Gender, institutions, and household bargaining: Panel evidence from Ghana

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Abstract[1]

In this paper we analyze the gender yield gap among smallholder farmers in Northern Ghana. We estimate a linear regression with crop, household, year fixed effects to examine the impact of gender on crop output and input use. We find evidence of a male/female yield and input gap in the same household, for the same crop. This suggests that these smallholder households may not be behaving Pareto efficiently. This may be a result of what we refer to as "institutional drivers" that prevent women from accessing or affording markets for inputs and output, or "bargaining power" drivers or factors that are decided at the household level through intrahousehold bargaining. We attempt to disentangle possible institutional drivers from bargaining power drivers by studying asymmetric input and output prices, credit access, and land tenure. To explore these institutional drivers, we modify our basic regression model either by changing the dependent variable, limiting the sample, or adding additional controls.

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I. Introduction

Women make up more than 50 percent of the agricultural labor force in Sub-Saharan Africa but yield significantly less on their plots than men (FAO, 2011). Since, smallholder agriculture is a driver of rural economic growth, prescribing and implementing policies to tackle this gender yield gap is essential for combating poverty and food insecurity in the region. To do so requires an understanding of the extent of the gender yield gap and its drivers.

There is a fairly large literature that analyzes productivity differences between female and male farmers. Some of that literature uses the gender of the household head to calculate the gender yield gap. These studies find evidence of a gender yield gap in Ethiopia (e.g., Bezabih and Holden, 2006; Tiruneh et al., 2001) but not in Zimbabwe (Horrell and Krishnan, 2007) or the Gambia (Chavas et al., 2005). Female-headed households often have less income and fewer assets than their male-headed counterparts. Market failures and discrimination in land, credit, input, and output markets, may further contribute to their lower yields than male-headed households.

But women in female-headed households are in a very different position than women in male-headed households. While they may face the same disadvantages at the institutional level, they also need to bargain for resources at the household level. Previously, economists have overlooked this intra-household element and modelled household behavior as one single individual using the unitary household model. However, because of strong evidence that households do not act as a single actor, this model was replaced by cooperative and non-cooperative bargaining models (Strauss and Thomas, 1995; Browning and Chiappori 1994). Cooperative bargaining models assume that household decision making is a two-stage process whereby members use their bargaining power to first decide on public good consumption and then on private consumption (Chiappori, 1992, 1988). They also assume that household decisions are efficient or *Pareto optimal*. For a farm household this means that resources, including technology and inputs are allocated efficiently between plots controlled by different members of the household that grow the same crop. If men and women use the same technology, then they should have the same marginal product of land and should produce the same amount.

Several studies use plot level data to analyze productivity differences across female and male plots within the same households. Unlike the literature that uses the gender of the household head as the unit of analysis, these studies consistently find that within a household, women achieve lower yields than men (Udry, 1996; Akresh 2005; Peterman et al., 2011; Osenti et al., 2014). This suggests that improving the position of women in household bargaining is essential to closing the gender yield gap.

Some authors find that the yield gap is a direct result of unequal distribution of productive inputs including land, fertilizer, labor, and technology (Saito et al., 1994 for Kenya; Gilbert et al., 2002 for Malawi; Kilic et al. 2013 for Malawi; Goldstein and Udry, 2008 for Ghana; Osenti et al., 2014 for Nigeria). This could be evidence that the assumption of Pareto efficiency does not hold. Other studies find that even after controlling for input use there is still a large gender yield gap (e.g., Saito et al., 1994 for Nigeria; Udry, 1996 for Burkina Faso; Quisumbing et al., 2001 for Ghana; Peterman et al., 2011 for Uganda; Osenti et al., 2014 for Nigeria). This signals that there may be other constraints that account for the productivity differences across genders.

Institutional factors or factors that are external to the household may contribute to the gender productivity gap. Several studies find that institutional factors account for to the gender yield gap including tenure security, extension, market, and credit access (Kinkingninhoun-

Medagbe´ et al., 2008; Goldstein and Udry, 2008 Gilbert et al. 2002). Additionally, the lower use of inputs by female farmers compared with male farmers may be related to institutional factors. In their review of gender differences in non-land agricultural inputs, technologies and services, Peterman et al., (2010) point out that most literature on inorganic fertilizer use, finds that given equal access to fertilizer, female farmers adopt fertilizer at the same rates as male farmers (for plot level analysis see Chirwa, 2005 in Malawi, Gilbert et al. 2002 in Malawi, Freeman and Omiti, 2003 in Kenya, Jagger and Pender, 2006 in Uganda; Doss and Morris, 2001 in Ghana, Thapa, 2009 in Nepal).

What remains unclear from these studies is to what extent structural sexism (gender inequality within institutions) accounts for the limited access to inputs, services, productive infrastructure, and technologies and to what extent it is actually the result of intrahousehold bargaining and within household power differentials. This is a crucial distinction for policy makers because correcting one without the other may not improve the gap at all.

In our study, we test the assumptions of the collective model for farm households in Northern Ghana. Udry (1996) argues that if households were Pareto efficient, men and women in the same household would have the same yields when planting the same crop in the same year. He draws this conclusion from a recursive model, where separability between production and consumption holds and there is no influence of market imperfections (related to institutional or structural factors) on optimal choices. We argue that in a model with institutional or market constraints, where, even within the same household, women face deeper restrictions in access to markets or uneven price incentives, households could be optimizing their decisions by allocating their resources in such a way that men and women in the same household would not have the same yields, even when planting the same crop in the same year. Institutional gender inequalities may prevent women from achieving the same yields and remuneration than men, even after controlling for household characteristics. We test this assumption by calculating the female/male yield, and input gaps conditional on household, year, and crop. Then we attempt to disentangle possible “institutional drivers” from “bargaining power” drivers.

Institutional drivers are evidence of structural sexism; they can prevent women from accessing or affording inputs. They include land tenure security, access to credit, access to fair input and output prices. Bargaining power drivers are factors that operate at the household level and include the uneven allocation of land, input distribution, and input productivity between men and women.

Our paper makes important contributions to the literature on the male/female gender economic gap, its drivers, and its implications for collective household models. First, there have only been a few studies that test the assumption of Pareto efficiency for smallholder farm households (e.g., Udry, 1996, Akresh, 2005). Other papers that explore the gender/yield gap estimate production functions using cross-sectional data. Since choices such as input use, and technology are endogenous to crop choice and gender, these estimates may be less reliable. Second, while more recent studies have delved further into understanding the drivers of the yield gap (e.g., Udry, 1996; Osenti et al., 2014; Kilic et al. 2013 for Malawi), they do not differentiate between institutional and household drivers. Therefore, while they demonstrate that for example, less use of agricultural inputs such as inorganic fertilizer by women is an important driver of the gap, they do not identify whether this is a result of institutional factors, such as women facing higher fertilizer prices or higher transaction costs or bargaining power factors. Making this distinction is key to prescribing policies to tackle gender differentials.

2. Review of relevant literature

There is a sizeable literature that documents agricultural productivity differences on female versus male managed plots across households and within households. Many of the studies on the gender yield gap explore the question at the household level, using the gender of the head of the household as the key explanatory variable (e.g., Bezabih and Holden, 2006; Tiruneh et al., 2001; Chavas et al., 2005; Thapa, 2008; Horrell and Krishnan, 2007). While some of these studies document a yield gap between male-headed households and female-headed households (e.g., Bezabih and Holden, 2006; Tiruneh et al., 2001) others find no differences in yields achieved by female-headed households and male-headed households (e.g., Chavas et al., 2005; Thapa, 2008; Horrell and Krishnan; 2007). But there are systematic differences between women across female-headed households and with respect to women in male-headed households.

In their study of how female headship impacts incidence of poverty and agriculture productivity in three rural regions of Zimbabwe, Horrell and Krishnan (2007) highlight two types of female-headed households, *de jure* (widowed, separated, and divorced women) and *defacto* (wives of migrants). While de jure households are income-poor compared to male-headed households, de facto households have similar incomes but are comparatively asset poor. Despite these differences, using a maximum likelihood Heckman selection model with a Cobb–Douglas production function, Horrell and Krishnan (2007) demonstrate that groundnuts yields are no different for female-headed households than male headed households. The authors find no evidence for inefficient allocation of inputs across male and female headed households. Instead, input use, including labor, manure, fertilizer, and seeds were the most important divers of yield.

The literature on the gender yield gap at the household level provides us with important insights into the institutional sexism faced by women in agriculture. For example, Horrell and

Krishnan (2007) find that de-facto female-headed households receive significantly lower prices for their maize crop while widowed female-headed households earn less for their cotton crop. Tiruneh et al. (2001) demonstrate that compared to their male counterparts, female-headed households have less access to formal and informal financial institutions as well as extension services. Bezabih and Holden (2006) show that female-headed households face landlord tenure insecurity.

But female-headed households only make up a very small percent of African households (a roughly calculated average from 2015 to 2020 is 28.4 percent (World Bank, 2021)). Increasing productivity among female farmers certainly requires targeting female-headed households, but it also requires addressing productivity gaps on female versus male plots within male-headed household. This is trickier as it requires an understanding of whether the gap results from institutional sexism, unequal intrahousehold resource allocation or both.

Only a handful of studies break down the analysis at the intrahousehold level. They use plot level data to study productivity differences across female and male plots within the same households. Most studies confirm the existence of a large and statistically significant yield gap (Saito et al., 1994 Udry, 1996; Quisumbing et al., 2001; Osenti et al., 2014; Kilic et al. 2013; Peterman et al., 2011).

Udry (1996) in his pivotal study, examines productivity differences between male and female plots in six villages in three different agro-climatic zones in Burkina Faso. He tests the null hypothesis of pareto efficiency, conditional on plot size and land quality of plots planted within the same household to the same crop in the same year. He finds that plots controlled by women have significantly lower yields than plots controlled by men. He demonstrates that the yield differential can in part be explained by the lack of inputs used on female plots compared with male plots. Less male, child and external labor are applied to female plots compared with male plots. Further, almost no fertilizer is used on female plots.

Akresh (2005) builds on the work of Udry (1996) and uses plot level data from a nationally representative survey of 2406 households across all of Burkina Faso's provinces. When Akresh limits the sample to the three regions in Udry's paper he finds significant evidence of the gender yield gap. However, when he estimates the fixed effects regression at the country level, he finds no evidence of Pareto inefficient intrahousehold allocation. Households in the three regions included in Udry's paper had larger plot sizes, greater wealth, were more likely to plant cash crops including maize, rice and cotton and experienced more rainfall.

Akresh also extends the analysis to consider the impact of negative rainfall shocks on pareto efficiency. He argues that when there are rainfall shocks, households may have incentives to overcome pareto inefficiency to ensure food security. He finds that negative rainfall shocks do decrease pareto inefficiency. Further, when he breaks down the sample into wealthier and poorer households, he finds that females in wealthy households who experience a positive rainfall shock have 191.3 percent lower yields then men in their households. This is compared to women in poorer households who experience a negative rainfall shock who only have 2.6 percent lower yields then men in their households.

Petereman et al. (2011) estimate Tobit regressions to determine the impact of gender on agricultural productivity in Nigeria and Uganda. For Nigeria, they analyze how the gender of the household head impacts productivity, while in Uganda they study how gender of the plot manager influences productivity. They find that both female headed households in Nigeria and female headed plots in Uganda are associated with lower output values even when controlling for access to other inputs. After they include biophysical characteristics, they find that the gender yield gap becomes larger in absolute value, suggesting that women farm poorer quality land. When they aggregate the gender variable to the household level for Uganda and instead estimate the impact of having a female-headed household on productivity, they obtain a much smaller gender coefficient, indicating that household-level gender indicators underestimate gender gaps in productivity. Like Udry (1996) and Akresh (2005), they find that the extent of the gender yield gap varies by region, which they define by agro-ecological zone.

Osenti et al. (2014) examine the question of gender productivity in Nigeria as well, but this time at the plot level. Although, they have nationally representative data from a 2010/11 survey, they limit their sample to 2,995 households in the North and the South, where females manage plots. They find that women in the North produce 28 percent less than men and in the South 24 percent less than men. But while the yield gap stays large and significant after controlling for observed manager characteristics and factors of production in the North, it disappears after adding controls in the south.

They use Oaxaca-Blinder decomposition to decompose the gender gap into the portion that comes from observable differences in the factors of production and the unobservable portions (structural effect). In the North they find that the unexplained portion of the gender gap is larger than the explained portion; implying that even if women were given the same level of resources as men, the yield gap would still persist. While access to resources explains the gender differential in the south, in the North if women were given the same inputs as men, they would still have lower yields.

Kilic et al. (2013) uses the same methodology to explore gender differences in agricultural productivity in Malawi using a national representative panel survey from 2010/11. Using plot-level regression the authors find that female-managed plots are 25 percent less productive than male managed plots. When they control for key factors of production, the gender gap decreases to 4.5 percent. From Oaxaca-Blinder decomposition they find that 82 percent of the mean gender gap can be explained by observable covariates including years of schooling, use of agriculture inputs such as inorganic fertilizer, pesticide and herbicide, improved seeds, and adult male labor.

In an earlier study of Malawi, Gilbert et al. (2002) study how a legume cropping system trial implemented by the Malawian extension services in the 1998-89 cropping season impacts crop yields on male and female plots. First, extension agents only chose to work with females on 19 percent of plots, even though it is estimated that women make up 69 percent of Malawi's farmers. This highlights a male bias in extension. Second, they found that when female farmers were provided the seed and fertilizer inputs for the trial, their output was the same as their male counterparts. On the other hand, in the women's local control plots for maize (no treatment) women had significantly lower maize yields than men.

There are three important themes that emerge from these studies. First, in some contexts, the researchers demonstrate the gender yield gaps disappear once productive inputs are included in the estimation models (Saito et al., 1994 for Kenya; Gilbert et al., 2002 for Malawi; Kilic et al. 2013 for Malawi; Goldstein and Udry, 2008 for Ghana; Osenti et al., 2014 for Nigeria; Ally and Shields, 2010 for Nepal). This indicates that improving access to inputs for women is essential for decreasing the gender yield gap. Second, several studies find that even after controlling for input use there is still a large gender yield gap (Saito et al., 1994 for Nigeria; Udry, 1996 for Burkina Faso; Quisumbing et al., 2001 for Ghana; Peterman et al., 2011 for Uganda; Osenti et al., 2014 for Nigeria). This indicates that focusing on inputs alone, is not adequate to fully address the yield gap. Third, often there is a discrepancy within the same study because of different outcomes in different regions of the country.

When we explore this discrepancy, Udry (1996) finds that there is no significant difference in the Sahelian region, which is the poorest region in the country, but there are differences in the Sudanic and North Guinean regions. Peterman (2011) demonstrates that in Nigeria there are gender productivity differences in the moist and dry savannah areas, but not the humid forest zone, while Osenti (2014) shows that there are productivity differences in the North but not in the South. Overall, it is clear that the existence of the gender yield gap is regional, but it is unclear why. Wealth could be an important factor, with poorer households allocating resources more efficiently (e.g., Udry (1996) Akresh (2005)). Culture and institutions may be even more important. Since gender differences are socially determined by religious, ethnic, economic, and cultural factors it would stand to reason that the gender yield gap varies regionally. Unpacking these root causes is essential for prescribing policy that increases productivity among female farmers.

3. Conceptual model

Figure 1 shows a conceptual model of the pathways through which household bargaining and institutions can impact crop yield. The center of Figure 1 contains land, input, and output factors that influence yield directly. The outside of the figure contains factor that determine the input, and output factors in the center. The left panel contains factors that are determined by household bargaining. The right panel contains factors that are impacted by institutions.

The top of Figure 1 maps out how access to land impacts crop yield. In northern Ghana, land is often allocated at the time of marriage to the wife. The plot or plots allocated depend on the bargaining power of the wife and her position within the family (first wife, second wife, daughter … etc.). The woman's bargaining power is related to the religion and culture of the family and that of the society she lives in. If a female household member wishes to purchase or rent a plot, she needs cash. This depends on her bargaining power over allocation of her time (ability to generate income) and her bargaining power over control of income. At the institutional level, her ability to purchase, rent, or clear a plot depends on a lack of discrimination in the land market. It also may depend on access to credit. Together these factors determine the soil quality, location of the plot, and crop choice, all three of which impact yields.

Unequal application of inputs including fertilizer, improved seeds, pesticides, herbicides, technology, and labor is an important driver of the gender yield gap. Given the opportunity, women apply inputs at the same rates as men (Chirwa, 2005, Gilbert et al. 2002, Freeman and Omiti, 2003; Jagger and Pender, 2006; Doss and Morris, 2001; Thapa, 2009). So why do women not have the same opportunities to apply inputs as men? At the household level, a woman has to bargain to obtain the cash to purchase inputs. Again, she has to bargain for time and tasks to generate income and for control over that income. If the inputs have already been purchased by the family, she has to bargain for her share of the inputs. This is the case also for family labor; each household member has to negotiate for other member's labor time to dedicate to their plots.

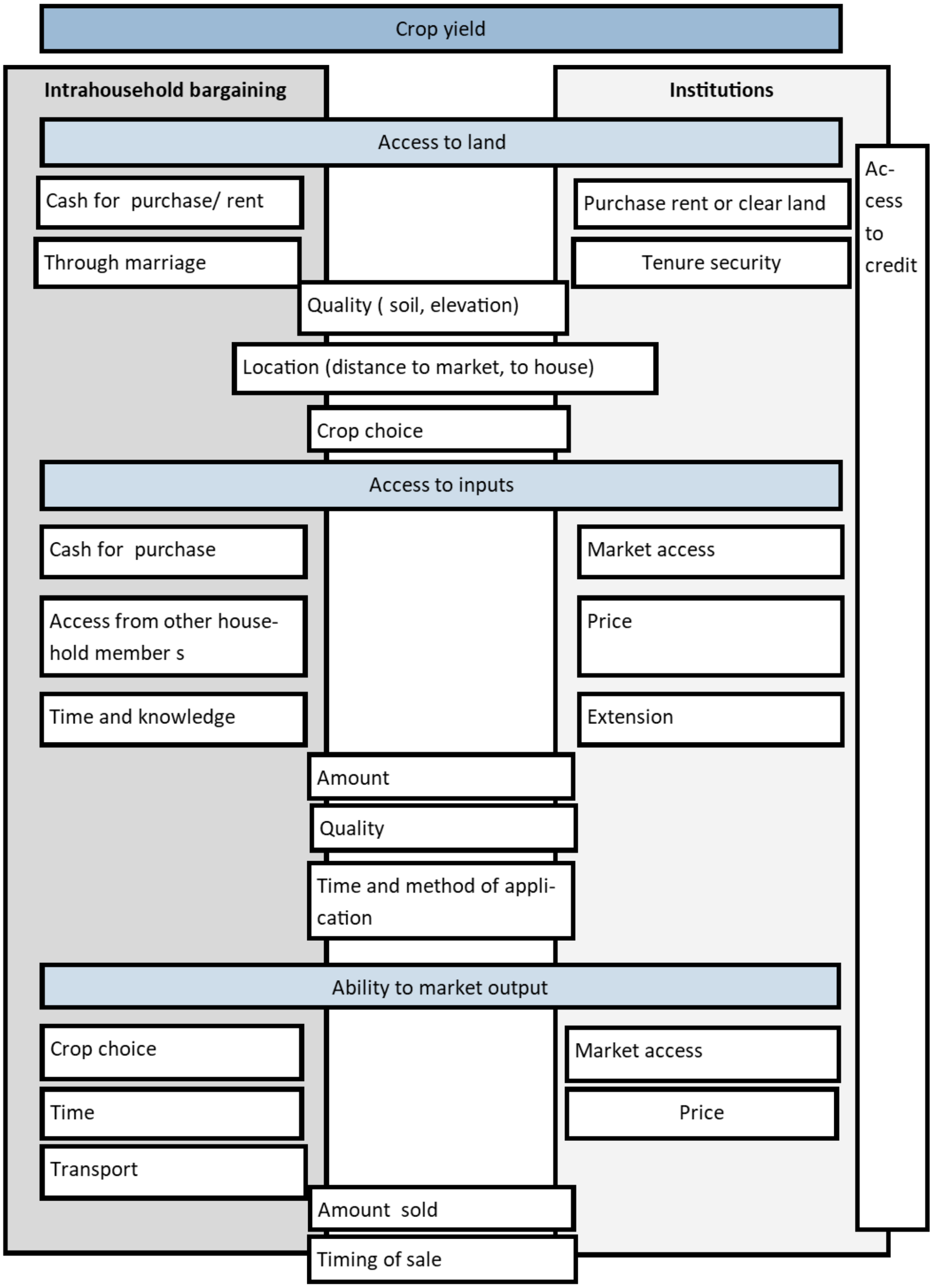
In addition to bargaining for time to generate income, the woman has to bargain for time to procure, apply or use the inputs in a well-timed manner. This is essential for the productivity of her crops. This process also requires knowledge, which depends on information sharing between household members. At the institutional level, access to inputs requires a lack of discrimination in terms of access and price in the different input markets. It also requires a lack of discrimination in the extension system. Together the process of household bargaining and the structure of the input markets determine, the amount, type, quality, method and timing of input application and use. And all of these factors play a key role in the productivity of the crops.

The bottom of Figure 1 sketches out how the ability to market output impacts crop yield. In addition to the land type, household bargaining influences a woman's choice of crop to plant. Doss (2002) analyzes crop planting patterns among men and women in Ghana. She finds that while there are not "women's crops" or "men's crops" there are some gender patterns in crop production. In the Savannah zone, which is the zone we use for our analysis, maize is grown disproportionately on land held by men. When she breaks down production by the household member who keeps the revenue from the plot, she finds that while pepper, tomato, cocoyam, and cassava are not disproportionately grown by men, when they are grown for revenue, they are. This suggests that there is not only bargaining over crop choice, but also bargaining of whether the crop will be marketed or kept for home consumption.

If the woman is growing a crop that she will sell, she also needs to bargain for time and transport to sell the crop. At the institutional level, marketing a crop depends on relationships with buyers (access) and the ability to negotiate a fair price. Crop choice, along with the ability to procure time and transport, build and maintain relationships with sellers and negotiate prices impacts how much crop is sold and the timing of the sale. This has an indirect impact on yields. Farmers who do not have a secure and profitable outlet for their crops, may choose to produce less on these plots. They may use less inputs and dedicate less time to these crops.

Finally, it is important to note that in Northern Ghana there are not well functioning, credit, input, and output markets. But to explore the gender yield gap, we are only concerned with whether they function equally for men and women.

Figure 1: Impact of intrahousehold bargaining and institutions on crop yield



4. Data

We analyze the gender yield gap for smallholder farm households in Ghana's Northern province. We use data from an Innovations for Poverty Action (IPA) field experiment: Disseminating Innovative Resources and Technologies to Smallholders (DIRTS). DIRTS was carried out to examine the impact of improved input supply and community-based extension in combination with access to rainfall index insurance on smallholder farmers' growing practices. The field experiment was carried out over the 2014 to 2016 farming seasons. Endline data was additionally collected in 2017. Participants in the field experiment lived in 162 communities across the nine districts of Ghana's Northern Region. At the end of the intervention, there were 3,178 households in the project, around 20 in each community.

Participants in the 162 communities were randomly assigned to one of four treatment groups, control (50 communities), extension (52 communities), inputs (31 communities) and extension and inputs (29 communities). All field experiment participants were given the opportunity to purchase "acre" units of rainfall insurance. Because of low purchase demand after the first season, the insurance product was simplified and made more uniform before the next season. The insurance paid out after 13 dry days in each farming stage: germination, crop growth, and flowering.

In Northern Ghana, the input markets do not function efficiently. While the government subsidizes fertilizer, the rates are generally not announced until the spring and the fertilizer is often made available late in the season, after the optimal time for application has passed. To determine if access to inputs was a bottleneck to productivity, IPA created an input supply chain, tailored to the needs of the smallholder farmers. Farmers in the treatment communities for inputs were given the opportunity to order inputs from a trained Community Based Marketer (CBM).

The CBM offered 100 different input products including fertilizer, certified seeds, weedicides, pesticides, and protective gear. To market the inputs to the farmers, input retailers visited input treatment communities three times, right after harvest, before planting, and Community Based Marketer two weeks after planting. IPA covered the costs for marketing and transportation of the goods while farmers paid retailers the market price for the goods. In 2016, however, this intervention was discontinued due to limited farmer response.

For the extension treatment, IPA hired, trained, and deployed Community Extension Agents (CEAs) to share videos and messages demonstrating best practices to farmers once a week in treatment communities. At first, extension was just provided for maize, but advice for legumes including groundnuts, soya, and cowpeas were also provided beginning in 2015. The information shared included advice on land clearing, fertilizer use, seed varieties and field maintenance. All male and female farmers in the treatment households participated in the extension meetings.

Comprehensive Annual Surveys (CAS) were carried out after the interventions to collect information on household characteristics, cultivation practices, agricultural investments and yield and farming profits. A Knowledge and Practice Surveys (KPS) was also carried out to collect more in-depth information on farming practices. Finally, a Crop Cut Survey (CCS) was carried out in which enumerators directly measured the yield of a randomly selected subset of DIRST sample plots.

1. Empirical model

1.1. Testing for pareto efficiency

In cooperative bargaining models, the assumption of pareto efficiency implies that differences in output and factor inputs across plots are functions only of the differences in plot characteristics. To test if this assumption holds across male and female plots we estimate a linear fixed effects regression where Y_{htci} is the yield of plot *i*, planted with crop *c*, in year *t*, by a member of household *h*, X_{htci} is a vector of plot characteristics, including land size and land quality, W_{htci} is the individual's gender, λ_{htc} is a household, crop, year, fixed effect, and ϵ_{htci} is the error term.

$$Y_{htci} = \boldsymbol{X_{htci}}\beta + \eta W_{htci} + \lambda_{htc} + \epsilon_{htci} \tag{1}$$

This regression tests whether female and male plots, planted with the same crop, in the same year, in the same household, have the same level of output. Our coefficient of interest is W_{htci}. If it is significantly different from zero, in Udry's interpretation this would imply that resources are not distributed Pareto efficiently within a household.

We also explore differences in inputs through Poisson estimates of plot-level labor and fertilizer use. We estimate a similar model to equation (1) where our dependent variables Y_{htci}, are total labor, own female labor, own male labor, family female labor, family male labor, communal labor, hired labor all in hours/ha and fertilize use (kg/ha). If W_{htci} is significantly different from zero, we observe that inputs are not distributed equally among plots planted to the same crop, in the same year, in the same household.

1.2. Household bargaining drivers

Ghanaian women in smallholder households are usually allocated plots at the time of marriage. At this point they begin to bargain for resources within the household. It is possible that the land that they are allocated is systematically different from the land kept by their husbands. It is possible that plots differ in soil characteristics. Although we control for soil type in our regression, there are other factors including elevation, water source, and soil health that may differ by gender of plot owner. To test whether differences in soil quality of the land farmed by men and women explain some of the yield differential, we add these land quality control variables to our fixed effects estimates and test whether the coefficient on gender is equivalent when the controls are not included.

Women may also be allocated plots farther from their homes, input, or output markets. This would make labor and transport costs more expensive on female plots. To examine whether this difference contributes to the gender yield gap, we estimate *equation 1* for a sample of plots at different distances from the home and market.

1.3. Institutional drivers

It is possible that difference in output and factor inputs across plots are functions of differences in access to institutions in addition to differences in plot characteristics. If women are unable to access inputs or sell outputs at equal prices as their male counterparts, access credit or feel secure in their land tenure, then unequal allocation of resources may be Pareto efficient.

To examine the broader institutional constraints, first we investigate whether access to credit can explain some of the gender/yield gap. We add controls in *equation 1* for male and female access to credit and their interactions with gender. Next, we examine whether gendered differences in land security explain the yield differential by including controls in *equation 1* for where and from whom the plot was obtained and whether and for how long the plot can be left fallow. If women struggle to access credit and feel secure in their land ownership these institutional factors contribute to the gender yield gap, we expect the gap to decrease with the addition of

To study how institutions impact women's access to inputs we make use of our treatment data. In the fertilizer treatment groups, CBMs travelled to each household and offered all the male and female farmers the chance to purchase inputs at the same price with free on farm delivery. Therefore, the treatment eliminates any possible institutional gender discrimination that could occur in input markets. We estimate *equation 1* for households in the control group and households in the fertilizer treatment group. If the coefficient on gender is the same for both groups, there is evidence that there are not institutional barriers to female access to inputs, but instead the barriers are most likely at the household level, with intrahousehold bargaining for inputs.

To test for systemic difference in access to markets we look at whether men and women face different output prices to market their identical commodities. We estimate the fixed effect regression in *equation 2*, where P_{htc} is the price of crop *c*, planted in year *t*, by a member of household *h*, $\boldsymbol{X}_{\boldsymbol{htc}}$ is a vector of market characteristics, including the type of buyer, distance to the buyer and quantity sold , W_{htci} is the individual's gender, λ_{htc} is a household, crop, year, fixed effect, and ϵ_{htci} is the error term.

$$\mathrm{P}_{htc} = \boldsymbol{X}_{\boldsymbol{htc}}\beta + \eta W_{htc} + \lambda_{htc} + \epsilon_{htc} \qquad (2)$$

1 Results

1.1 Descriptive statistics

In Table 1 we present summary statistics of the value of output (Ghanaian cedis (GHS) per hectare) and inputs that men and women use on their plots. Overall, women in Northern Ghana obtain smaller yields than men on smaller plots. Women use less fertilizer on their plots then men. While they obtain smaller yields and use less fertilizer, they actually benefit from more hours of labor, both from family and hired from the market. Women spend 716 hours per year per hectare on their own plots, and only 8 (hours per year/ha) on their husbands' plots. Men dedicate slightly fewer hours to their own plots, 685 (hours per year/ha), but slightly more to their wives' plot, 22 (hours per year/ha). Female family members dedicate more time to women's plots, whereas male family members dedicate more time to men's plots. Women's plots have more community labor hours and more hired labor hours. Women receive more labor on their plots, in part because of the basket of crops they grow is more labor intensive.

Table 1: Mean farm characteristics by gender of cultivator

	Crop output (GHS/ha)	Area (ha)	Fertilizer (kg/ha)	Female labor	Male labor	Family female labor	Male family labor	Communal labor	Hired labor
men	1342.7	1.9	58.4	8.5	685.4	599.8	945.0	49.4	60.8
	3200.8	2.7	122.1	114.1	914.5	957.9	1368.6	152.0	188.6
women	930.8	0.9	22.8	717.0	22.3	875.3	858.8	55.4	106.7
	1391.2	1.0	69.6	827.2	205.2	1061.3	1013.1	171.9	252.8

Note: standard deviations are below the means. Sample size is 41,811.

Table 2 shows the distribution of crops planted by gender and by crop. Men plant most of the cocoyam, cassava, rice, maize, and millet in the region. Men also plant around three-quarters of the tomato and sorghum in the region and slightly more than one half of the soybean and cowpea. Women on the other hand plant slightly more groundnut and pepper and most of the okra. If we look across crops, the four most important male crops are maize, cocoyam, groundnut, and rice while the four most important female crops are groundnut, okra, soybean, and maize. In Appendix Table 13 we present the distribution of crops planted by area by gender and by crop. When we consider area dedicated to each crop, women plant only 15 percent of the area planted in our sample, compared with 28 percent of the crops. For crops planted by area, the patterns are consistent with the distribution by crops planted. The only changes between the proportion of crops men and women plant by area is that men plant 58 percent of the groundnut, 65 percent of the pepper but only 53 percent of the tomato.

Table 2: Distribution of crops planted by gender of the cultivator

	Across genders		Across crops	
	Men	Women	Men	Women
Maize	88.7	11.3	37.1	12.1
Rice	92.4	7.6	9.6	2.0
Soybean	58.3	41.7	8.6	15.7
Sorghum	78.2	21.8	3.2	2.2
Millet	85.3	14.7	6.8	3.0
Cassava	97.5	2.5	3.6	0.2
Cocoyam	98.5	1.5	13.7	0.5
Cowpea	60.8	39.2	1.9	3.2
Groundnut	46.2	53.8	12.0	35.6
Okra	12.2	87.8	1.0	17.9
Pepper	44.6	55.4	2.3	7.3
Tomato	79.6	20.4	0.3	0.2
Total	71.9	28.1	100.0	100.0

1.2 Testing for pareto efficiency

In Table 3 we estimate the difference in yields achieved between male and female farmers in the same household who plant the same crop in the same year. Because female plots may systematically differ from male plots in terms of location, size, and soil type, we include a dummy for whether the plot is located at the compound, plot size deciles, and soil type categories as defined by the farmer. In column 1 of Table 3 we estimate the plot level difference in male and female yields for all crops using crop, household, year fixed effects. We find that there is a large difference between the value of female output per hectare and the value of male output per hectare. Across all crops, women earn on average 232.00 fewer GHS about $40.00 less in 2021 dollars. The mean yield value across all plots is 1,235 GHS. Women therefore have a 19 percent lower yield on average than men. In Appendix Table 14 we present results at the crop level. We find that women earn 50 GHS less per crop on their plots than men. In Appendix Table 15, we present the results for the household heads only. When considering just the principal man and women, the yield gap increases slightly to 246.26 GHS.

In columns 2 through 4 of Table 3 we present crop specific estimates for maize, soybean, and groundnut, the three most widely cultivated crops in the region. The average maize yield value is 856 GHS, the average soybean yield value is 897 GHS, and the average groundnut yield value is 1,165. Females' yields are therefore 12 percent, 21 percent, and 30 percent lower respectively. In column 5 we estimate the same regression for vegetables, with crop fixed effects for okra, pepper, tomato, and lettuce. Women have much lower yields on their vegetable plots than men. More men grow maize and soybean, while more women grow vegetables and groundnut (Table 2). Despite this, vegetables and groundnut are the crops with the larger gender yield gaps.

Table 3: OLS fixed effects estimates of the impact of gender on plot yield

	(1) All crops	(2) Maize only	(3) Soybean only	(4) Groundnut only	(5) Vegetables
Gender: (1 = female)	-232.03***	-101.38***	-145.48***	-344.21***	-1395.06***
	(40.19)	(23.74)	(22.80)	(53.82)	(357.25)
Intercrop (0,1)	559.79***	290.94***	180.40***	243.63***	860.24**
	(35.38)	(17.40)	(44.13)	(53.45)	(276.49)
Plot at compound (0,1)	67.88	39.19	-23.56	61.51	-862.51
Plot size:	(49.89)	(25.57)	(40.63)	(79.91)	(524.70)
1st decile	1133.73***	801.51***	1034.81***	1501.71***	2843.45***
	(87.23)	(43.15)	(91.12)	(208.92)	(713.86)
2nd decile	352.75***	386.72***	280.27***	374.55***	1279.08
	(53.86)	(27.94)	(38.63)	(86.76)	(677.24)
3rd decile	166.57*	189.24***	167.12*	34.68	1172.57
	(81.30)	(41.20)	(68.89)	(135.18)	(815.54)
4th decile	91.81	124.75***	99.95**	100.92	685.27
	(49.79)	(25.13)	(34.66)	(80.87)	(688.76)
6th decile	-78.95	-62.59*	-83.36	-282.09**	883.60
	(60.57)	(29.69)	(45.48)	(101.56)	(1228.57)
7th decile	-201.30**	-103.59**	-47.31	-288.21*	893.15
	(74.09)	(36.74)	(55.78)	(129.79)	(1448.85)
8th decile	-128.25	-166.11***	-124.98*	-236.34	-238.57
	(71.04)	(34.71)	(54.13)	(139.74)	(1437.92)
9th decile	-329.87***	-222.63***	-238.27**	-457.66*	3044.94
	(94.08)	(45.77)	(73.58)	(191.16)	(4797.23)
10th decile	-413.94***	-332.37***	-163.84**	-496.41***	-448.64
Soil type:	(70.78)	(34.87)	(57.20)	(137.89)	(1672.01)
Soil rocky	53.68	46.49*	2.85	-104.66	-187.64
	(39.25)	(19.10)	(28.97)	(64.44)	(327.88)

Soil sandy	-72.54	11.01	36.80	-178.57**	57.63
	(38.92)	(19.17)	(30.13)	(65.12)	(325.81)
Soil silty	42.65	2.55	-45.16	-96.79	92.47
	(56.92)	(29.44)	(46.30)	(111.22)	(478.47)
Soil clay	-40.72	-11.41	-92.73	-56.52	319.61
	(55.96)	(29.55)	(58.32)	(133.92)	(491.62)
Constant	21.167	222.426**	105.588	-102.860	57.820
	[184.568]	[100.317]	[115.040]	[183.269]	[306.154]
Observations	41867	15598	5025	7789	2196
R-squared	0.188	0.402	0.480	0.445	0.552

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. Plot at compound is a binary variable equal to one if the plot is located at the household compound. Intercrop is a binary variable equal to one if the plot is intercropped. The omitted plot decile is the fifth. The omitted soil type is loamy. The regression includes, household, year, main crop fixed effects.

The large gender yield gap observed in Table 3 may be a result of differences in input intensities used across plots. In Table 4 we present Poisson fixed effects estimates of the intensity of labor and fertilizer used across plots. When comparing the same crop, in the same household, in the same year overall more labor is used on male plots compared with female plots (col 1). Different types of labor are used on male and female plots. While women use significantly more labor on their own plots (col 2) their husbands' use significantly less labor on their plots (col 3). Both female and male family members spend less time working on female plots planted to the same crop as male plots in the same household (col 4 and col 5). Interestingly, while slightly more communal labor is used on male plots than on female plots (col 6), more hired labor is used on female plots compared with male plots (col 7). As shown in Table 1, communal and hired labor hours account for only a small percentage of the farm labor in the region. The fact that women are using more hired labor, while men are using more family labor could indicate that women are unable to bargain for family labor for their plots and therefore turn to hired labor. Because of this, any inefficiencies in the labor market may disadvantage women more greatly.

There are significant differences in fertilizer use across female and male plots planted to the same crop, in the same household, in the same year. Holding other variables constant, females compared to males are expected to have a rate of 65 percent less fertilizer use. In Appendix Table 16, we examine the impact of gender on yield value for household where no member applies fertilizer. We have 1,005 households and 2,295 observations who apply no fertilizer in our sample. For these households, our yield gap estimate is no longer significant.

Table 4: Poisson fixed effects estimates of the impact of gender on plot input intensities

	(1) Total labor	(2) Female labor	(3) Male labor	(4) Family female	(5) Male family	(6) Communal labor	(7) Hired labor	(8) Fertilizer (kg/ha)
Gender: (1 = female)	-0.13***	3.90***	-3.54***	-0.05***	-0.23***	-0.12***	0.24***	-0.42***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Intercrop (0,1)	0.15***	0.17***	0.19***	0.17***	0.11***	0.12***	0.20***	0.16***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Plot at compound	-0.01***	-0.10***	0.02***	0.04***	-0.03***	-0.05***	-0.11***	0.00
Plot size:	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
1st decile	1.36***	1.66***	1.51***	1.28***	1.27***	0.97***	1.18***	0.46***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2nd decile	0.79***	0.97***	0.85***	0.75***	0.76***	0.64***	0.73***	0.33***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
3rd decile	0.46***	0.59***	0.53***	0.41***	0.45***	0.36***	0.40***	0.05***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
4th decile	0.30***	0.35***	0.30***	0.30***	0.29***	0.19***	0.29***	0.04***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
6th decile	-0.16***	-0.37***	-0.20***	-0.14***	-0.14***	-0.25***	-0.17***	-0.14***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
7th decile	-0.33***	-0.57***	-0.36***	-0.29***	-0.31***	-0.36***	-0.35***	-0.28***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
8th decile	-0.50***	-0.92***	-0.54***	-0.44***	-0.48***	-0.53***	-0.40***	-0.38***
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
9th decile	-0.70***	-1.30***	-0.73***	-0.66***	-0.65***	-0.73***	-0.65***	-0.49***
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
10th decile	-1.11***	-1.71***	-1.16***	-1.03***	-1.04***	-1.09***	-1.00***	-0.79***
Soil type:	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Soil rocky	0.00***	0.01***	-0.02***	0.02***	0.01***	-0.01*	0.03***	0.14***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Soil sandy	0.01***	0.06***	0.02***	0.01***	0.01***	-0.07***	-0.01***	0.05***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Soil silty	0.00***	0.10***	0.03***	0.02***	-0.04***	0.02***	-0.00	0.04***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Soil clay	0.02***	0.10***	0.03***	-0.00	0.02***	0.03***	0.05***	0.04***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	41811	41811	41811	41811	41811	41811	41811	41815

Note: Dependent variables in col 1 through col 7 are hours of labor per hectare. Plot at compound is a binary variable equal to one if the plot is located at the household compound. Intercrop is a binary variable equal to one if the plot is intercropped. The omitted plot decile is the fifth. The omitted soil type is loamy. The regression includes, household, year, main crop fixed effects.

Household bargaining drivers

In northern Ghana, as shown in Table 8, most land managed by women is allocated to them from their husband at the time of marriage. Women may be allocated systematically worse land than the men in their family. This may depend on her bargaining power and her position within the family. If women farm worse land, then the gender differentials in yields may be consistent with Pareto efficient allocation of factors across plots. Although we control for soil type in our regression, the type of soil does not necessarily depict the quality of the soil. Further, the makeup of the plot impacts the soil's ability to retain water and prevents erosion. In Table 5 we perform a series of tests to determine how plot characteristics impact the gender yield gap. Column (1) of Table 5 shows that when soil characteristics are dropped, the size of the gender yield differential remains nearly the same, which suggests that women have similar plots in terms of underlying soil type. This is logical if men's and women's plots are both located at or near the compound; the underlying soil type will be similar. The quality of that soil, however, depends on farming practice, including fertilizer application, burning, intercropping, as well as the structure of the land and its tendency to erode.

In the 2017 Endline survey more specific questions were asked about soil characteristics and quality. Farmers were asked to comment on the quality of their land, whether it was poor, fair, or good. Farmers were also asked to describe their land in terms of its terrain. Further, farmers were asked whether their land was prone to erosion. In column (2) of Table 5 we estimate the regression for 2017 only with household, crop fixed effects. We find that when we estimate the yield gap for 2017, it is slightly smaller than for the four-year period. In column (3) we estimate the same regression, but with our additional soil controls. We find that the gender yield gap is almost identical to that in Column (2), suggesting that along these additional dimensions, the quality of the female plot is not different from that of the male plot.

Table 5: Yield differentials with soil controls: OLS fixed effects estimates of the impact of gender on plot yield

	(1) No soil controls, whole sample	(2) Basic controls, 2017 only	(3) Additional soil controls, 2017 only
Gender: (1 = female)	-228.42***	-189.37**	-175.83*
	(40.21)	(72.97)	(74.12)
Intercrop (0,1)	557.68***	405.86***	406.24***
	(35.39)	(71.15)	(71.39)
Plot at compound	65.85	-124.76	-118.50
Plot size:	(49.90)	(143.02)	(143.24)
1st decile	1132.11***	279.42	240.84
	(87.20)	(168.63)	(170.35)
2nd decile	351.38***	64.59	41.82
	(53.88)	(103.73)	(104.98)
3rd decile	164.58*	-242.60	-251.03
	(81.29)	(146.65)	(146.76)
4th decile	93.80	-61.14	-68.23
	(49.82)	(95.24)	(95.36)
6th decile	-82.29	-56.01	-56.05
	(60.62)	(119.28)	(119.37)
7th decile	-202.44**	-263.03	-263.41
	(74.14)	(150.60)	(150.66)
8th decile	-130.80	-247.88	-239.39
	(71.09)	(154.19)	(154.36)
9th decile	-346.60***	-538.26*	-528.82*
	(94.10)	(218.89)	(219.32)
10th decile	-414.01***	-701.63***	-689.08***
Soil type:	(71.14)	(177.79)	(178.58)
Soil rocky		102.71	99.18
		(79.34)	(79.79)
Soil sandy		58.56	59.94
		(75.12)	(75.18)
Soil silty		59.01	46.55
		(106.05)	(106.20)
Soil clay		-3.34	-2.21
		(103.02)	(103.34)
Soil fair			-20.54
			(78.00)
Soil poor			-283.47
			(177.49)
Hilly			-78.98
			(230.20)
Flat			-219.58
			(182.85)
Slope			-124.93
			(195.33)
Steep slope			-604.27
			(333.71)
Prone to erosion			-29.42
			(72.70)

No fallow			138.43
			(105.95)
Some fallow			-191.64
			(119.22)
Observations	41775	10129	10127
R-squared	0.188	0.451	0.452

It is also possible that the land allocated to female household members is located in a different place than that kept by or allocated to male household members. Because of differences in location, women may have to travel farther to their plots, or travel farther from input markets or to output markets. This would mean that there may be nonconvexities associated fixed travel costs.

Udry (1996) tests whether the difference in gender plot yield is a result of the assumption that crops are produced with convex technologies. He hypothesizes that nonconvexities may result from fixed travel costs to providing labor on a plot. Since workers travel by foot, the farther the plot from the compound, the greater the travel costs. It therefore may be optimal to set some labor inputs to zero on farther plots, to avoid the transportation costs.

We also test this relationship. In col (1) of Table 6 we estimate the gender yield gap only for a subsample of plots located within 1 mile of the compound. For these households, the gender yield gap remains consistent with that of all the plots. However, when we examine the yield differential for samples of plots at increasingly greater distances from the home, we find that the gender yield differential increases significantly. Since the mean yield value at these distances is 1,200 (GHS), 1,193 (GHS), and 1,344 (GHS) respectively, this trend represents a large increase in the gender yield gap as the plots increase in distance from the home.

Several different hypotheses arise to explain this relationship. First, it is possible that while nonconvexities may result from fixed travel costs to providing labor on plots far from home for women, they do not arise for men. This may be because women face higher opportunity costs of labor. Because women dedicate time to home production, they may have less time to travel to plots far away for farming, making the fixed travel expenses costly for women but not men. To account for the other responsibilities of the female members that the male members do not share, household may choose to allocate factors differently across identical plots. We test this hypothesis by looking at drivers of yields for men and women separately. We find that in the same household, for the same crop, men have significantly higher yields on plots farther from the household while women do not have different yields on farther plots (Appendix Table 18). This does not support our hypothesis of nonconvexities of travel costs from the household. There may, however, still be nonconvexities with fixed travel costs to input markets or output markets. Unfortunately, we did not collect this information in our data so we cannot test this hypothesis.

We can, however, look at the gender yield gap for plots located next to a road and far from a road (col 5 and 6 of Table 6). We see that the gender yield gap is much greater on plots located next to a road than on plots not located next to a road. In Appendix Table 18, we test separately for men and women whether they obtain higher yields next to a road for the same crop in the same household. Both men and women obtain higher yields on plots near a road.

Why do men achieve higher yields on plots farther from home planted to the same crop in the same household while women achieve similar yields across all their plots. It may be that there are still unobservables in soil quality variables that explain this relationship. Male plots located farther away from home could be recently cleared from the forest, whereas women's plots may have similar soil quality to their other plots.

Table 6: Yield differentials on plots close to home: OLS fixed effects estimates of the impact of gender on plot yield

	(1) Within 1 mile	(2) 1 mile to 1.5 miles	(3) 1.5 miles to 2.5 miles	(4) Greaten than 2.5 miles	(5) Next to road	(6) Not next to road
Gender: (1 = female)	-330.51***	-544.89***	-677.35***	-1148.70***	-911.60***	-590.12***
	(66.11)	(60.30)	(79.15)	(174.83)	(134.96)	(44.56)
Observations	12142	11839	9078	7702	9840	21255
R-squared	0.332	0.263	0.261	0.204	0.206	0.196

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. These regressions include all controls included in col (1) table 3. They are omitted here for space. For regressions 10 and 11 we do not have 2017 data.

Institutional drivers

Why are female plots farmed less intensively than male plots? Further does this striking difference in yield and input distribution indicate that households are not Pareto efficient in production? Institutional sexism may prevent women from accessing inputs for production and selling their outputs. Gender discrimination in credit, land, output, and input market may explain differences in yields between men and women.

Purchasing inputs requires cash on hand throughout the growing season. Often farmers turn to friends or family, credit group or collectives, and banks and microfinance institutions to obtain cash to purchase inputs. In Table 7 we attempt to estimate the impact of access to credit on the gender yield gap. We define access to credit as access to any form of borrowing either from a formal institution or informally from friends or family. In any given year there were only 331 households where a female accessed credit, or 1,169 households over the whole sample period. Column (1) of Table 7 includes separate controls for whether a male or female household member accessed credit. Column (2) of Table 8 instead controls for whether the male or female plot owner accessed credit. While none of these additional controls are significant, adding the household level credit variables increases the gender yield gap slightly. In Column

(3) we include a dummy for whether the male plot owner accessed credit and an interaction of that dummy with the gender variable. We set the dummy equal to 0 if the male accessed credit. The coefficient for gender shows the difference in output between males and females when men access credit. Gender is no longer significant in this regression, suggesting that access to credit for any member may help reduce the gender yield gap.

Table 7: Yield differentials on plots with credit: OLS fixed effects estimates

	(1)	(2)	(3)
Gender (1=female)	-239.81***	-229.40***	-221.83
	-40.46	-42.31	-874.43
Credit men	12.35		
	-38.24		
Credit women	-1.84		
	-147.54		
Credit both	-26.71		
	-194.1		
Credit male plot owner		39.98	
		-39.86	
Credit female plot owner		25.6	
		-164.3	
Credit men (0= credit)			-39.91
			-39.91
Credit men * female			-6.82
			-875.61
Observations	41563	41582	41582
R-squared	0.19	0.19	0.19

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. These regressions include all controls included in col (1) table 3. They are omitted here for space.

The differences in yields could also result from differences in the tenure security of the plot. Table 8 shows differences in how the plot was obtained, from whom the plot was obtained, and whether the plot manager can sell the land or leave the land uncultivated by gender. Almost no plots, male or female are purchased or rented. Most women are allocated their plots from their husband or beg for their plots from their husband. Most men inherit their plots from a deceased relative or are allocated a plot by the chief or by themselves by clearing it. Only a small percentage of men and women feel they can sell their plots, or use them as collateral, 16 percent. This indicates that there is a very weak land market in Northern Ghana. Finally, most men and women feel they can keep their land uncultivated, and they will not lose it.

Table 8: Plot characteristics by gender of plot manager

	Male	Female	Overall
Purchase or rented	0.3	0.1	0.2
Begged or borrowed	14.0	20.6	84.1
Husband	9.3	71.5	27.5
Chief	63.1	15.3	49.1
Other relative	3.1	2.4	2.9
Other non-relative	24.6	10.8	20.6
Inherited from deceased	58.9	15.8	15.5
Allocated	26.8	63.5	36.0
Husband	37.5	89.2	58.4
Chief	33.2	2.8	20.9
Other relative	22.2	6.6	15.9
Other non-relative	7.1	1.3	4.7
Can sell land	18%	12%	16%
Can use land as collateral	18%	11%	16%
Can leave land uncultivated	94%	90%	93%

Table 9 provides logit estimates of the determinants of two measures of tenure security, whether the plot manager can sell the land, and whether they feel they can leave the land uncultivated. In column (1) and column (3) we present estimates for plots within the same household and year. In column (2) and column (4) we present estimates for plots planted to the same crop, within the same household and year. Being female decreases the probability of being able to sell a plot by 13 percentage points and 12 percentage points for plots planted to the same crop. Being female also decreases the probability of being able to leave land uncultivated by 9 percentage points and 7 percentage points for the same crop.

Table 9: Logit fixed effect estimates of the determinants of tenure security

	(1) Sell, all crops	(2) Sell, same crop	(3) Leave land, all crops	(4) Leave land, same crop
Gender: (1 = female)	-1.00***	-0.93***	-0.67***	-0.56***
	(0.03)	(0.03)	(0.03)	(0.04)
Margins	-0.14***	-0.13***	-0.08***	-0.07***
	(0.01)	(0.01)	(0.01)	(0.01)
Observations	27689	27689	15458	15449

Note: Dependent variable is a binary variable for whether the plot owner feels they can sell their plot or leave their plot uncultivated. The regressions also include controls for plot characteristics including, location, size, and soil type.

Table 10: Yield differentials on plots with different tenure security: OLS fixed effects estimates

	All crops
Gender: (1 = female)	-262.10***
	(44.62)
Leave land	-74.73
	(62.06)
Sell	228.50***
	(42.58)
Observations	37711
R-squared	0.208

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. These regressions also include all controls included in col (1) table 3. They are omitted here for space. In the next iteration of this paper, I plan to combine all the institutional controls into one model.

To study the impact of institutions on women's access to inputs we compare the input treatment group with the control and other treatment groups. The households in the input treatment group were visited by CBMs who shared with them a catalogue of 100 different inputs including many different types of chemical fertilizers, herbicides, weedicides, and farming gear. The female and male farmers had the opportunity to purchase any of these inputs and the CBM would deliver them to the farm. Because of the farm delivery, the input treatment group eliminates the opportunity cost of time of accessing inputs, as well as any possible gender-based discrimination in accessing input markets. All farmers were given equal opportunity to buy inputs.

In Table 11 we estimate the impact of the input treatment on the gender yield gap. The coefficient gender shows the difference in outputs between men and women for the treatment. For the treated households, the gender yield gap is still very large. Note that female has been coded to 0, and therefore the large positive coefficients indicate that men have larger yields then women in the treatment. But the treatment does decrease the gender yield gap. The coefficient on treatment shows the difference in output between the control and the experiment for female farmers. Female farmers have considerably higher outputs in treated households. The impact differs across crops. Women in the treatment group do not achieve significantly higher maize or vegetable yields but do harvest more soybean and groundnut.

Since yields do improve for females in the treatment group, the treatment does seem to eliminate some impediment to input purchasing for females. It is difficult to say if this is an institutional barrier or a time-use barrier. It is possible that women do not have the time, or access to transportation to purchase inputs. If this is the case, men are not sharing the inputs they purchase with their wives or other female household members. Plot management is separate, and this includes the purchase of all inputs. Access to inputs, therefore, may largely depend on household bargaining.

But there may also be institutional factors such as lack of relationships with input sellers that prevent women from accessing inputs or purchasing them at the same price. We test if women face different prices for inputs and present the results in Appendix Table 17. While we do not find any significant difference in input prices for men and women in the same household, there may still be other institutional factors driving the difference in input use across genders.

Table 11:Yield differentials on plots in the treatment: OLS fixed effects estimates

	(1)	(2)	(3)	(4)	(5)
	All crops	Maize only	Soybean only	Groundnut only	Vegetables
Gender: (0 = female)	375.34***	246.41***	168.75**	483.13***	1771.38**
	(85.84)	(66.48)	(56.35)	(123.70)	(633.47)
Treatment (0 = treatment)	431.99***	126.98	144.13*	397.77**	722.07
	(96.45)	(75.47)	(56.92)	(128.35)	(588.35)
Female *treatment	-197.51*	-121.09	-29.22	-34.22	-421.13
	(88.09)	(73.49)	(59.07)	(130.39)	(643.09)
N	31335	11188	3915	5793	1789
R-sq	0.198	0.477	0.522	0.503	0.627

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. These regressions include all controls included in col (1) table 3. They are omitted here for space. Household in the treatment group include all households in the input treatment groups. The years included are only 2014, 2015 and 2016 or the years of the RCT.

How productively a farmer grows their crops may depend on their ability to access a market to sell their crops. If women and men receive different output prices for the same crop, it may be pareto efficient to distribute inputs unequally. In Table 12 we estimate the impact of gender on output price. In Col (1) of Table 12 we estimate the impact of gender on output price for the same crop, sold from the same household, in the same year. The average retail price for all crops is 133 GHS. Therefore, women receive 11 percent lower for their crops than men farming the same crops in their household. While women do not receive lower, maize, soybean, and vegetable prices, they do receive lower groundnut prices. Groundnut is the crop that is most widely grown by women in our sample, yet they receive a significantly lower price when selling it.

The fact that women receive lower prices for the same crops as the men in their household, suggests that while household may achieve higher output by reallocating inputs from male plots to female plots, they would receive lower profits. Therefore, in the current system, reallocating land from women to men would result in both higher output and higher profit. This would be the Pareto efficient outcome.

Table 12: OLS fixed effects estimates of the impact of gender on output prices

	(1)	(2)	(3)	(4)	(5)
	All crops	Maize only	Soybean only	Groundnut only	Vegetables
Gender: (1 = female)	-15.24***	-5.34	-2.12	-25.96***	-6.41
	-1.64	-2.99	-2.29	-4.31	-10.67
Distance transported	0.46***	-0.19	0.07	1.77**	0.84
	-0.12	-0.23	-0.26	-0.61	-0.82
Community market	-1.39	1.04	6.85	-8.05	-2.33
	-2.51	-4.26	-4.63	-8.19	-12.23
Other community market	-14.08***	1.05	-12.91	-37.60**	11.15
	-3.78	-6.65	-7.57	-13.96	-16.58
Observations	15131	2942	2538	3439	1482
R-squared	0.519	0.699	0.623	0.634	0.758

Note: Dependent variable is the price of the crop in GHS. Distance transported is the number of miles the crop travelled to the market. Community market means the crop was sold by the grower in the community. Other community market means the crop was sold by the grower in another community. The omitted category is crop was sold to a trader or wholesaler.

6. Conclusion

Women in Northern Ghana obtain significantly lower yields than men in the same household when farming the same crop. Women have 19 percent lower yields when farming the same crop as the other men in their household. Although groundnut and vegetables are the most widely grown crops among women, the male/female yield gap is largest for these crops. The yield gap in part results from differences in input use between men and women. While men use more labor on their plots, the difference is small in terms of labor hours per hectare. But women and men use different types of labor. Women use their own labor and that of female family members and hired laborers, while men use their own labor and that of other male family members and community laborers. Women use fertilizer at a rate of 68 percent less than men and are 16 percentage points less likely to use any chemical fertilizer on their plots. While it appears that this distribution of inputs is not Pareto efficient there may be household and institutional factors that make it efficient.

Almost no men and women in Northern Ghana purchase land. Instead, men receive it from deceased family members, are allocated it from the chief, or clear it from the forest. Women are mainly allocated land from their husbands. We investigate if there are systemic differences in the land farmed by women and men in terms of characteristics. While we do not find any evidence of differences in land quality or attributes, there could still be unobservable land characteristics that we cannot control for that may explain part of the gender yield gap.

Institutional sexism can impact a women's ability to achieve the same output as men if it makes it difficult for women to obtain inputs, make investments on their land, or sell their outputs. In our sample women had less access to credit than their husbands. Women who did have access to credit had higher yields and the gender yield gap declined. Women in our sample also did not have the same tenure security as their husbands. Women felt that they would not be able to sell, use as collateral, or leave fallow their plots. This may limit their ability to make investments on their plots, hindering their potential yields. It also seems that women have less access to inputs as men. Further, women received significantly lower prices for selling the same crop, in the same household, to the same type of buyer. This structural discrimination may mean it is Pareto efficient for households to distribute inputs unequally among plots. In fact, in the current environment, it may be more efficient for households to reallocate land from men to women if they want to be more profitable.

This is the first draft of our paper. We would like to continue to investigate the gender yield gap by looking at how the structure of the household, in terms of age, gender, and income composition impacts the gender yield gap. All of these factors impact the households bargaining process and therefore are likely to impact the extent of the yield gap. Perhaps these factors can explain why smallholder households are not or appear not to be behaving Pareto efficiently. Further, they may shed some light on how the household bargaining process works. We would also like to compare yields of women in female headed households with yields of women in male headed households. This could perhaps illuminate the extra burden faced by women, who also have to bargain for resources in addition to navigate institutional discrimination. Further, we would like to test whether men and women have access to the same technology to farm their plots. Technology may not be shared between members, especially when it is rented instead of owned. Finally, we would like to explore gender yield differences for different ethnic groups in the region.

7. References

Bezabih, M., Holden, S., 2006. Tenure Insecurity, Transaction Costs in the Land Lease Market and their Implications for Gendered Productivity Differentials. Working Paper 1–24.

Bourguignon, F., Browning, M., Chiappori, P.A., 2009. Efficient intra-household allocations and distribution factors: Implications and identification. Review of Economic Studies 76, 503–528. https://doi.org/10.1111/j.1467-937X.2008.00525.

Browning, M., and Chiappori, P.A., 1994. Efficient Intrahousehold Allocations: A General Characterization and Empirical Tests. Working Paper no. 94-07. Hamilton, Ont.: McMaster Univ., Dept. Econ.

Chavas, A.J., Petrie, R., Roth, M., American, S., Economics, A., Feb, N., Chavas, J., Petrie, R., Roth, M., 2005. Farm Household Production Efficiency: Evidence from The Gambia Published by: Oxford University Press on behalf of the Agricultural & Applied Economics Association Stable URL: https://www.jstor.org/stable/3697999 REFERENCES Linked references are availab 87, 160–179.

Chiappori, P.-A., 1992. Collective Labor Supply and Welfare. Journal of Political Economy. https://doi.org/10.1086/261825

Chiappori, P.-A., 1988. Rational Household Labor Supply. Econometrica. https://doi.org/10.2307/1911842

Chirwa, E. W. 2005. Adoption of fertilizer and hybrid seeds by smallholder maize farmers in southern Malawi. Development Southern Africa 22 (1): 1–12.

Doss, C. R., 2002. Men’s crops? Women’s crops? The gender patterns of cropping in Ghana. World Development 30, 1987–2000.

Doss, C. R., and M. L. Morris. 2001. How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural Economics 25 (1): 27–39.

FAO, 2013. Synthesis of guiding principles on agriculture programming for nutrition.
Gilbert, R.A., Sakala, W.D., Benson, T.D., 2002. Gender analysis of a nationwide cropping system trial survey in Malawi. African Studies Quarterly 6.
Goldstein, M., Udry, C., 2008. The profits of power: Land rights and agricultural investment in Ghana. Journal of Political Economy. https://doi.org/10.1086/595561
Freeman, A. H., and J. M. Omiti. 2003. Fertilizer use in semi-arid areas of Kenya: Analysis of smallholder farmers' adoption behavior under liberalized markets. Nutrient Cycling in Agroecosystems 66 (1): 23–31.
Horrell, S., Krishnan, P., 2007. Poverty and productivity in female-headed households in Zimbabwe. Journal of Development Studies 43, 1351–1380. https://doi.org/10.1080/00220380701611477
Jagger, P., and J. Pender. 2006. Impacts of programs and organizations on the adoption of sustainable land management technologies in Uganda. In Strategies for sustainable land management in the East African highlands, ed. J. Pender, F. Place, and S. Ehui. Washington, D.C.: International Food Policy Research Institute.
Kilic, T., Palacios-López, A., Goldstein, M., 2015. Caught in a Productivity Trap: A Distributional Perspective on Gender Differences in Malawian Agriculture. World Development 70, 416–463. https://doi.org/10.1016/j.worlddev.2014.06.017
Oseni, G., Corral, P., Goldstein, M., Winters, P., 2015. Explaining gender differentials in agricultural production in Nigeria. Agricultural Economics (United Kingdom) 46, 285–310. https://doi.org/10.1111/agec.12166
Peterman, A., Quisumbing, A., Behrman, J., Nkonya, E., 2011. Understanding the complexities surrounding gender differences in agricultural productivity in Nigeria and Uganda. Journal of Development Studies 47, 1482–1509. https://doi.org/10.1080/00220388.2010.536222
Quisumbing, A.R., 1996. Male-Female Differences in agricultural productvity: methodological issues and empirical evidence. World Development 24, 1579–1595.
Quisumbing, A.R., Payongayong, E., Aidoo, J.B., Otsuka, K., 2001. Women's land rights in the transition to individualized ownership: Implications for tree-resource management in western Ghana. Economic Development and Cultural Change 50, 157–181. https://doi.org/10.1086/340011
Saito, K.A., Mekonnen, H., Spurling, D., 1994. Raising the Productivity of Women Farmers in Sub-Saharan Africa.
Strauss, J., and Thomas, D., 1995. Human Resources: Empirical Modeling of Household and Family Decisions. In Handbook of Development Economics, vol. 3, edited by Jere Behrman and T. N. Srinivasan. New York: North-Holland, 1995.
Tiruneh, A., Tesfaye, T., Mwangi, W., Verkuijl, H., 2001. Gender Differentials in Agricultural Production and Decision-Making Among Smallholders in Ada, Lume, and Gimbichu Woredas of the Central Highlands of Ethiopia., Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).
Thapa, S. 2009. Gender differentials in agricultural productivity: Evidence from Nepalese household data. University of Trento, Department of Economics, Trento, Italy. Electronic paper.
Udry, C., Hoddinott, J., Alderman, H., Haddad, L., 1995. Gender differentials in farm productivity: implications for household efficiency and agricultural policy. Food Policy 20, 407–423. https://doi.org/10.1016/0306-9192(95)00035-D
Udry, C., Journal, T., Oct, N., Udry, C., 2007. Gender, Agricultural Production, and the Theory of the Household 104, 1010–1046.

Appendix

Appendix Table 13: Distribution of crops planted by area and by gender of cultivator

	Average yearly ha		Across crops		Across genders	
	Men	Women	Men	Women	Men	Women
Maize	6,073.7	479.6	92.7	7.3	44.6	19.8
Rice	1,457.4	61.9	95.9	4.1	10.7	2.6
Soybean	1,159.7	545.6	68.0	32.0	8.5	22.5
Sorghum	142.3	26.3	84.4	15.6	1.0	1.1
Millet	355.3	42.5	89.3	10.7	2.6	1.8
Cassava	178.8	8.5	95.5	4.5	1.3	0.4
Cocoyam	2,808.2	29.4	99.0	1.0	20.6	1.2
Cowpea	75.6	37.5	66.9	33.1	0.6	1.5
Groundnut	1,270.7	921.0	58.0	42.0	9.3	38.1
Okra	27.5	204.1	11.9	88.1	0.2	8.4
Pepper	65.1	59.1	52.4	47.6	0.5	2.4
Tomato	4.9	4.3	53.3	46.7	0.0	0.2
Total	13,619.3	2,419.7	84.9	15.1	100.0	100.0

Appendix Table 14: OLS fixed effects estimates of the impact of gender on crop yield

	(1)	(2)	(3)	(4)	(5)
	All crops	Maize only	Soybean only	Groundnut only	Vegetables
Gender: (1 = female)	-50.379***	-27.639***	-35.469***	-51.113***	-122.198***
	[3.540]	[3.644]	[6.125]	[6.250]	[16.366]
Observations	63,204	11,626	6,638	18,747	6,084
R-squared	0.251	0.429	0.406	0.402	0.410

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. These regressions include all controls included in col (1) table 3. They are omitted here for space.

Appendix Table 15: OLS fixed effects estimates of the impact of gender on plot yield household heads

	(1)	(2)	(3)	(4)	(5)
	All crops	Maize only	Soybean only	Groundnut only	Vegetables
Gender: (1 = female)	-246.26***	-107.85***	-147.82***	-369.69***	-1476.08***
	-41.86	-24.21	-23.78	-57.69	-382.5
Observations	40370	15347	4819	7235	2050
R-squared	0.191	0.409	0.481	0.45	0.563

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. These regressions include all controls included in col (1) table 3. They are omitted here for space.

Appendix Table 16: OLS fixed effects estimates of the impact of gender on plot yield for households who use and do not use fertilizer

	(1) No fertilizer	(2) Fertilizer
Gender: (1 = female)	-166.35	-236.86***
	[130.32]	[41.8]
Observations	40370	15347
R-squared	0.191	0.409

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. These regressions include all controls included in col (1) table 3. They are omitted here for space. No fertilizer includes households where no member uses chemical fertilizer. Fertilizer includes households where at least one member uses fertilizer.

Appendix Table 17: OLS fixed effects estimates of the impact of gender on input prices

	chemical fertilizer (kg)
Gender: (1 = female)	0.24
	(0.15)
Observations	14,430
R-squared	0.236

Note: Dependent variable is value in Ghanaian cedis (GHS) of chemical fertilizer in KG. These regressions include all controls included in col (1) table 3. They are omitted here for space.

Appendix Table 18: OLS fixed effects of plot distance on plot yield by gender

	(1) Women	(2) Men
1 mile to 1.5 miles	-14.37	-26.48
	(50.60)	(58.17)
1.5 miles to 2.5 miles	2.41	9.45
	(56.66)	(67.05)
Greaten than 2.5 miles	54.34	195.90**
	(65.66)	(74.26)
Observations	10750	29923
R-squared	0.442	0.229

Note: Dependent variable is value in Ghanaian cedis (GHS) of plot output/hectare. These regressions include all controls included in col (1) table 3, including household, crop, fixed effects. They are omitted here for space. The base category is within one mile from the household.