The paradox of household resource endowment and land productivity in Uganda

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Abstract
The paper investigates the conflicting findings in empirical studies linking land productivity to plot size, livestock ownership, investment in farm assets, and land improvement practices. The conflicting impacts found are partly as a result of different model specifications, the type of data used – panel or cross sectional data – and possibly due to imperfections in rural markets. We control for these problems using household and plot level panel data from rural farmers in Uganda. We find that ownership of cattle has a negative and significant impact on land productivity. Investment in farm related assets, land improvements and other small livestock, however, significantly increases productivity. The conflicting impacts are a result of measurement error. The plot size inverse productivity is robust to different specifications and is largely explained by plot-specific unobserved heterogeneity and imperfections in rural markets.

Key words: Endogeneity, assets, investments, land productivity, Uganda

JEL classification; C10, O12, Q12

1. Introduction

What should the policy makers do when the researchers are reporting conflicting conclusions? Adopting the "one size fits all" is never a solution when empirical research on, for example, the relationship between land productivity and household asset endowments is inconclusive. Much of the empirical literature attest to an inverse farm size – productivity relationship in developing countries, thus one may literally conclude that the resource poor are efficient. While this inverse productivity relationship has been identified and often attributed to high labor-to-land ratio (Carter, 1984; Newell *et al*., 1997), small farm sizes might have adverse effects on land productivity (Niroula and Thapa, 2007; Rahman and Rahman, 2008). A positive farm size – productivity relationship may result when small farmers are capital constrained, use less profitable technologies (Kevane, 1996) and specialize in subsistence crop production (Fafchamps, 1992; Dorward, 1999). This kind of argument may lead to formulating two complementary policies to enhance productivity: land reform that redistributes land from large owners to smallholders (landless), and policies that enable the poor to access capital (credit) markets.

However, these policies might be sub-optimal if the conclusions reached are due to different estimations or specifications used. Indeed both theoretical and empirical studies have argued that the ambiguity between farm size and land productivity relationship is not only explained by imperfections in land, labor and capital markets (Feder *et al*., 1985; Eswaran and Kotwal, 1986; Assunção and Ghatak, 2003; Lamb, 2003), but also measurement error, land quality and unobserved plot heterogeneity (Lamb, 2003; Kimhi, 2006; Assunção and Braido, 2007).

Although the farm size – productivity relationship has received much attention, a few studies on the impact of other household resource endowments on land productivity have produced indefinite results too. While heterogeneous results may be due to different production technologies in different countries or regions in the same country, mixed results are also possible under similar production conditions. Pender *et al*. (2004) found that ownership of livestock substantially reduces land productivity in Uganda. In the same country, Nkonya *et al*. (2005) found positive effects, while Kijima *et al*. (2006a) observed no effect at all. Elsewhere, positive impacts of livestock ownership on land productivity have been observed in Nicaragua (Deininger *et al*., 2003), Madagascar (Minten and Barrett, 2008) and Ethiopia (Kassie *et al*., 2008). These positive impacts could be attributed to a synergistic effect whereby livestock supply manure and crops provide animal feeds. But an inverse relationship effect is also conceivable: if livestock production has a comparative advantage over crop production, more land and other inputs are allocated to the livestock enterprise. Or, there might be a capital market accessibility effect: if livestock can be used as collateral, more credit may lead to less investment in crop production. Apparent from all these case scenarios is that the farmer is involved in simultaneous decision-making process that may lead to correlation between regressors and the error term in a land productivity model resulting in biased and inconsistence estimates.

Another key resource endowment having inconclusive impacts on land productivity is farm equipments. Acquisition of farm equipments improves land productivity due to increased labor efficiency (Deininger *et al*., 2008; Minten and Barrett, 2008), but reductions in land productivity are also likely (Nkonya *et al*., 2005; Sserunkuuma, 2005) when farm assets are re-allocated to more profitable enterprises.

In addition to the possible explanations for the reported conflicting impacts of landholding, livestock and farm assets on land productivity, similar impacts may also be attributed to unobserved heterogeneity in the farmers' decision-making framework. For instance, faced with both imperfect capital markets and reasonably well functioning markets for any of the three factors (land, livestock and farm assets) may lead poor farmers to making simultaneous production decisions: where farmers make decisions that restrict themselves to using small input quantities in one period while deferring some inputs to the next period. In this decision-making framework, there might be a threshold level of production upon which standard efficient conditions are met and other situations upon which they are not. This simultaneity in decision-making process, if not controlled for, may explain the conflicting impacts between inputs and land productivity.

Thus, this paper attempts to provide alternative explanations for the indefinite impacts of household resource endowments on land productivity by: (i) testing whether the inverse productivity relationship is robust to different model specifications; and (ii) identifying the source of conflicting effects of livestock ownership and farm assets. Our main contribution is to extend the analysis of Lamb (2003), Kimhi (2006), and Assunção and Braido (2007) that control for unobserved heterogeneity across plots within the same household. This kind of analysis does not control for plot-specific unobserved heterogeneity such as the slope of the plot that may lead to top soil being washed away to the lower part of the plot or distance from homestead to the plot that may determine the use of bulk inputs like organic manure. We attempt to solve this problem by controlling for parcel (plot)-specific unobserved heterogeneity.[1] This enables us to test whether the intra-household resource allocative inefficiency and parcel-specific unobserved heterogeneity explain the inverse productivity relationship and the indefinite effects of livestock ownership and farm assets on land productivity. We use both theoretical and empirical analyses to test and explain the source of these indefinite effects. The theoretical analysis (available in a longer version of the paper) shows that mixed impacts can be due to endogeneity problems emanating from simultaneous decision making in crop production. Using panel data from Uganda, we find that endogeneity due to measurement error; simultaneity and unobserved household and parcel heterogeneity explain the conflicting findings between land productivity and resource endowments.

[1] In the data used, a parcel was defined as a continuous piece of land under one tenure system with same land rights and owned by one household. Plots are specific crop gardens within a parcel. Although some may argue that different plots on the same parcel may have varied characteristics such as slope, our data show that the average parcel size was 3.2 acres with plot size of 0.75 acres. We assume that plot level characteristics are nearly similar to those of its parcel. Thus, the terms parcel and plot may be used interchangeably.

The rest of the paper is organized as follows: Section two presents description of the data. Empirical estimation, results and discussion of results follow in section three. Section four concludes with research implications.

2. Data

The paper uses a two-period household panel data from Uganda collected in 2003 and 2005 by the Foundation for Advanced Studies on International Development (FASID), Graduate Institute for Policy Studies (GRIPS) and Makerere University. The 2003 survey included 940 households, and 894 households were re-surveyed in 2005. Details of sampling procedure and attrition can be found in Yamano *et al*. (2004) and Kijima *et al*. (2006b). The 2003 survey collected agricultural production data for the second and first cropping seasons of 2002 and 2003 respectively. The 2005 survey covered the second and first cropping seasons of 2004 and 2005 respectively.

The surveys collected agricultural production data for the first cropping season of the survey year and the second season of the previous year. Parcels of land identified in 2003 were also surveyed in 2005. The raw sample contains 2,380 parcels with 10,786 plots (pooled number of plots for both seasons) in 2003 and 2,896 parcels with 13,472 plots in 2005. The increase in number of parcels and plots in 2005 survey is due to land acquisition. After dropping inconsistent and missing data, the analysis uses 1,398 parcels that were identified in the two periods and owned by 788 panel households. The 1,398 parcels had 6,308 plots in 2003 and 9,045 plots in 2005.

Table 1 shows descriptive statistics of key variables. The value of production per acre – the measure of land productivity – was used instead of the quantity output per acre due to multiple crops of different value, and different forms in which some crops were harvested. Crops like maize and beans can have both fresh and dry harvests. The data provide for both fresh and dry forms with their respective prices for those farmers that sold part of the output. For those crops that were not sold, the respective median market price was used.

Livestock ownership was categorized into cattle and other small livestock like goats, sheep or pigs[2]. Farm related assets included mainly plough sets, hand hoes, wheelbarrows, spray pumps and bicycles. The value attached to each farm asset was estimated by farmers based on the duration of use and its condition. Daily off-farm wage rate and distance to the nearest rural market from village center are village level factors.

The data also provide for resource endowments and demographics at the time of household formation. These characteristics at the time of household formation are used to instrument for potentially endogenous variables – plot area, land under fallow, livestock ownership and farm assets in the productivity model. These variables are assumed to directly determine the amount of assets (land, livestock and other capital) currently owned by the household, but they may not directly determine the current land productivity.

[2] We disaggregate livestock into cattle and other small livestock to allow us to capture effects of the two groups. Since input requirements, particularly labor and farm assets, for cattle and other livestock may vary greatly.

Table 1: Descriptive statistics

Variable	Mean (N=15,353)	Std. Dev.	Min	Max
Value of production per acre (Uganda Shillings (UShs))	134804	263633	50	9840000
Plot area (acres)	0.75	0.81	0.001	11
Parcel area (acres)	3.20	3.86	0.02	36.5
Area rented in (acres)	0.41	1.21	0	20
Number of cattle owned	1.26	3.23	0	51
Number of goats/sheep/pigs owned	2.28	4.60	0	49
Value of farm related assets (Ushs)	105750	172326	400	1546000
Land under investment (bush fallow or grazing land) (acres)	2.45	3.69	0	34.9
Age of household head	47.4	14.26	20	105
Education of household head (years in school)	5.89	3.76	0	19
Household dependency ratio	0.46	0.20	0	1
Proportion of household members engaged in off-farm work	0.10	0.12	0	1
Distance to nearest market (km) at community level	1.66	3.36	0	30
Off-farm daily wage rate (Ushs) at community level	2112	878	333	4886
% of plots with legumes (beans, field peas, ground nuts & soybean)	0.22	0.41	0	1
% of plots with cereals (maize, millet, sorghum & wheat)	0.19	0.39	0	1
% of plots with roots and tubers (cassava, potatoes & yams)	0.19	0.40	0	1
% of plots with perennial crops (bananas, coffee)	0.29	0.45	0	1
% of plots with other crops (fruits, vegetables)	0.10	0.30	0	1
Key instrumental variables				
Amount of land owned at the start of the household (acres)	3.56	7.39	0	150
Amount of capital owned at the start of the household including assets, livestock, cash at hand (Ushs)	471079	3077621	0	72500000
Amount of land owned by parents of household head and spouse at the start of the household (acres)	19.5	40.3	0	569
Number of male siblings of head and spouse at the start of the household	6.18	3.08	0	19

3. Empirical estimation

The farmer's decision to invest depends on the relative land productivity to the level of investments, which in turn may depend on prior knowledge (experience) or learning by doing, implying that a decision to invest may be endogenously determined. Let y_{ijht} be the crop yield from plot *i* on parcel *j* cultivated by household *h* in time *t*, we specify the following crop production equation as:

$$y_{ijht} = \beta_0 + \beta_1 P_{ijht} + \beta_2 \ell_{ijht} + \beta_3 A_{ijht} + \beta_4 C_{ijht} + \beta_5 G_{ijht} + \beta_6 X_{ijht} + \omega_{jh} + \varepsilon^0_{ijht} \quad (1)$$

where P_{ijht} , ℓ_{ijht} , A_{ijht} , C_{ijht} and G_{ijht} are suspected endogenous variables – plot area, land under bush fallow, farm related assets, number of cattle and number of other small livestock owned respectively. X_{ijht} is the vector of exogenous variables that directly affect y_{ijht} , $\beta_1 - \beta_5$ are parameters of interest to be estimated, ω_{jh} is the composite parcel level and household-specific fixed effects that may be correlated with explanatory variables and ε^0_{ijht} is the error term.

Ordinary least squares (OLS) estimation of (1) assumes direct effects of all regressors on y_{ijht} while ignoring indirect effects attributed to simultaneity among regressors. For instance, β_1 reflects direct effects of farm size on productivity but also potential indirect effects on allocation of land for fertility improvement through fallowing or grazing. Given the potential nature of simultaneity and unobserved heterogeneity as discussed above, estimation of (1) by OLS may lead to inconsistent estimates. Even using two stage least squares (2SLS) does not solve the problem since ω_{jh} will consistently appear in the reduced form equation. Although applying fixed effects–2SLS (FE-2SLS) controls for endogeneity of regressors in (1) and unobserved heterogeneity, FE-2SLS does not account for possible simultaneity problem among other regressors. Thus, we use the following procedure to estimate (1).

In *stage I*, we estimate a pooled 2SLS and test for endogeneity of suspected regressors using Wu-Hausman and Smith-Blundell tests. In addition to other household characteristics, we use the instruments described in Table 1 for the operated plot area, land under fallow, farm related assets, and ownership of livestock. Results in Table 2 indicate that all suspected variables are endogenous in equation (1).

Table 2: Testing for potential endogenous variables in y_{ijht} and other reduced equations

Variables	**Wu-Hausman F test**	
Value production per acre model (y_{ijht})	Test stat.	p–Value
Plot area	15.375	0.000
Land under investment	13.553	0.000
Farm related assets	12.727	0.000
Cattle ownership	25.857	0.000
Other livestock (goats/sheep/pigs) ownership	15.576	0.000
Farm related asset model		
Plot area	63.987	0.000
Land under investment	24.265	0.000
Cattle ownership	85.326	0.000
Other livestock (goats/sheep/pigs) ownership	168.125	0.000
	Smith-Blundell test	
Plot area tobit model		
Land under investment	118.596	0.000
Farm related assets	50.735	0.000
Cattle ownership	217.599	0.000
Other livestock (goats/sheep/pigs) ownership	222.578	0.000
Land under fallow tobit model		
Plot area	951.813	0.000
Farm related assets	263.374	0.000
Cattle ownership	774.524	0.000
Other livestock ownership	750.017	0.000
Cattle ownership tobit model		
Plot area	97.288	0.000
Land under investment	66.462	0.000
Farm related asset	113.653	0.000
Other small livestock ownership tobit model		
Plot area	106.406	0.000
Land under investment	43.482	0.000
Farm related asset	77.940	0.000

In *stage II*, we proceed to test for endogeneity due to simultaneity among the identified endogenous variables. Results in Table 2 show that indeed the potentially endogenous variables in (1) are simultaneously determined. We use results in Table 2 to develop a system of equations to consistently estimate equation (1):

$$P_{ijht} = \alpha_0 + \alpha_1 \ell_{ijht} + \alpha_2 A_{ijht} + \alpha_3 C_{ijht} + \alpha_4 G_{ijht} + \alpha_5 Z^{p}_{ijht} + \omega_{jh} + \varepsilon^{1}_{ijht} \quad (2)$$

$$\ell_{ijht} = \tau_0 + \tau_1 P_{ijht} + \tau_2 A_{ijht} + \tau_3 C_{ijht} + \tau_4 G_{ijht} + \tau_5 Z^{\ell}_{ijht} + \omega_{jh} + \varepsilon^{2}_{ijht} \quad (3)$$

$$A_{ijht} = \sigma_0 + \sigma_1 C_{ijht} + \sigma_2 G_{ijht} + \sigma_3 Z^{a}_{ijht} + \omega_{jh} + \varepsilon^{3}_{ijht} \quad (4)$$

$$C_{ijht} = \delta_0 + \delta_1 P_{ijht} + \delta_2 \ell_{ijht} + \delta_3 A_{ijht} + \delta_4 Z^{c}_{ijht} + \omega_{jh} + \varepsilon^{4}_{ijht} \quad (5)$$

$$G_{ijht} = \gamma_0 + \gamma_1 P_{ijht} + \gamma_2 A_{ijht} + \gamma_3 Z^{g}_{ijht} + \omega_{jh} + \varepsilon^{5}_{ijht} \quad (6)$$

To allow for the identification of the system of equations (1) to (6), the vector Z^{ϖ}_{ijht} (where $\varpi = p, \ell, a, c, g$) consists of both household and community level factors in addition to aforementioned instruments.

In *stage III*, we use fixed effects – three stage least squares (FE-3SLS) to estimate equations (1) to (6) that control for measurement error, simultaneity and unobserved heterogeneity.[3] The 3SLS approach is asymptotically efficient unlike the 2SLS approach (Greene, 2003). To enable comparisons with other empirical studies on land productivity, we estimate pooled OLS, FE, 2SLS and FE-2SLS models in addition to FE-3SLS. The 2SLS approach follows a procedure in Wooldridge (2002, 99-91).

Results and discussion

The pooled OLS (I) results appear to be consistent with most cross sectional studies. We observe a significant inverse plot – productivity relationship. Similarly, land productivity is negatively correlated with small livestock owned, while ownership of cattle appears to have no influence on land productivity. A positive relationship exists between land productivity

[3] Since there is no direct routine to deal with FE-3SLS in panel data in Stata, we transform the data into a form suitable for fixed-effects estimation using "*xtdata, fe*" and then run 3SLS using "*reg3*" (for details, see Stata 10 manual)

and farm related assets, and the more land the household puts under fallow, the higher productivity on each plot.

Similar qualitative results to (I) are observed after controlling for household-specific unobserved heterogeneity in (II).[4] Compared to (I), the household FE results show that omitted household heterogeneity exists, and biases the estimates both upward and downward. The plot area estimate changes from -0.58 to -0.61 suggesting that the omitted household fixed effects have positive productivity effects. A similar observation is made for small livestock owned and land under fallow, while unobserved household fixed effects bias the farm assets estimate downward.

In model (III), the pooled 2SLS controls for measurement error by instrumenting for plot area, land under fallow, farm related assets and livestock ownership. Relative to (I) and (II), the magnitude of coefficients on variables of interest (in absolute terms) increases significantly suggesting consistence with measurement error attenuation bias. The other interesting observation is that the coefficients for cattle, other small livestock and farm assets switch signs. Both cattle and farm assets estimates switch from positive to negative, whereas other small livestock changes from reducing to improving land productivity.

[4] The Hausman specificaton test rejected random effects ($p<0.0001$) in favor of fixed effects model.

Table 3: Determinants of land productivity

Dependent variable = log of crop value per acre	POLS (I)	Hhd FE (II)	P2SLS (III)	Hhd FE-2SLS (IV)	Hhd FE-3SLS (V)	Hhd-par FE-3SLS (VI)
log of plot area (acres)	-0.581*** (0.012)	-0.611*** (0.021)	-4.834*** (0.191)	-1.995*** (0.594)	-1.570*** (0.336)	-1.303*** (0.271)
log (land under investment +1)	0.132*** (0.015)	0.141*** (0.040)	0.770*** (0.051)	1.618*** (0.259)	0.945** (0.362)	0.703** (0.295)
log (value of farm related assets +1)	0.151*** (0.009)	0.139*** (0.027)	-0.595*** (0.036)	-0.547*** (0.117)	0.748*** (0.073)	0.809*** (0.067)
log (number of cattle +1)	0.004 (0.004)	0.006 (0.011)	-3.205*** (0.147)	-4.675*** (0.362)	-1.683*** (0.487)	-1.509*** (0.419)
log (number of small livestock (sheep, goats and pigs) +1))	-0.009** (0.003)	-0.015** (0.007)	4.627*** (0.164)	5.339*** (0.330)	0.927** (0.349)	0.859** (0.306)
Age of household head	-0.005*** (0.001)		-0.020*** (0.001)			
Education of household head (years in school)	0.006** (0.003)		0.115*** (0.005)			
Household dependency ratio	-0.060 (0.054)	-0.126 (0.266)	-1.977*** (0.078)	-1.635*** (0.324)		
Proportion of household members working off-farm	-0.346*** (0.087)	-0.078 (0.231)	-1.451*** (0.110)	-1.216*** (0.334)	-0.183 (0.191)	-0.304* (0.170)
log (area rented +1)	-0.024 (0.025)	-0.249*** (0.063)	-0.048* (0.028)	-0.178* (0.092)	-0.226*** (0.065)	-0.245*** (0.060)
log (distance to nearest market (km)) at village level	-0.045*** (0.013)	-0.030 (0.047)	0.051** (0.016)	0.278*** (0.068)	-0.001 (0.046)	-0.006 (0.045)
log of wage daily rate (Ushs.) at village level	0.114*** (0.026)	0.031 (0.071)	0.112*** (0.026)	0.071 (0.074)	0.092 (0.082)	0.058 (0.080)
Year dummy	yes	yes	yes	yes	-	-
Crop type dummies	yes	yes	yes	yes	yes	yes
Constant	7.933*** (0.220)	8.459*** (0.627)	15.678*** (0.427)	13.949*** (1.311)		
F-value	237.70***	219.12***	196.40***	84.28***		
R^2	0.209		0.178			
Number of observations	15,353	15,353	15,353	15,353	15,353	15,353
Bootstrap replications	500	500	500	500		

Figures in parentheses are standard errors (bootstrapped for all except 3SLS models).
***, **, * are significance levels at 1%, 5%, 10% respectively.

In model (IV), we control for unobserved household heterogeneity, and the correlation between the error term and plot area, land under fallow, farm assets and livestock ownership. The inverse productivity relationship still holds, and the positive of impact of fallow land on productivity is magnified more than in the previous models. This suggests that ignoring both unobserved household effects and the correlation between the fallow land and the error term are associated with a positive bias.

Moving to model (V), we control for the three sources of endogeneity due to unobserved household heterogeneity, simultaneity and measurement error. Model (VI) controls for similar sources of endogeneity in addition to unobserved parcel-specific fixed effects. We note that from (I) through (VI), the negative relationship between plot-area and productivity and the positive relationship between fallow land and productivity are robust to different model specifications. The impacts of farm assets and livestock ownership on productivity, however, switch signs under different specifications. The implications from these varying sizes and directions of biases for estimates of interest along with ambiguous impacts underscore the importance of different model specifications in determining the impact of these variables and hence the conflicting conclusions. We check the robustness and sensitivity of the estimates in (VI).

Robustness and sensitivity checks

As earlier mentioned in section (1), some conflicting findings on the impact of resource endowment on land productivity are reached to due to employing different analytical approaches or imperfections in rural markets. So far, we have been concerned with the former source of conflicting results. Before moving on to assess how sensitive our estimates are to omission of some resource endowments, rural market effects and crop selection effects, we first present unconditional estimation of land productivity.

Figure 1 shows the nonparametric regression of logarithm of value of production per acre on the logarithms of plot area, value of farm related assets, land under improvement (fallow land), number of cattle and other small livestock. The curves are obtained by locally weighted regression. Figure 1 shows that land productivity is inversely related to the plot area, but positively related to fallow land and the value of farm assets. These results are consistent with our estimates in (VI) in Table 3. The slopes of land productivity with respect to cattle and other small livestock are not clearly defined.

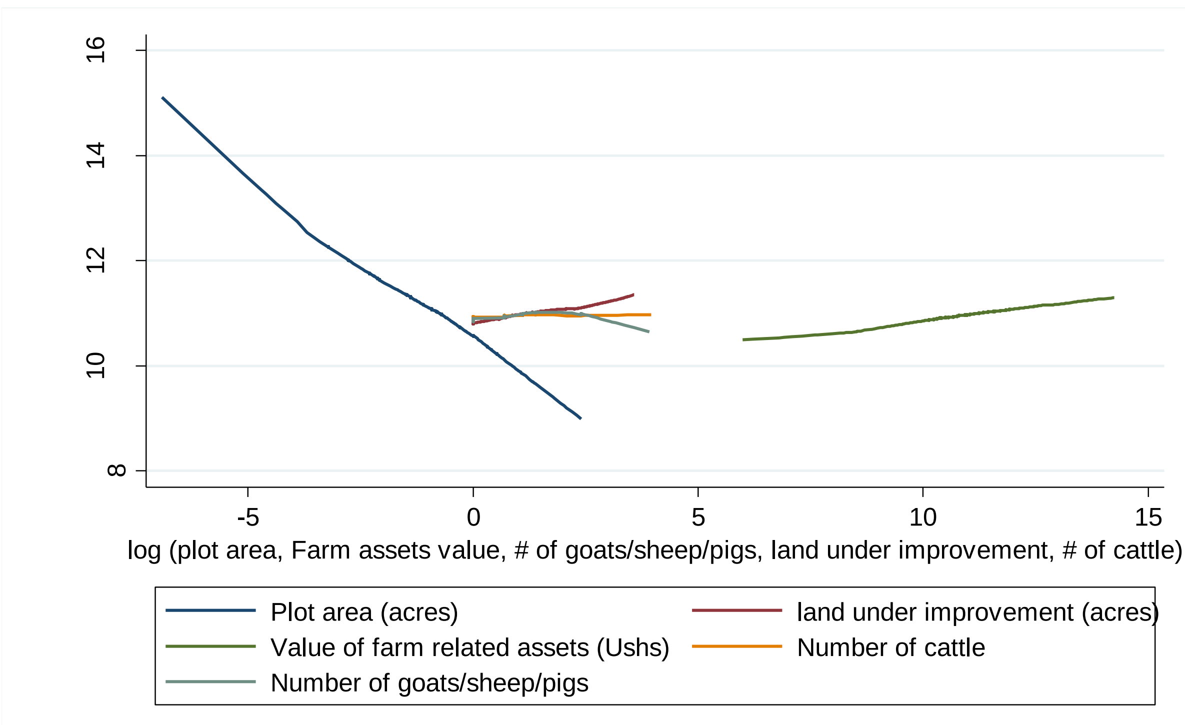

Figure 1: Nonparametric of value of yield on plot area, farm related assets, land under improvement, number cattle and other small livestock

We turn to explanations due to imperfections in rural markets. The sensitivity analysis is carried out by omitting variables linked to participation in rural markets and making comparisons with the preferred specification (VI) in Table 3. These results are shown in Table 4.

Table 4: Sensitivity analysis of household-parcel FE-3SLS model

Dependent variable = log of crop value per acre	Without crop categories	Without community variables	Without labor and land rental	Without livestock	Without farm assets	Without land investment
log of plot area (acres)	-1.489*** (0.281)	-5.515* (3.025)	-3.582*** (0.539)	-0.758*** (0.119)	-0.681** (0.262)	-0.234 (0.144)
log (land under investment +1)	1.015*** (0.303)	3.901 (2.380)	2.430*** (0.454)	0.381** (0.138)	0.280 (0.279)	
log (value of farm related assets +1)	0.804*** (0.068)	5.501* (3.192)	3.298*** (0.632)	0.067 (0.172)		-0.635 (0.412)
log (number of cattle +1)	-0.934** (0.440)	-3.364*** (0.896)	-2.167*** (0.536)		-0.825** (0.367)	-0.112 (0.352)
log (number of small livestock (sheep, goats and pigs) +1))	0.322 (0.315)	-0.073 (1.290)	0.088 (0.381)		0.690** (0.255)	0.402 (0.328)
Proportion of household members working off-farm	-0.236 (0.179)	-1.078** (0.432)		-0.087 (0.135)	-0.112 (0.143)	0.074 (0.151)
log (area rented +1)	-0.227*** (0.054)	0.076 (0.372)		-0.198*** (0.044)	-0.233*** (0.054)	-0.190*** (0.055)
log (distance to nearest market (km)) at village level	-0.018 (0.045)		-0.052 (0.047)	-0.031 (0.042)	-0.016 (0.043)	-0.034 (0.044)
log of wage daily rate (Ushs.) at village level	0.068 (0.080)		0.007 (0.082)	0.025 (0.073)	0.046 (0.076)	0.025 (0.078)
Crop type dummies		yes	yes	yes	yes	yes
Number of observations	15,353	15,353	15,353	15,353	15,353	15,353

Figures in parentheses are standard errors. ***, **, * are significance levels at 1%, 5%, 10% respectively.

The first specification in Table 4 omits crop categories to control for crop selection. The results indicate that the inverse productivity relationship improves slightly, and the positive impact of fallow land on productivity is strengthened. This suggests that some crop types have weakening effects on land productivity. On the other hand, crop effects appear to weaken the impact of cattle, while that of other small livestock on land productivity is wiped out. This may imply that the impact of livestock ownership on land productivity depends on the type crop grown.

After the omission of village level factors, daily wage rate and distance to the nearest rural market, there are significant changes in the magnitude and explanatory power of coefficients. The inverse productivity relationship still holds but with weak explanatory power. Similarly, farm assets weakly improve productivity, while the coefficients on small livestock and fallow land are no longer significant. The explanatory power and the magnitude of the number of cattle estimate increases significantly. Distance to the rural market and wage rate account for imperfections in factor and output markets that may lead to inverse relationship and re-allocation of resource endowment from crop production.

Area rented in and the proportion of household members engaged in off-farm wage employment are assumed to control for imperfections in land and labor markets. Exclusion of these variables increases both the magnitude and the explanatory power of all variables of interest except for the number of small livestock. These results suggest that imperfections in factor and output markets may worsen productivity effects.

Finally, the omission of resource endowments, livestock ownership and farm related assets reduces the magnitude of inverse productivity relationship substantially. The effect of farm related assets and that of fallow land on land productivity vanishes when ownership of livestock and farm related assets are omitted. The exclusion of fallow land reduces the explanatory power of all variables of interest to insignificant levels.

Main findings

Several findings are worth highlighting. We find that the inverse plot area–productivity relationship is robust to different model specifications, but its magnitude varies substantially with the source of endogeneity, resource endowments and factor markets. We observe stronger downward bias on inverse relationship when endogeneity due to measurement error is not controlled for compared to when we ignore endogeneity due to unobserved heterogeneity and simultaneity. We also note that household fixed effects do not explain much of the variation in the inverse relationship, but rather large variation is attributed to parcel (plot) level FE. The latter result is consistent with Assunção and Braido (2007) findings. The larger the parcel the greater the dispersion of parcel fixed effects and hence the less the soil fertility. For instance, the fixed attributes of a parcel such as the slope may result in higher soil fertility levels for plots at the lower end of the parcel than those on the steep slope of the same parcel due to soil erosion.

The results also show that investment in land improvement through bush fallowing unambiguously increases land productivity. This finding is robust to all specifications used. On the other hand, our data indicate that the relationship between livestock ownership and land productivity is influenced by measurement error. Farm assets are influenced by both measurement error and simultaneity and appear to be simultaneously determined with livestock ownership. Increasing cattle ownership increases land productivity under the no measurement error assumption, but the impact is reversed when measurement error is controlled for. The reverse is true for other small livestock. These results continue to hold after controlling for both household and parcel-specific fixed effects, and imperfections in factor and output markets. Similarly, farm assets appear to have negative effects on land productivity when we control for measurement error and simultaneity, but positive effects are observed after controlling for unobserved heterogeneity at household and parcel levels. We find the latter results to be robust to imperfections in factor markets for cattle ownership, but not other small livestock.

4. Conclusion

Previous studies – particularly those using cross sectional data – have yielded conflicting findings on the relationship between land productivity and ownership of livestock, investment in farm related assets and land improvement practices. This paper shows that findings from cross sectional data might suffer from model specification problems, in particular failure to control for unobserved heterogeneity. Even studies that do not account for simultaneity between livestock ownership, investment in farm related assets and land improvement practices, are likely to yield conflicting findings. We have used household and plot level panel data from Uganda to illustrate these problems.

Our estimation procedure shows the inverse productivity relationship is largely explained by plot–specific unobserved heterogeneity and imperfections in factor, capital and output markets rather than household effects. The conflicting impacts of resource endowments (farm assets, livestock) on land productivity are mainly due to measurement error rather than imperfections in rural markets. Thus, the mixed impacts of resource ownership and investments on land productivity observed in the literature might to a large degree be the result of model specification errors and the type of data used, rather than reflecting real on-the-ground differences

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