonfarm income, important to the income strategies of our sample households, greatly affects the adoption of an expensive package of animal traction equipment. We would not expect own-liquidity sources to be so important unless there were credit market constraints. Animal traction, in turn, is important to land and labor productivity. Together, these results suggest that policies promoting rural nonfarm activities will help capitalize smallholder African agriculture, in turn raising productivity.

Second, traction households allocate labor in an economically rational way across crops.

Yet households' factor allocation strategies are different in cotton and maize, crops which use inputs intensively and to which higher-quality land is allocated, from millet and sorghum, which are "safety-first" crops, utilizing fewer inputs, and to which lower-quality land is allocated. Policies that increase access to fertilizer and manure assist farmers in intensifying cash crop production. It seems probable that as land constraints grow in the Guinean zone of West Africa, the incentive to complement land-extensive subsistence grain cropping with land-intensive cash cropping will increase. Policies that aid this transition will improve smallholder land productivity.

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TABLE 1. Input use, average productivities and results of animal traction selection models.

A. Sample means of input use per hectare

	Animal traction households					Manual households				
	Cotton	Maize	Sorghum	Millet	All	Cotton	Maize	Sorghum	Millet	All
Labor, hours	938	946	543	451	672	1003	1016	541	512	692
Fertilizer, kg	109	49	5	2	41	113	36	3	1	37
Manure, kg	1776	8588	624	226	1345	402	4351	39	28	323

B. Average productivity in Francs[a]

Labor, hours	90	72	61	61	57	75	64	48
Land, ha	76680	67450	31560	24830	53430	71450	33270	24310

C. Maximum likelihood estimates of probit-type animal traction selection model[b]

	Intercept	Nonfarm	Size	Age	Livestock	Road
Param. estimate	-0.117	0.936E-06*[c]	0.151*	-0.028*	-0.947E-06*	-0.309*
	(0.379)	(0.444E-06)	(0.023)	(0.008)	(0.653E-06)	(0.210)

[a] Output prices used are: cotton 76 CFA/kg, maize 50 CFA/kg, sorghum 60 CFA/kg and millet 65 CFA/kg.

[b] Correct prediction 75 %.

[c] An asterisk (*) denotes significance at the 10 %, two tailed level. Standard error estimates are reported in parentheses

TABLE 2. Marginal value products and their standard errors.

	Animal traction households				Manual households			
	Cotton	Maize	Sorghum	Millet	Cotton	Maize	Sorghum	Millet
Labor, hours	36.3*	30.1*	31.9*	32.4*	28.7*	10.5	15.8*	24.8*
	(3.97)	(4.98)	(4.20)	(18.2)	(4.53)	(11.4)	(6.66)	(7.00)
Land, ha	39400*	43500*	8520*	7280	22500	22800	25000*	10300*
	(13500)	(27800)	(4730)	(12100)	(24500)	(26100)	(10600)	(6100)
Fertilizer, kg	40.9	25.3	n.a.	n.a.	67.3	278	n.a.	n.a.
	(102)	(143)			(196)	(490)		
Manure, kg	6.79*	0.515	4.77*	n.a.	-20.4	0.243	n.a.	n.a.
	(3.58)	(0.790)	(3.19)		(19.1)	(1.82)		

See notes in the table 1.