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Understanding the Complexities Surrounding Gender Differences in Agricultural Productivity in Nigeria and Uganda

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ABSTRACT *We investigate gender differences in agricultural productivity in Nigeria and Uganda. Results indicate persistent lower productivity on female-owned plots and among female-headed households, accounting for a range of socio-economic variables, agricultural inputs and crop choices using multivariate tobit models. Results are robust to inclusion of household-level unobservables and alternative specifications that account for decisions to plant crops. However, productivity differences depend on aggregation of gender indicator, crop-specific samples, agro-ecological zone and biophysical characteristics. More nuanced gender data collection and analysis are encouraged to identify interventions that will increase productivity and program effectiveness for male and female farmers.*

I. Introduction

There is much interest in the sources and consequences of agricultural productivity differences between male and female farmers, particularly in sub-Saharan Africa. Although it has often been argued that female farmers' lower levels of physical and human capital result in lower measured productivity or inability to respond to economic incentives, a review of studies undertaken in the late 1980s and early 1990s found that when differences in inputs are controlled for, no significant differences in technical efficiency of male and female farmers' are observed (Quisumbing, 1996). Indeed, a number of new programmatic and funding initiatives targeting women farmers have centred on assumptions of potential farm and non-farm gains by improving women's ability to access resources (IFAD, 2003; BMGF, 2008; WFP,

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2009; WB et al. 2009). However, many of the reviewed studies were flawed. Most studies did not investigate why inputs tended to be lower on female managed plots, neglecting the endogeneity of input choice and the influence of intrahousehold allocation processes, many of which are culture and context specific, on the division of labour and other resources on male and female-managed plots. Most studies also focused on a single crop and typically used sex of the household head as the basis for stratifying sample observations. These methodological and data constraints oversimplify the diverse multi-crop farming systems in sub-Saharan Africa and neglect the widespread phenomenon of crop cultivation by male and female individuals within the same household, whether independently or jointly.[1] Later studies attempt to address some of these issues, but their conclusions are mixed; some showing lower productivity of female farmers, whereas others show no significant differences.

This article provides new estimates of gender differences in agricultural productivity using data collected by the International Food Policy Research Institute (IFPRI) in Uganda and Nigeria. We contribute to the literature by explicitly addressing the issue of crop choice, the sensitivity of productivity estimates to the choice of stratifying variable, and the possible heterogeneity of agricultural productivity differences within different agro-ecological zones controlling for household-level unobservables when possible. Knowing the source of these productivity differences is a key factor in identifying possible levers for policy intervention to improve the productivity of poor male and female farmers. Because estimates are likely to vary by cultural context and over time, we provide updated information for agricultural policy and targeting in both countries.

Data from Uganda were collected in 2003 at the plot level with the objective of linking natural resource management to poverty levels. Data from Nigeria were collected in 2005 at the household level to evaluate the second round of *Fadama*, a national agricultural welfare programme. We use multivariate tobit models to model productivity differences, controlling for socio-economic indicators, agricultural inputs, crop choice, access to markets and, in Uganda, biophysical plot characteristics. Findings from both countries indicate significantly lower productivity on plots owned or managed by females; these results hold when accounting for background factors including the decision to plant any crops. However, findings vary across crops as well as by agro-ecological zone and inclusion of biophysical characteristics, suggesting either cultural or regional gender differences or crop-specific comparative advantages that interact with productivity and gender. Findings from Uganda also indicate that type and specificity of gender indicator matter, as the size of the productivity differential is diluted when household-level indicators, rather than plot-specific crop ownership variables, are used. In addition, results from the Uganda analysis suggest that plot-level productivity is lowest among crops with mixed gender ownership, possibly owing to household bargaining difficulties between men, women and children. However, when we control for household fixed effects, productivity on female-owned plots is lower, but the mixed ownership indicator is no longer significant. This finding implies that the mixed ownership classification may capture the impact of unobserved household characteristics that may complicate decision making patterns. We conclude with directions for further research and policy.

II. Gender Differences in Agricultural Productivity: Frameworks, Methods and Evidence

The conventional method for measuring and modelling differences in technical efficiency between men and women in agricultural productivity is through the estimation of production functions that model the maximum output produced from the set of inputs given technology available to the household (Battese, 1992). The production of a farm manager i in household j is given by Equation (1):

$$Y_{ij} = f(V_i, X_i, Z_j) \tag{1}$$

where Y_{ij} is the quantity produced; V_i is a vector of inputs used by farm manager i (including land, labour, capital, and extension advice); X_i is a vector of individual attributes; and Z_j are household and community-level variables. This approach typically is implemented by pooling observations of male and female farmers to estimate a productivity outcome (yield or value of production) and normally includes a gender indicator as one of the control variables in X_i. Alternatively, regressions may be estimated separately for subsamples of male and female farmers.

This production function approach focuses on technical efficiency, which assumes men and women produce the same output and use the same technology, rather than allocative efficiency, which takes into account the distribution of inputs among household members. Attaining allocative efficiency implies that no reallocation of inputs within the household would result in an increase in total output (yields). Resource allocations within the household may indicate asymmetric distribution of productive inputs, rights and responsibilities and in fact may be more appropriate for gender differences in comparison to total technical efficiency (Quisumbing, 1996), as revealed in Udry's (1996) paper on Burkina Faso and other similar work. This latter approach is increasingly important to determine not just how productivity differs by gender, but why productivity differs, and may better inform policies to increase agricultural productivity and incomes within marginalised groups.

A number of possible factors may lead to agricultural productivity differences between men and women in the developing world.[2] First, assuming men and women have the same agricultural production function and use the same technique for the same crop, the quantity of inputs (for example fertiliser, seeds or labour) applied by men and women may differ (see a review of gender differences in nonland agricultural inputs by Peterman et al., 2010). Second, the quality of inputs may differ: land quality may differ between men and women, including but not limited to soil quality, topography and proximity to access points such as water sources, roads and housing (increasing travel costs among other things) (Tiruneh et al., 2001; Nkedi-Kizza et al., 2002). Third, men and women may have different agricultural production functions, possibly because crop choice differs by gender, whether influenced by cultural norms (Doss, 2002) or by other considerations such as the lack of resources to cultivate specific crops and the culturally appropriate division of labour.[3] Fourth, even if men and women had the same agricultural production function, shadow prices of inputs and credit may lead women's production frontier to lie beneath men's, implying that women are less productive. In fact, in a review of empirical evidence and methodology in gender analysis of agricultural productivity, Quisumbing (1996) finds that the majority of studies conducted from the mid-1980s to 1990s show female farmers are equally productive as male farmers once inputs and other background characteristics are controlled for.

The literature in the last decade-plus has not provided definitive conclusions on gender differences in productivity nor has it sufficiently addressed data or methodological constraints. Perhaps the most influential papers on gender and agricultural productivity come from a four year panel collected by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Burkina Faso. Enumerators visited sample households approximately every 10 days to collect farm operation and output information, resulting in a rich 4655 plot-level data set including 150 households in six villages.[4] Udry et al. (1995) use the ICRISAT data to estimate agricultural production functions for men and women in the same household, who are farming the same crop within the same year, and conclude that the value of household output can be increased by 10 to 15 per cent by reallocating inputs (labour and manure) from men's plots to women's plots. Another analysis of the ICRISAT data measure output gains to be 5.89 per cent on average by reallocating inputs; however, the definition of men's plots includes both those cultivated exclusively by men as well as household collective plots under the control of or owned by men with labour inputs from wives and children (Udry, 1996).[5]

However, when Akresh (2005) attempts to replicate the results of Udry and colleagues using nationally-representative data from Burkina Faso (2406 households in 401 villages) collected by the World Bank between 1990 and 1991, he finds no evidence of pareto inefficiency.[6] Arkesh argues allocative differences may in fact be due to productivity shocks, transaction costs and asymmetric information involved in trading labour and resources between household members and he cautions against making policy prescriptions from geographically restrictive data. However, while Akresh uses similar household-year-crop fixed effects models, he is unable to control for plot-level characteristics such as soil type, topography or distance from the family compound. Therefore, questions remain regarding observed productivity differentials and whether they are a result from methodology or reflect actual differentials.

Conclusions from recent published literature and from work in progress on gender differences in productivity are mixed.[7] A subset of these analyses examines the gender of the farmer, consistent with the aforementioned analyses by Udry et al. (1995) and Akresh (2005), and come exclusively from sub-Saharan Africa. Goldstein and Udry (2008) in Ghana find large differences in profits between plots controlled by men and women; however, this is completely explained by duration of the fallow period. Quisumbing et al. (2001) find evidence of lower yields on female-owned parcels of cocoa also in Ghana, although this result is only weakly significant (at the 10% level). Kinkingninhoun-Mêdagbé et al. (2008) find productivity differences between male and female farmers within a Benin semi-collective rice irrigation scheme, but the finding can be attributed to scheme membership, access to land, and equipment. Oladeebo and Fajuyigbe (2007) find female rice farmers are more technologically efficient compared to male farmers in Osun State, Nigeria. In an evaluation of a nation-wide cropping trial, Gilbert et al. (2002) in Malawi find no crop yield differences by gender of farmer once socio-economic and input differences are controlled for. Thus, although the majority of findings indicate the existence of productivity differences, further analysis indicates that access to inputs or specific constraints account for the differences.

Although additional research has contributed to the debate surrounding gender and agricultural productivity, most studies use household headship as a gender indicator, again with mixed findings. In Ethiopia, Holden et al. (2001) attribute the lower productivity of female-headed households to resource poverty (insufficient male labour and oxen) and low substitutability among factors of production. Two additional studies in Ethiopia find female-headed households have persistently lower productivity measures as compared to their male headed counterparts (Tiruneh et al., 2001; Bezabih and Holden, 2006). Studies from Ethiopia also suggest female-headed households tend to rent out their land to tenants with much lower productivity and renew land contracts of tenants at higher rates than their male counterparts (Bezabih and Holden, 2006; Holden and Bezabih, 2008; Bezabih and Holden, 2009). This is largely attributed to higher tenure insecurity and lower bargaining power of female landlords, who were less able to use threat of eviction to increase productivity on rented-out land. However, studies from the Gambia and Nepal find no significant productivity differences by gender of household head, after controlling for other inputs (Chavas et al., 2005; Thapa, 2008; Aly and Shields, 2010). Likewise, Horrell and Krishnan (2007) find that once inputs are controlled for, female-headed households in Zimbabwe are equally as productive as male-headed households, with the exception of cotton growers. With further disaggregation they do find differences in sources of the disadvantages: de jure female headed households (for example, widows, separated or divorced women) are comparatively income-poor and thus are disadvantaged with regard to access to inputs, whereas de facto female-headed households (for example, wives of male migrants who identify as household heads) have similar incomes as their male-headed counterparts, but are asset-poor.[8] Thus, although studies examining household headship have contributed to the literature, their findings are not conclusive.

As can be intuited from this discussion, much of the inconclusiveness comes from methodological challenges inherent in collecting and analysing data on gender productivity differences. Many the studies reviewed are also based on data with relatively small sample sizes (up to 150 households), which limits the choice of methods.[9] The use of female headship as an indicator of the gender of the farmer or plot manager in the African setting is complicated by the complex familial structure of households, including monogamous, polygamous and skipped-generation households. Unfortunately, underlying cultural and household structural considerations are often not noted or collected in agricultural economic surveys. These limitations are the topic of an active debate regarding the validity and generalisability of overly simplistic, geographically narrow, time-specific studies focusing on gender and agriculture (Kevane and Gray, 1999; Whitehead and Kabeer, 2001; O'Laughlin, 2007). Furthermore, the inconclusiveness of gender research due to either methodological or data limitations obscures the policy and programmatic recommendations that emerge from gender productivity analysis, and do not enable us to ascertain whether gender matters in producing evidence-based agricultural policy.

III. Data and Settings

The agricultural sector remains a significant component of both Uganda and Nigeria's economies, employing upwards of 80 and 70 per cent of the respective Ugandan and Nigerian labour forces (CIA WFB, 2009a, 2009b). Both countries have experienced increasing urban–rural tensions as urban areas move toward service and manufacturing, while rural areas continue to be dominated by small-scale subsistence farming. The two countries differ in their dominant exports and staple crops. Nigeria's primary non-petroleum exports are agricultural products such as cocoa and rubber. In northern Nigeria, staple crops are millet, cowpeas and guinea corn; in the central region staple crops are yams, sorghum, millet, cassava, cowpeas and corn; in the south staple crops are yams, cassava and cocoyams (Metz, 1991). In Uganda, coffee is the primary export of large-scale farmers, however, most small scale farmers grow tubers and *matooke* (plantains) for consumption and maize, grains, groundnuts and beans for consumption and sale (Kasente et al., 2001; CIA WFB, 2009a, 2009b).

Nigeria is Africa's most populous nation (estimated 149 million in 2009), and has a significantly larger population and land mass compared to Uganda (estimated population of 32.4 million in 2009) (CIA WFB, 2009a, 2009b). Nigeria is noted for its enormous ethnic, religious and cultural diversity, boasting more than 250 different ethnic groups and large Muslim and Christian populations with a sizeable Animist minority. The three largest ethnic groups in Nigeria are the Igbo (predominantly Christian, located in the south/south east), the Yoruba (Muslim and Christian, located in the west and southwest) and the Hausa-Fulani (Muslim, located in the North). Uganda is known for its complicated clan structure which encompasses about 11 ethnic groups (none of which holds a majority) and a predominantly Christian population with a sizable Muslim minority. Scholars of both countries concur that women play essential roles in planting, farming, harvesting, processing and preparing agricultural products (Kasente et al., 2001; Tripp, 2004; Ajani, 2008). In Nigeria, women's role in agriculture is determined largely by geographic region, culture and religion. For example, yams, the 'prestige' crop, are regarded by many as a male crop, whereas 'ephemeral' crops, such as cassava, melons, beans, maize, and cocoyams are regarded as female crops (Ezumah and Domenico, 1995; Achebe and Teboh, 2007; Ajani, 2008). In the northern part of the country, among the pastoralist Hausa-Fulani, women play a notable role in the production and marketing of dairy products, such as milk and butter, although cattle are typically formally owned by men (Boserup, 1970; Waters-Bayer and Bayer, 1994). According to Kasente et al. (2001), within Ugandan households men focus on land clearing and marketing and women are largely responsible for weeding, post-harvest processing and food preparation, although some flexibility exists in the household allocation of tasks. Household crops (such as plantains and tubers) are typically considered female crops while cash crops are typically considered male crops.

Fadama II Data (2005)

The data used in this study, the *Fadama II* data, were collected in 2005 by IFPRI as part of an evaluation of the second phase of the World Bank sponsored National

Fadama Development Project. *Fadama* is the largest agricultural development project in Nigeria and is focused on community-driven development. The project included a range of development services, such as cost-sharing infrastructure investments, capacity building, projects in crop improvement, livestock, agro-forestry, fishing and post-harvest services selected through local development planning (Nkonya et al., 2008b). *Fadama II* was conducted in 10 selected local government areas in 12 states, encompassing all three major agro-ecological zones and was scheduled to run for six years between 2004 and 2010. The *Fadama II* survey sample includes project beneficiaries, other respondents living in project areas (but not direct recipients) and comparable respondents living in different communities within the same states. Approximately 25 households were randomly selected per *Fadama* community association, stratified on state and gender of the respondent, resulting in a sample of 3750 households. For more detailed information on the *Fadama II* project, sample selection and midterm results, see Nkonya et al. (2008b). It is important to note that data are not nationally representative or population representative within the 12 *Fadama* states and instead represent programme areas within each state (see Figure A1 in the Online Appendix for map of *Fadama II* participating states).

Natural Resource Management Linkage Study (2003)

The Natural Resource Management (NRM) data were collected by IFPRI and collaborators (World Bank, the National Agricultural Research Organization, Makerere University and Norwegian Trust Fund) in order to explore linkages between natural resources and poverty levels. The NRM survey included an extensive agricultural module administered at the plot level containing questions on ownership and usage rights, investments, crop and input choice, land and soil characteristics, livestock and agricultural knowledge (Nkonya et al., 2008a). The sample was drawn from 123 communities in the 565 enumeration areas surveyed in the Ugandan National Household Survey (UNHS, 2002/3), originally stratified on rural/urban location and employment status, and conducted by the Ugandan Bureau of Statistics. The NRM data covers eight districts (Arua, Iganga, Kabale, Kapchorwa, Lira, Masaka, Mbarara and Soroti), selected for natural resource and poverty levels, resulting in a total sample of 3625 plots distributed in 851 households. Because the NRM data are statistically representative of the selected eight districts, survey weights are used in all analyses. However, household plots that were remotely located or in different geographic areas were not surveyed. Figure A2 in the Online Appendix shows locations of communities included in the sample. For more detailed information on project background or sample selection see Nkonya et al. (2008a).

IV. Methods and Framework

Empirical Model

Although we strive to conduct parallel analysis between Nigeria and Uganda, where richer indicators are available, we use more detailed indicators and do not 'dilute' the information available for either country. Typically, empirical studies estimating male-female productivity differences use the Cobb-Douglas production function, estimated by taking logarithms on both sides, as in Equation (2) below:

$$\ln\ Y_i = \alpha_0 + \alpha_1 \ln L_i + \alpha_2 \ln T_i + \beta \ln E_i + \gamma\, EXT_i + \delta\, Gender_i + \varepsilon \qquad (2)$$

where Y_i is the i^{th} farm manager's output, L_i is labour input (hired or family), T_i is a vector of land, capital, and other conventional inputs, E_i is educational attainment or an indicator variable for the level of schooling (of the farm manager, household head, or members of the household), EXT_i is an index of extension services, $Gender_i$ is a dummy variable for the sex or gender of the farm manager or household head and ϵ is the error term.[10] Note that in the analysis that follows, we do not explicitly model a true production function, which has intensive data requirements focusing on modelling of all production factors, and rather are concerned with the coefficient on gender, while controlling for access to other inputs.

In estimating Equation (2) to model agricultural productivity, special consideration must be given to the distribution of the outcome measure. Although productivity is a positive continuous indicator, we observe a mass point at zero productivity, which may occur for a number of reasons. For example, a plot could have been cultivated, but crops lost due to adverse weather shocks, pests or other natural disasters. Alternatively, the area could have been left fallow to improve soil fertility, serve as pasture or grazing land, or abandoned due to poor crop expectations and high input costs or inability to farm because of limited resources. Finally, due to the timing of survey visits and fluctuations in the time of harvesting, a certain crop (or portion of crop) produced may not have been harvested yet, resulting in low or zero productivity measurements. Therefore, we do not observe the potential productivity for all plots that report zero productivity. Given these factors, the following tobit model (Tobin, 1958) may be the most appropriate estimation procedure given the left censoring of the dependent variable at zero:

$$\ln\ Y_i* = Gender_i + X_i\beta + \eta_i, \qquad (3)$$

$$\ln\ Y_i = 0 \text{ if } \ln\ Y_i* \leq 0, \qquad (3a)$$

$$\ln\ Y_i = \ln\ Y_i* \text{ if } \ln\ Y_i* > 0,\ i = 1, \ldots, N \text{ and } \eta_{\rm i} \sim \mathrm{N}\ (0,\ \sigma^2), \text{ iid.} \qquad (3b)$$

where Y_i is an indicator of output (productivity), *Gender* is the gender indicator, $\boldsymbol{X}$ is a set of control variables, N is the number of observations and η_i is the error term that is assumed to be independent and identically distributed with zero mean and fixed variance. The set of Equations (3–3b) indicates the expected value of productivity given the observable characteristics (including a gender indicator) is a function of the probability Y_i is non-zero (or uncensored) and the expectation of Y_i given positive productivity. To further account for the possibility that the decision to leave land fallow is responsible for the reporting of zero productivity, we include an indicator for fallow plot as part of the vector of control variables. Although leaving land fallow can be considered a decision variable, in the short-run context in which we estimate productivity differences, we assume that this decision has been previously made and is exogenous to current production decisions.[11] Survey weights are applied in all descriptive and regression analysis in Uganda (main results hold without weighting). We run the same specification using the full sample, as well as by major primary crop and agro-ecological zone. In addition, we conduct several sensitivity analyses. We model the decision to grow any and specific types of crops using probit regressions as well as Cragg's two-tiered unconditional tobit alternative model (Cragg, 1971). In Uganda, we also explore the robustness of our findings to the inclusion of household fixed effects using Honoré's fixed-effects tobit estimator (Honoré, 1992).

Measurement of Key Variables

Productivity. Following Owens et al. (2003), our multi-crop productivity outcome is a measure of value of crop yield per area unit. In Nigeria, productivity is measured by multiplying the quantity of each crop produced per hectare (in kg) by the average annual state-level price, and then aggregating across crops. In Uganda, total value of crop production is measured by multiplying the quantity of crops produced per acre (in kg) by the village-level price, aggregating over crops and two previous planting seasons. In both countries, the productivity value is transformed into thousands of logged Nigerian Naira (N) and thousands of logged Ugandan shillings (Ush) for the purpose of analysis, respectively. The value of crop production in these settings is a more appropriate measure than the crop yield because the majority of plots are intercropped and area estimates for each crop are difficult to calculate. Using actual yield measures per crop when intercropping is practised would be misleading because individual crop yields will be artificially low. Of note, although we are able to control for general seasonal-specific price effects by using average prices at the village or state level, we are not able to explore or control for gender or other related price discriminations due to market access or asymmetrical information.[12]

Gender. In Nigeria, the sex of the household head is used as an indicator of female-owned plot production, because gender-disaggregated information on control or ownership of plots was not collected at the plot level. For Uganda, we have information at the plot level. For each plot, the question was asked 'who claims ownership of crops on this plot?' The coding of the question gives categories of ownership but does not specify an individual per se (response categories include household head, spouse, female children, male children, children, whole family, relative and other responses). By matching these categories to the household roster, in most cases the gender of the owner can be attributed to either male or female, while in other cases (whole family or relative), the gender is ambiguous. We code this ambiguous category as 'mixed gender', possibly owing to multiple cultivators on a single plot. Therefore, in the Ugandan analysis we include indicators of female crop ownership and mixed crop ownership and compare them to the omitted comparison group of male crop ownership. If no crop ownership was reported because the plot was commercially owned, this observation was dropped from the analysis.[13] Note that although plot level gender disaggregation is not available for Nigeria, the results add to the richness of findings as they provide counterfactual results for a higher level of gender aggregation and comparative findings for zone and crop-specific regressions.

Control Variables

The vector $\boldsymbol{X}$ of control variables is divided into four groups: 1) socio-economic characteristics, 2) agricultural inputs, 3) crop indicators and 4) community-level controls. Socio-economic characteristics include age and education indicators for the household head and household size. Agricultural inputs include measures of land, irrigation, fertiliser and seeds, extension services and labour inputs.[14] Because input use may be endogenous, we use measures that rely on prices, wages or community-level non-self-clustered indicators. In addition, we use previous year (or season) indicators for inputs. For Uganda we include tenure security variables in accordance with the recognised tenure categories in the 1998 Ugandan Land Acts (Republic of Uganda, 1998). Tenure categories representing variations in farmers' ability to secure, lease, sell, make improvements upon or sublet land in order of tenure security are: the proportion of land under freehold, customary or mailo tenure (see Table A1 in the Online Appendix for further description of tenure categories). For Nigeria we include participation indicators for the *Fadama II* programme. Crop indicators are dummy variables of primary crop and secondary crop (in certain specifications) grown, aggregated at either the household level (for Nigeria) or the plot level (Uganda). Community-level indicators include distances to markets and roads and agro-ecological zone indicators. Finally, in Uganda in certain specifications we include biophysical indicators of stock of macronutrients in the soil (nitrogen (N), phosphorus (P) and potassium (K)) and natural resource capital (topsoil depth and average slop of plot). The construction and definition of all control variables for both countries are described in detail in the Online Appendix (Table A1).

V. Results

Descriptive Differences in Gender and Productivity

Table 1 gives the breakdown of primary crops grown by 3706 households in the full Nigerian sample and stratified by gender of the household head. Approximately 29.8 per cent (or 1105 households) are headed by females. The most commonly grown crops in the sample are maize (14%), rice (8%) and cassava, cowpea, tomato, leafy green and other vegetables (all between 3 and 4%). There are significant differences in crop choice. Female-headed households are significantly more likely to grow leafy green vegetables and are significantly less likely to grow nearly all other main crops except cassava and yams. Of the included crops, past research indicates rice, tomatoes and yams are all traditionally sold for cash (Nweke, 1996). Table 2 gives the breakdown of primary crops grown in 2700 plots in the full Ugandan sample and stratified by the sex of the crop owner. Using sample weights, approximately 18.7 per cent of the plots are female owned crops, 53.3 per cent of the plots are male owned crops and 26.1 per cent of the plots are mixed ownership crops. The most commonly grown crops across Ugandan plots are banana (15%), beans and peas (13%) and maize, cassava, sweet potato and sorghum (all 6 to 8%). Male-owned plots are significantly more likely to be planted with banana, maize and coffee, whereas female-owned plots are significantly more likely to be planted with sweet potato, sorghum, beans and peas compared to other plots. Past research indicates maize can

Table 1. Gender indicators and crop choice in Nigeria

Primary crop choice (= 1)	Full sample [SD] N = 3706	Female mean [SD] N = 1105	Male mean [SD] N = 2601
Maize	0.14	0.11	0.15
	[0.35]	[0.31]***	[0.36]***
Rice	0.08	0.06	0.10
	[0.28]	[0.24]***	[0.29]***
Cowpea	0.04	0.02	0.05
	[0.19]	[0.12]***	[0.21]***
Cassava	0.04	0.04	0.04
	[0.19]	[0.20]	[0.19]
Tomato	0.03	0.01	0.04
	[0.18]	[0.07]***	[0.20]***
Leafy green vegetable	0.03	0.05	0.03
	[0.18]	[0.21]**	[0.17]**
Other vegetable	0.03	0.01	0.03
	[0.16]	[0.12]***	[0.18]***
Yam	0.02	0.02	0.02
	[0.15]	[0.15]	[0.15]
Sugar cane	0.02	0.01	0.03
	[0.15]	[0.08]***	[0.17]***
Peppers	0.02	0.00	0.02
	[0.12]	[0.06]***	[0.14]***
Fallow, missing or no crop	0.54	0.67	0.48
	[0.50]	[0.47]***	[0.50]***

Notes: Mean values reported with standard deviations in brackets [ ]. Sample is stratified on gender of household head. Primary 10 crops presented. For list of all crop indicators see Table A1 in the Online Appendix. **indicates significant mean differences at the 5 per cent level; ***significant at 1 per cent level.
Source: 2005 Fadama II evaluation data.

be either a cash or a subsistence crop, whereas tobacco traditionally is regarded as a cash crop (Nweke, 1996).

Note that both Tables 1 and 2 include the number of plots classified as primarily fallow in both countries. In Nigeria, 54 per cent of all plots are fallow or are missing crop indicators and a significantly larger percentage of female-headed households fall into this category compared to male-headed households. In contrast, in Uganda 21 per cent of all plots are classified as fallow, however there are no significant differences by plot ownership.

Figures 1 and 2 display kernel density plots showing cumulative differences in the logged value of productivity by gender in Nigeria and Uganda respectively. Each density line charts the probability distribution of the productivity variable across the range of logged productivity values. In Nigeria the mean value of crop production is 554.68 N in the full sample, and as can be seen from the higher dashed line representing the male density, this value is significantly higher (at the 1% level) among the male headed households (mean of 714.72 N) compared to female headed households represented by the solid line (mean of 177.93 N). In Uganda, the mean value of crop production is 330.94 Ush in the full sample, 257.88 in the female owned sample, 276.97 in the mixed and 388.08 in the male owned sample and these

Table 2. Gender indicators and crop choice in Uganda

Primary crop choice (=1)	Full sample [SE] N = 2700	Female mean [SE] N = 565	Mixed mean [SE] N = 830	Male mean [SE] N = 1305
Banana	0.15	0.12	0.13	0.18
	[0.01]	[0.02]**	[0.02]**	[0.01]**
Beans and peas	0.13	0.16	0.14	0.11
	[0.01]	[0.02]**	[0.01]**	[0.01]**
Maize	0.08	0.06	0.06	0.09
	[0.01]	[0.01]**	[0.01]**	[0.01]**
Sweet potato	0.08	0.09	0.10	0.06
	[0.01]	[0.01]***	[0.01]***	[0.01]***
Cassava	0.07	0.07	0.07	0.08
	[0.01]	[0.01]	[0.01]	[0.01]
Sorghum	0.06	0.10	0.07	0.04
	[0.01]	[0.02]***	[0.01]***	[0.01]***
Ground nut	0.04	0.05	0.03	0.03
	[0.01]	[0.01]*	[0.01]*	[0.01]*
Coffee	0.03	0.02	0.02	0.04
	[0.00]	[0.01]***	[0.01]***	[0.01]***
Millet	0.02	0.02	0.02	0.02
	[0.00]	[0.01]	[0.01]	[0.00]
Other vegetable	0.02	0.02	0.01	0.02
	[0.00]	[0.01]**	[0.00]**	[0.00]**
Fallow or pasture	0.21	0.20	0.20	0.23
	[0.00]	[0.01]	[0.01]	[0.02]

Notes: Weighted mean values reported with linearized standard errors in brackets [ ]. Sample is stratified on plot-level crop ownership indicators. Primary 10 crops presented. For list of all crop indicators see Table A1 in the Online Appendix. **indicates significant mean differences at the 5 per cent level; ***significant at 1 per cent level.
Source: 2003 Natural Resource Management survey data.

differences are significantly different at the 5 per cent level. These differences are reflected in the density plots in Figure 2, where the dashed line representing male density outcomes is higher than the solid line representing female and dotted line representing mixed ownership plots. Note, however, that since the kernel densities are plotted using log transformed values and they also reflect a large portion of the sample reporting zero productivity (mass point at zero), which is another important source of gender differences. Among the approximately 49 per cent of the Nigerian sample reporting no output, female headed households make up 38.4 per cent of the sample (versus 21.4% of the nonzero sample). Among the approximately 21.3 per cent of the Ugandan sample reporting no output, 17.9 per cent of these are female, 37.6 per cent are mixed and 44.4 per cent are male crop owned plots.

Tobit Results Among Full and Crop Specific Regressions

Tables 3 and 4 display the core results from tobit regressions in Nigeria and Uganda respectively. Each column represents a separate regression, moving from left to right we first present the full sample, followed by crop specific regressions. All regressions include agro-ecological zone indicators and primary crop indicators in the case of the

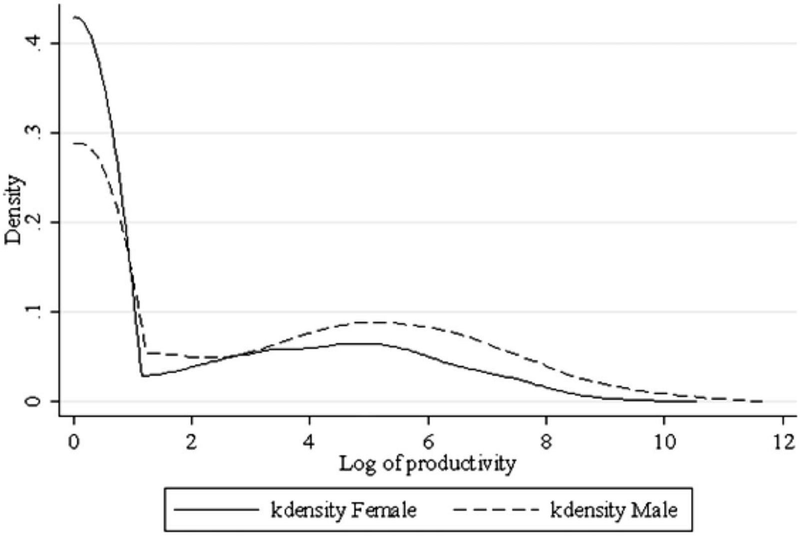

Figure 1. Kernel density of log productivity by gender in Nigeria.
Source: 2003 Fadama II Evaluation data, N = 3706 households.

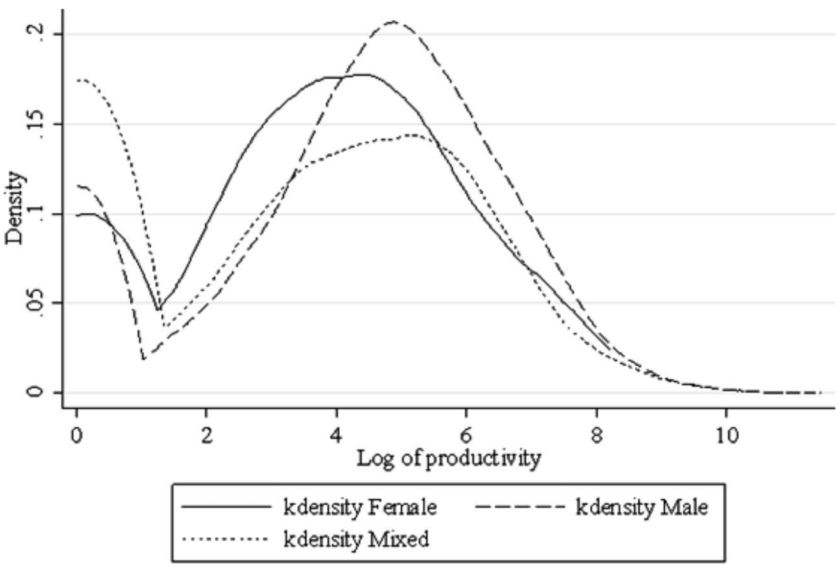

Figure 2. Kernel density of log productivity by gender in Uganda.
Source: 2003 NRM data, N = 2700 plots.

full sample regressions (coefficients not reported). Descriptive statistics including mean values and standard deviations for all control variables are included by gender in Tables A2 and A3 in the Online Appendix. In both countries, when we consider households and individuals farming any type of crop, female-headed households and

Table 3. Tobit productivity results for full sample and by major crop in Nigeria

Variable (N)	Full N = 3706	Maize N = 497	Rice N = 326	Cassava N = 138	Tomato N = 129	Leafy green veg N = 128	Cowpea N = 123
Female headed household (=1)	−0.321	−0.252	−0.031	−0.493	−2.083	−0.340	−0.062
	(0.116)***	(0.202)	(0.294)	(0.570)	(0.987)**	(0.392)	(0.302)
Age head (years)	0.012	−0.099	−0.006	0.152	0.057	0.113	−0.156
	(0.021)	(0.054)**	(0.052)	(0.191)	(0.093)	(0.075)	(0.107)
Age of head squared (years)^2	0.000	0.001	0.000	−0.001	0.000	−0.001	0.002
	(0.000)	(0.001)**	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Head primary schooling (=1)	0.328	0.534	−0.358	0.358	−0.461	0.554	0.073
	(0.125)***	(0.250)**	(0.299)	(0.714)	(0.482)	(0.462)	(0.374)
Head secondary schooling (=1)	0.128	0.171	0.182	−0.363	−0.101	0.522	0.011
	(0.148)	(0.286)	(0.301)	(0.859)	(1.048)	(0.538)	(0.353)
Head post-secondary schooling (=1)	−0.046	−0.014	−0.369	−0.080	1.348	0.952	0.246
	(0.162)	(0.293)	(0.323)	(0.819)	(0.521)**	(0.752)	(0.462)
Log household size (ln)	0.108	0.639	0.581	0.693	−0.622	−0.196	0.411*
	(0.093)	(0.226)***	(0.253)**	(0.486)	(0.450)	(0.494)	(0.217)**
Log rainfed land area (ln acres)	0.080	0.347	0.229	−0.403	0.144	−0.053	0.736
	(0.054)	(0.154)**	(0.285)	(0.311)	(0.287)	(0.327)	(0.110)***
Log of irrigated land area (ln acres)	0.242	0.166	0.279	1.408	0.365	0.009	0.218
	(0.106)**	(0.317)	(0.252)	(0.649)**	(0.401)	(0.421)	(0.286)
NSC log NPK fertiliser (ln naira/bag)	−0.003	−0.006	−0.006	−0.005	0.002	−0.004	−0.004
	(0.001)**	(0.005)	(0.003)*	(0.004)	(0.006)	(0.003)	(0.003)
NSC log urea fertiliser (ln naira/bag)	0.000	0.002	0.002	0.007	−0.001	0.002	0.002
	(0.001)	(0.003)	(0.003)	(0.003)**	(0.002)	(0.002)	(0.003)
NSC log SSP fertiliser (ln naira/bag)	0.003	0.007	0.002	0.090	0.000	−0.003	0.012
	(0.002)	(0.004)*	(0.003)	(0.028)***	(0.005)	(0.003)	(0.002)***
NSC log price of seeds (ln naira/kg)	−0.000	−0.001	−0.000	−0.001	0.017	−0.002	0.007*
	(0.000)**	(0.001)***	(0.000)***	(0.000)	(0.005)***	(0.003)	(0.004)**
NSC extension (contact = 1)	−0.098	−1.769	−0.144	4.681	−6.740	0.285	1.560

(*continued*)

Table 3. (*Continued*)

Variable (N)	Full N = 3706	Maize N = 497	Rice N = 326	Cassava N = 138	Tomato N = 129	Leafy green veg N = 128	Cowpea N = 123
	(0.615)	(1.024)*	(0.887)	(2.485)*	(2.550)***	(2.184)	(0.972)
NSC log wage (naira/day)	0.591	−0.012	0.487	3.713	2.108	−0.184	−2.114
	(0.192)***	(0.614)	(0.556)	(1.501)**	(0.858)**	(1.076)	(0.515)***
Log distance to nearest road (km)	−0.123	−0.278	−0.137	−0.028	−0.364	0.012	−0.070
	(0.047)***	(0.131)**	(0.146)	(0.226)	(0.125)***	(0.257)	(0.073)
Log distance to nearest town (km)	−0.003	−0.048	0.038	−0.244	−0.044	0.298	0.331
	(0.060)	(0.226)	(0.150)	(0.242)	(0.136)	(0.331)	(0.119)***
Fadama II programme indicators	X	X	X	X	X	X	X
Agro-ecological zone indicators	X	X	X	X	X	X	X
Primary crop indicators	X						
Pseudo R squared	0.23	0.06	0.06	0.06	0.18	0.04	0.20

Notes: NSC stands for non-self clustered means at the village level. For construction of control variables see Table A1 in the Online Appendix; for descriptive statistics of control variables see Table A2 in the Online Appendix; all coefficients are reported as average partial effects from corresponding Tobit models and standard errors clustered at the local government area are reported in parenthesis ( ). *indicates significant at 10 per cent; **significant at 5 per cent; ***significant at 1 per cent.
Source: 2005 Fadama II evaluation data.

Table 4. Tobit productivity results for full sample and by major crop in Uganda

Variable (N)	Full N = 2700	Banana N = 393	Beans & peas N = 345	Maize N = 212	Sweet potato N = 204	Cassava N = 197	Sorghum N = 195	Including biophysical N = 2180
Crop ownership female (=1)	−0.269	0.226	0.066	−0.060	−0.798	−0.273	−0.930	−0.332
	(0.119)**	(0.277)	(0.351)	(0.415)	(0.411)*	(0.389)	(0.365)**	(0.157)**
Crop ownership mixed (=1)	−0.292	0.211	−0.824	−0.655	−0.981	−0.662	−0.378	−0.202
	(0.166)*	(0.343)	(0.400)**	(0.428)	(0.351)***	(0.586)	(0.438)	(0.166)
Age head (years)	0.017	0.064	0.062	−0.128	−0.127	0.037	−0.093	0.040
	(0.029)	(0.052)	(0.069)	(0.103)	(0.062)**	(0.087)	(0.079)	(0.028)
Age of head squared $(\text{years})^2$	0.000	−0.001	−0.001	0.001	0.001	0.000	0.001	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)*	(0.001)	(0.001)	(0.000)
Head primary schooling (=1)	0.170	0.149	0.536	0.005	0.971	−0.640	−0.109	0.226
	(0.181)	(0.332)	(0.292)*	(0.380)	(0.345)***	(0.418)	(0.418)	(0.172)
Head secondary schooling (=1)	0.137	0.542	0.403	0.218	0.431	−0.414	−1.130	0.250
	(0.264)	(0.388)	(0.532)	(0.524)	(0.499)	(0.667)	(0.539)**	(0.237)
Head post-secondary schooling (=1)	0.164	0.256	−0.024	−1.362	−0.169	0.892	−0.304	0.267
	(0.366)	(0.576)	(0.753)	(0.641)**	(0.864)	(0.753)	(1.086)	(0.357)
Log household size (ln)	−0.225	−0.256	−0.453	1.049	−0.225	−0.216	0.274	−0.309
	(0.138)	(0.234)	(0.278)	(0.480)**	(0.310)	(0.422)	(0.343)	(0.156)*
Log rainfed land area (ln acres)	0.070	0.215	0.111	0.094	−0.545	0.189	0.181	0.063
	(0.053)	(0.123)*	(0.156)	(0.175)	(0.288)*	(0.225)	(0.220)	(0.061)
NSC log seed price (ln shilling/kg)	−0.374	−0.398	−0.461	−0.148	0.024	−0.882	−0.185	−0.351
	(0.084)***	(0.241)	(0.180)**	(0.126)	(0.178)	(0.244)***	(0.218)	(0.138)**
NSC extension (contact = 1)	1.462	0.541	2.362	2.990	−1.681	2.947	3.680	1.239
	(0.706)**	(1.423)	(0.936)**	(1.136)***	(1.735)	(1.388)**	(1.699)**	(0.823)
Proportion land free/leasehold (%)	0.009	0.166	−0.334	3.549	5.770	−1.437	4.583	−0.190
	(0.690)	(0.923)	(0.841)	(0.757)***	(3.454)*	(0.675)**	(1.352)***	(0.721)
Proportion land mailo (%)	−0.197	−0.328	−0.326	2.626	6.348	−0.378	1.999	−0.345
	(0.646)	(0.890)	(0.468)	(0.650)***	(3.751)*	(0.629)	(1.602)	(0.686)
Proportion land customary (%)	−0.085	0.229	0.193	2.923	6.135	0.000	0.000	−0.167
	(0.637)	(0.920)	(0.642)	(0.715)***	(3.773)	(0.000)	(0.000)	(0.702)

(*continued*)

Table 4. (*Continued*)

Variable (N)	Full N = 2700	Banana N = 393	Beans & peas N = 345	Maize N = 212	Sweet potato N = 204	Cassava N = 197	Sorghum N = 195	Including biophysical N = 2180
Log community wage (shillings/day)	0.115	0.090	−1.652	−0.123	0.893	0.727	2.264	0.150
	(0.290)	(0.707)	(0.558)***	(0.524)	(0.665)	(0.719)	(1.126)**	(0.317)
Log distance to nearest market (km)	0.245	−0.035	0.293	0.270	0.822	0.542	−0.445	0.240
	(0.139)*	(0.260)	(0.304)	(0.306)	(0.280)***	(0.434)	(0.345)	(0.145)
Log distance to nearest road (km)	−0.054	0.015	0.036	−0.320	−0.537	0.300	0.343	−0.040
	(0.102)	(0.210)	(0.191)	(0.245)	(0.293)*	(0.421)	(0.302)	(0.115)
Agro-ecological zone indicators	X	X	X	X	X	X	X	X
Primary crop indicators	X							X
Pseudo R squared	0.04	0.03	0.05	0.07	0.06	0.06	0.04	0.03

Notes: NSC stands for non-self clustered means at the village level. For construction of control variables see Table AI in the Online Appendix; for descriptive statistics of control variables see Table A3 in the Online Appendix; all coefficients are reported as average partial effects from corresponding Tobit models using survey weights and standard errors clustered at the community level reported in parenthesis ( ). *indicates significant at 10 per cent; **significant at 5 per cent; ***significant at 1 per cent.
Source: 2003 NRM survey.

female farmers are significantly associated with lower output value when controlling for access to other inputs. Including biophysical characteristics of the plot in Uganda (last column) further increases this disadvantage, indicating that women are allocated or farm land that is comparatively resource poor. However, we find that the persistent disadvantage varies by crop. For example, in Uganda, the negative association is driven by farmers growing sweet potatoes or sorghum as their primary crop, while in Nigeria it is driven by households growing tomatoes as their primary crop. These main results are robust to a number of checks, including controlling for secondary crop indicators and the use of quantity produced (in kg) of each crop as an outcome instead of value of crop produced in Nigeria. In the next section we explore several other robustness checks to assess if these core results hold across geographical variation and choice of gender indicator. Finally, it is of note that in Uganda, where we include a category of mixed crop ownership, we find that these plots are associated with coefficients representing the lowest comparative productivity outcomes (in the full sample and crop-specific samples of beans and peas, and sweet potato). We will return to this finding in the discussion section.

Regional Specific Results

We estimate region-specific results by agro-ecological zone while maintaining all other components of the estimation equations, including primary crop fixed effects to control for the variability of crop choice agro-ecological zone (summary of results are available in the Online Appendix Table 4). Similar to primary crop-specific regressions, gender indicators vary based on the regional area of analysis. In Nigeria, female headed households are associated with significantly lower productivity in the moist and dry savannah areas, however, there are no significant productivity differences between male and female households in the humid forest zone. In Uganda, female and mixed crop ownership are associated with significantly lower productivity in the southwest highlands.

Gender Indicator Robustness Checks

Because we are specifically interested in the interactions between gender and productivity, we conduct several robustness checks using four different forms of the gender indicator using the Uganda data, where such sensitivity analysis is possible because gender indicators were gathered at different levels of aggregation. Summaries of results for each gender indicator are reported in the Online Appendix, Table 5.

The first variation excludes the mixed crop ownership category to proxy a situation where data is not collected to allow a joint gender or group ownership category. All other aspects of the estimation, including control variables remain identical to the main analysis. The second variation tests an indicator for female headed household to simulate results if gender indicators are only collected at the household level (as in Nigeria). The third variation is again at the household level, but the gender indicator is a continuous variable measuring the proportion of land which is female owned and managed. We also consider the implications of diverse household structure by excluding polygamous households (16% of the sample) but using the same crop ownership variables (female and mixed) as in the main analysis. Results show none of the gender indicators are significant across regressions and gender differences are lost when indicators are aggregated to a higher level (household) or when specific household structures are disregarded. This suggests that gender differences in agricultural productivity may not be revealed at higher levels of aggregation that do not correspond to the basic decision making unit in specific farming systems.

Household Fixed Effects and Crop-growing Decision Robustness Checks

It could be argued that the above results may reflect selection bias owing to unobservables such as the decision to grow any crops, unobserved plot characteristics, unobserved inputs such as skills and ability, or other unobserved household-level factors. In Uganda, we are able to control for a range of plot characteristics using detailed biophysical indicators data. However, without panel data, we cannot control for unobserved skill and ability of the plot owner, but because households may farm more than one plot devoted to the same crop in a single season, we can control for household-level unobservables using a fixed effects estimator. We use Honoré's (1992) tobit with fixed effects estimator to model the same regressions as above, noting that variables that do not vary within a household will be dropped from the estimation. In addition, households that do not cultivate more than one plot will also be dropped from the estimation, but this does not constitute a source of selection bias because selection into the sample is accounted for by the fixed effect. This least-absolute deviations estimator is preferred to a tobit with dummy variables.[15] In addition, gendered productivity outcomes may also depend on the decision to plant any crops at all, given the large number of fallow or zero productivity plots in our data. To examine this possibility, we estimate Cragg's two-tiered or double hurdle tobit alternative using the full samples in both countries (Cragg, 1971). This specification assumes conditional independence of the decision to plant any crops in the first tier estimated using a probit model, and the amount of crop productivity in the second tier estimated using a truncated normal distribution. We include results from this alternative specification for the full samples in both Nigeria and Uganda.

Table 5 presents a summary of the coefficients on gender for different specifications from the tobit with fixed effects regressions (top panel) and for the Cragg tobit alternative (bottom panel).[16] When household level unobservables are controlled for using the fixed effects tobit, the female ownership indicator remains significant and negative for all crops. This result is robust to the inclusion of biophysical characteristics and the exclusion of fallow plots. The female ownership indicator is insignificant for banana, and negative and significant for beans. However, the loss of significance of the mixed ownership dummy indicates that the previous negative and significant result is not robust to controls for unobservable household characteristics. This implies that the previous result for mixed ownership may be reflecting unobserved household-level variables that may drive the phenomenon of mixed ownership. For example, extended families may be more likely to report mixed ownership, or families that have bargaining difficulties or intra-familial conflict may be more likely to report mixed ownership. This

Table 5. Summary of selected coefficients on gender indicators for tobit fixed effects estimates in Uganda (panel A) and two-tiered Cragg tobit alternative in Nigeria and Uganda (panel B)

Panel A: Tobit fixed effects (Uganda)

	Basic model, all plots	All crops including biophysical controls	Excluding fallow plots	Banana basic model	Beans basic model	Maize basic model
Crop ownership female (=1)	−0.911	−0.918	−0.791	0.184	−3.697	−0.170
	(0.373)**	(0.395)**	(0.392)**	(0.380)	(1.110)***	(.)
Crop ownership mixed (=1)	−0.318	−0.431	−0.477	1.858	0.504	−0.718
	(0.343)	(0.356)	(0.354)	(1.985)	(0.762)	(0.720)
Number of plots	2700	2180	2134	393	345	212
Number of households	763	594	755	287	263	182
Minimum number of plots per household	2	2	2	2	2	2
Maximum number of plots per household	18	18	16	7	8	4

Panel B: Two-tiered Cragg tobit alternative (Nigeria and Uganda)

	Nigeria Tier 1 Any crop (=1)	Nigeria Tier 2 Unconditional productivity	Nigeria Conditional productivity	Uganda Tier 1 Any crop (=1)	Uganda Tier 2 Unconditional productivity	Uganda Conditional productivity
Female household head (=1)	−0.097	−0.299	−0.281	–	–	–
	(0.042)**	(0.147)**	(0.077)***	–	–	–
Crop ownership female (=1)	–	–	–	−0.022	−0.175	−0.227
	–	–	–	(0.020)	(0.094)*	(0.138)*

(*continued*)

Table 5. (*Continued*)

Panel B: Two-tiered Cragg tobit alternative (Nigeria and Uganda)

	Nigeria Tier 1 Any crop (=1)	Nigeria Tier 2 Unconditional productivity	Nigeria Conditional productivity	Uganda Tier 1 Any crop (=1)	Uganda Tier 2 Unconditional productivity	Uganda Conditional productivity
Crop ownership mixed (=1)	–	–	–	−0.030	0.085	−0.195
	–	–	–	(0.026)	(0.112)	(0.114)*
Sample size	3706	1879	3706	2700	2099	2700
LR test difference in log likelihood between tiers	917			899851		

Notes: For construction of control variables used in all models see Table A1 in the Online Appendix; for descriptive statistics of control variables see Table A3 in the Online Appendix; Panel A: all coefficients are from fixed effects tobit models using the Pantob stata ado program developed by Honoré (1992). Panel B: Tier 1 estimated using probit models, Tier 2 estimated using truncated normal distribution, third and sixth column report effects conditional on producing any crop and are reported using bootstrapped standard errors following Burke (2009). All coefficients are reported as average partial effects. (.) indicates not computed; *indicates significant at 10 per cent; **significant at 5 per cent; ***significant at 1 per cent.
Sources: 2005 Fadama II evaluation data and 2003 NRM survey.

phenomenon could also reflect enumerator error (if, for example, certain enumerators did not probe the ownership or management of specific plots). Panel B reports the first tier, unconditional (second tier) and the average partial effects conditional on growing any crop for the Cragg model. Although the LR tests indicate significant differences in contribution of coefficients between the first and second tiers, the conditional results largely mirror those of the full tobit models presented in Tables 3 and 4. The exception is the magnitude of effects in Uganda, for example the average partial effect of female crop ownership changes from -0.27 (5% significance level) to -0.23 (10% significance level). Note that gender indicators are significant in predicting growing any crops in Nigeria, while they are not correlated with this decision in Uganda, consistent with the bivariate analysis presented in Tables 1 and 2.

VI. Exploring Heterogeneity Across Headship Definitions and Agro-ecological Zones

A key contribution of this analysis is to demonstrate that the variability of results depends on the choice and implementation of gender indicators. Although female headed households may be easily identifiable and headship is the most routinely collected gender indicator, the very concept of household head may be less concrete and more fluid than many researchers conceptualise, encompassing typologies ranging from de jure and de facto to skipped generation female headed households (Fuwa, 2000; Finely, 2007). For example, Doss (2002) notes that approximately 14 per cent (616 out of 4,552) women in the third Ghanaian Living Standards Survey report being *both* married *and* the head of the household. Doss speculates this may demonstrate the more fluid use of the term 'household head' or may hint at the number of women in polygamous marriages who have husbands residing elsewhere. In addition, Bourdillon et al. (2002) find even in female headed households of rural Zimbabwe, men (such as adult sons) are expected to make agricultural decisions. In the often-cited Burkina Faso ICRISAT sample, on average there are 1.8 wives per household head (Udry, 1996), and the high prevalence of polygyny may have important implications for agricultural productivity analysis. Jacoby's (1995) study of the 'economics of polygyny' in Cote d' Ivoire finds conditional on wealth, men with more productive farms have more wives, and that in regions where food crops are relatively more important than cash crops, there is a higher demand for additional wives. In our robustness checks, we find indications that important differences in agricultural productivity may be driven by the sample of polygamous households. In this context, intrahousehold bargaining, not only between men and women, but across generations with adolescents and children may influence productivity outcomes, an issue which has been largely ignored by the intrahousehold literature.

Another interesting feature of this study is the diversity of agro-ecological zones under investigation. As previously noted, some of the most cited works on gender and agricultural productivity differences are within a fairly limited geographic sample. For example, Udry and colleagues (1995) draw their sample from 150 households in six villages in Burkina Faso; Goldstein and Udry (2008) examine 60 married couples in four village clusters in eastern Ghana. Clearly this limited regional scope has implications for generalisability of results. Other studies which disaggregate by geographical zone have also found estimates change, often significantly between regions (Somda et al., 2002). Beyond indicating that regional differences matter, a number of interesting trends emerge from our analysis. Both in Uganda and Nigeria we find female-headed households are associated with lower productivity in the dry savannah area. This may occur because the dry savannah ecology increases the domestic work burdens of women and girls, reducing the time spent on farming activities. For example, Appiah et al. (2000) find that in the savannah area of Ghana women and girls spend considerably more time fetching firewood and water on a daily basis than in other agro-ecological zones in the country.[17] In Sudan, production costs are much higher in the savannah zones than those in the equatorial forest (Kebbeh et al., 2003). The authors partially attribute this to the greater needs for fertilisers and herbicides and the higher costs of irrigation in the dry area. In this case women, who often have less access to important assets, are at a further disadvantage (Peterman et al., 2010). Uganda has a diverse representation of agro-ecological zones, spanning those characterised by dry unimodal rainfall and low agricultural productivity (north and northeastern regions), to those with bimodal rainfall and high agricultural productivity (highlands and Lake Victoria region in the south). This makes Uganda a good 'case study' in which to test a range of diverse ecological characteristics faced by farmers in many sub-Saharan countries (Nkonya et al., 2008a).

In addition to trends within agro-ecological zones, it is worth noting religious and cultural norms which may also vary by region. For example, scholars note the relatively recent emergence of Islamic Sharia Law throughout states in northern Nigeria and the accompanying adoption of the hijab and a more rigid male 'public' female 'private' dichotomy (Ludwig, 2008; Mahdi, 2009). Given that there is some geographic overlap between these northern states and the agro-ecological zones where we find female productivity is lower in Nigeria, it is worth exploring the impact of an Islamic revival on women and farming. These issues are also intertwined with access to inputs such as land and legal provisions surrounding women's property rights. Unfortunately due to data constraints we are unable to explore these issues in greater depth using the Nigeria data. However, a larger body of research has begun to acknowledge the critical importance of cultural interactions inherent in the linkages between gender and agriculture (Cotula, 2006).

VII. Conclusions and Research Implications

Although the attention to gender analysis in agricultural research has increased substantially in the past decade, the need for continued and more robust treatment of gender persists. This effort necessitates not only learning and redefining how gender can be incorporated and analysed within agricultural economics, but also more nuanced and specific data collection efforts. Our study, using large sample size data sets in Nigeria and Uganda, offers several insights for future research on gender gaps in agricultural productivity. First, using Ugandan data, we show that household-level gender indicators tend to underestimate gender differences in productivity. Therefore, particular attention should be paid to the level of aggregation of gender indicators in agricultural research and where possible, sensitivity analysis should be conducted to provide more robust and credible results. This necessitates attention to gender issues at the onset of survey design, rather than an *ex post* analysis using routine indicators collected in agricultural surveys, such as household headship. Second, even when household-level unobservables and other inputs are controlled for, female-owned plots have the lowest productivity in Uganda. This suggests attention to gender differences in control of resources and intrahousehold bargaining should be components of research and programme implementation. Third, we find results vary substantially by region and primary crop choice in both countries as well as with inclusion of biophysical characteristics in Uganda. Consequently, we recommend that gender be integrated in agricultural programmes and research within the context of regional ecological and biophysical needs, as well as regional cultural differences. If, for example, women are culturally proscribed to cultivate low return crops, there may be significant returns to crop diversification for women. Given the context-specifity of gender relations, this article clearly warns against the extrapolation of policy findings from region and crop-specific studies that focus exclusively on localised programmes. This means that governments and other donor organisations should consider carefully the geographical representativeness of data collection and evaluation efforts to maximise the validity of recommendations across agro-ecological zones. As programmes seek to improve agricultural productivity, rural livelihoods and food security, attention to gender as a cross-cutting dimension is a potential avenue of increased success in accomplishing these goals.

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Notes

1. It has been argued that static productivity analyses do not pay adequate attention to historical processes such as increased integration into the market economy and individualisation of property rights (O'Laughlin, 2007) as well as the extent to which colonial policies have influenced patterns of landownership, crop production, and specialisation. Because our study uses cross-sectional data collected over one or two years, we are unable to analyse these long-run processes.
2. This article focuses on the measurement of gender differences in agricultural productivity. Because rural households are engaged in a number of productive activities, including wage labour, off-farm employment, and non-agricultural self-employment, measures of agricultural productivity are only partial measures of the range of the household's productive activities.
3. For example, in Ghana, women view maize production as a profitable, income-generating activity, yet they do not grow maize because they lack the capital to purchase the required inputs or to recruit wage-labour to plough fields (WB et al., 2009). This is different from the first point, in which men and women may cultivate the same crop, but women apply lower levels of the same inputs.

4. The data were collected from 1981 to 1985. In addition to information on operations, inputs and outputs, the ICRISAT data include area of plot, location toposequence and local name for soil type (categorised into one of 88 soil types). For more information on the ICRISAT data see Udry (1996) or Udry et al. (1996).
5. Alternatively, total household output could be increased by allocating land from women to men, however, this recommendation is less cited, presumably due to its unappealing equity implications.
6. Akresh (2005) does find evidence of inefficiency when he limits the sample to 'near-ICRISAT' provinces. These near-ICRISAT provinces on average contain households with larger plot sizes, greater wealth, higher percentage of cash crops and higher than long-run provincial rainfall.
7. Note that many of these studies do not focus on explaining gender differences explicitly; rather they include gender as an explanatory variable or as an extension to the main analysis. Although the literature on gender differences in agriculture is much more vast, this literature has already been summarised in reviews, and therefore we focus here on that published or available in the last 10 years (1999 to 2009).
8. As mentioned, a household may be de facto female-headed during a limited period while a spouse is working away from home or is ill and may be more likely to be receiving remittances from internal or international migrants. This type of female headship is differentiated from de jure headship, which usually occurs upon divorce, separation or widowhood. Distinctions between types of female-headed households are discussed in Quisumbing et al. (2001) and literature surveying these differences is reviewed in Fafchamps and Quisumbing (2008).
9. It should be noted the sample sizes in several gray literature publications are small: Tiruneh et al. (2001) have sample sizes of N = 100 and N = 77 on male- and female-headed households respectively, so results should be interpreted with caution. Sample sizes in several published literature are also small: Kinkingninhoun-Mêdagbé et al. (2008), N = 45; Oladeebo and Fajuyigbe (2007), N = 100 and Chavas et al. (2005), N = 115.
10. If all other inputs are measured correctly, the gender dummy captures the sex of the farm manager and is an indicator of biological differences. However, if the other inputs are incorrectly measured, or some variables are omitted, the gender dummy is appropriately called a 'gender', not a 'sex' dummy variable because it will capture socially determined allocations of inputs between men and women.
11. In Uganda, there is an option to code the primary crop in the most recent crop season as 'fallow' or 'pasture'. However, in Nigeria if no crop was observed, the indicator was simply left missing; therefore, we cannot attribute it specifically to fallow, because the indicator could be missing for a variety of reasons. However, because this option refers only to the primary crop, there exists the possibility of positive productivity due to 'secondary crops'. In Uganda where the primary crop and secondary crop are missing in the first crop season, the crop choice variable is replaced by the second crop season.
12. A limitation of our productivity outcome is the use of village- or state-level prices instead of own prices obtained per crop. This means our crop value is not the actual market value obtained but is rather a proxy measure of produced value. This is important for our analysis if we believe that the market value will differ by gender of the household head or farmer. However, even if we had own prices, there likely would be a large number of missing price values in cases where an output was used for home consumption or had not yet been sold; moreover, it could be argued that own prices are endogenous to farmer characteristics.
13. This resulted in the dropping of approximately 5.3 per cent of observations. We experiment with including this group and controlling for missing values in multivariate models, however, doing so does not change the magnitude or relationship of the main results, so we exclude it for simplicity of presentation. Note that this distinction is different from productivity missing or zero reports, which are included in the sample.
14. Note we drop irrigation and fertiliser indicators in Uganda because less than two per cent of our sample reports each.
15. This estimator is preferred because it is both consistent and asymptotically normal under suitable regularity conditions and assumes neither a particular parametric form nor homoscedasticity.
16. Cragg models are implemented in Stata using the 'craggit' command and average partial effects are based on bootstrapped standard errors (Burke 2009). Fixed effects tobit models are implemented using 'Pantob' ado programme developed by Honoré (1992). Although we attempt to replicate crop-specific regressions in Panel B, only those of banana, beans and maize have sample sizes large enough to

support this estimation. In addition, we report coefficients instead of average partial effects, because, as Honoré (2008) explains, computing marginal effects depends on the unobserved fixed effects, which the Honoré estimator strips away. Although it is computationally possible to recover marginal effects, they would not be comparable to those in a tobit model, so we do not compute them.

17. On average, women and girls spend 48 minutes per day collecting water in the Savannah region, as compared to 28 minutes per day in forest areas and 13 minutes per day in coastal areas (Appiah et al., 2000).

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