# Understanding Pareto Inefficient Intrahousehold Allocations

Richard Akresh*
Department of Economics
University of Illinois at Urbana-Champaign

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## Abstract

Udry (1996) uses household survey data and finds that the allocation of resources within households is Pareto inefficient, contradicting the main assumption of most collective models of intrahousehold bargaining. He finds that among plots planted with the same crop in the same year, within a given household, those controlled by women produce lower yields than the men's plots. This paper challenges that finding. Using an alternative nationally representative dataset, I find that only households in regions geographically proximate to those studied by Udry exhibit Pareto inefficient intrahousehold allocations, while the rest of the country reveals no evidence of Pareto inefficiencies. Households in regions experiencing negative rainfall shocks are on average less likely to exhibit Pareto inefficient intrahousehold allocations, and these negative rainfall shocks are correlated with increases in labor resources allocated to the wife's plots, further confirming that in bad years, households try to avoid losses from Pareto inefficiency.

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Contact Information: University of Illinois at Urbana-Champaign, Department of Economics, 504 E. Armory Avenue, Champaign, IL 61820. Email: akresh@uiuc.edu

# 1 Introduction

Extensive evidence against the unitary model of household decision making, which treats the members of a family as if they behave as a single individual, has led economists to consider more general models that emphasize the role of individual actors and allow for intrahousehold bargaining among family members.[1] The most general collective model of the household (Chiappori, 1988; Browning and Chiappori, 1998) argues that, although individuals may bargain over the allocation of household resources, the outcome is assumed to be Pareto efficient. Using data from France (Bourguignon, Browning, Chiappori, and Lechène, 1993), Canada (Browning, Bourguignon, Chiappori, and Lechène, 1994), Taiwan (Thomas and Chen, 1994), Indonesia (Thomas, Contreras, and Frankenberg, 2002), Bangladesh, Ethiopia, South Africa (Quisumbing and Maluccio, 2003), and Ghana (Rangel, 2004), researchers empirically reject the unitary model, but the results remain consistent with Pareto efficiency.

However, an influential paper by Udry (1996) using plot-level agricultural data from households in Burkina Faso finds that the allocation of resources within these African households is Pareto inefficient.[2] Udry estimates household-year-crop fixed effects regressions and finds that within a given household, among plots planted with the same crop in the same

[1] Seminal theoretical papers by Manser and Brown (1980), McElroy and Horney (1981), and Lundberg and Pollak (1993) develop cooperative bargaining models. Influential empirical papers by Schultz (1990), Thomas (1990), and Lundberg, Pollak, and Wales (1997) reject the unitary model. For a more recent review of the intrahousehold bargaining literature see Strauss and Thomas (1995), Behrman (1997), Haddad, Hoddinott, and Alderman (1997), and Strauss, Mwabu, and Beegle (2000).

[2] Anthropologists have also argued that in the African context, there is a broad division between the economic spheres of men and women and that husbands and wives separately control their productive resources, have different constraints on their choices, have different responsibilities to satisfy with their personal incomes, and have different prospects for risk diversification (Hill, 1975; Guyer, 1986). Previous research by an economist using data from Cameroon (Jones, 1986) showed that husbands and wives were not being efficient in terms of production decisions. A more recent paper using data from Côte d'Ivoire (Duflo and Udry, 2004) also finds evidence of Pareto inefficiencies in intrahousehold allocations. All of the evidence of Pareto inefficient intrahousehold allocations is based on African surveys with the exception of Djebbari (2005) who finds similar results using Mexican PROGRESA data.

year, those plots controlled by women produce lower yields than the men's plots. This evidence implies that productive resources (labor, land, or fertilizer) reallocated from husband to wife within a household would yield a larger output for both members of the family.

This paper extends Udry's analysis by examining why households might choose to behave in a Pareto inefficient manner and further testing the robustness of his original results. The data Udry uses were collected by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and are from 150 households in six villages in three Burkina Faso provinces. I compare the ICRISAT data with a different nationally representative household survey that was collected by the World Bank's Technical Department for Africa in conjunction with the Burkina Faso National Directorate for Studies and Planning (DEP is the French acronym used throughout the paper). This nationally representative survey interviewed 2406 households in 401 villages in all thirty Burkina Faso provinces. Results examining intrahousehold Pareto inefficiency using the DEP data vary depending on which provinces are used for the fixed effects regressions. Using the DEP data, when the regressions include only those provinces located geographically close to the three ICRISAT provinces, there is a significant, negative effect on yields for women, confirming Udry's findings. However, when the fixed effects regressions are estimated using the other Burkina Faso provinces (those not located near the three ICRISAT provinces), the results indicate no evidence of Pareto inefficient intrahousehold allocations. This within country heterogeneity, in terms of which regions exhibit Pareto inefficiencies, highlights the fact that generalizing conclusions based on data from only six villages should be made with caution.

I then examine why certain regions exhibit Pareto inefficiencies in a given year. Udry argues that the Pareto inefficient results are due to women having less access to household fertilizer and labor resources (male, child, and non-household labor). While it is feasible there could be a Pareto efficient allocation of husband and wife resources that yields a larger output for both individuals, in practice there might be costs involved in achieving this improvement. These costs might include monitoring labor inputs over geographically dispersed plots, transaction costs and asymmetric information involved in trading labor and resources between household members, and social norms that discourage such exchanges. If these costs are greater than the loss due to the Pareto inefficiency, husbands and wives will not change their behavior. However, in periods when there are negative rainfall shocks, households might have larger incentives to overcome these transaction and monitoring costs or ignore the social norms because the consequences of inefficiency are greater. I present evidence that households in regions experiencing negative rainfall shocks are on average less likely to exhibit Pareto inefficiencies, while households in regions experiencing better than average rainfall are more likely to observe social norms and exhibit Pareto inefficient intrahousehold behavior. Additional evidence shows that negative rainfall shocks are correlated with increases in labor resources allocated to the wife's plots in the household, further confirming that, in bad years, households try to avoid the losses due to Pareto inefficiency.

The remainder of the paper is organized as follows. In Section 2, I describe the ICRISAT and DEP data and the empirical setting in Burkina Faso. Section 3 describes the empirical identification strategy Udry uses and the relevant test of Pareto efficiency, followed by an extension of that test to examine the role of rainfall shocks in intrahousehold resource allocation. Section 4 presents the empirical results and Section 5 concludes.

# 2 Data and Empirical Setting

Farm production in Burkina Faso is primarily at the subsistence level and is based on rain-fed agriculture in which each household cultivates multiple plots growing different crops (for a more detailed description of the farming system refer to Udry (1996) or Matlon (1988)). As Udry also explains in detail (and is described by anthropologists who work in sub-Saharan Africa (Guyer, 1986; Berry, 1993; Saul, 1993)), an individual within a household has substantial control over which crops are planted on his or her plot, the timing of sowing, weeding, and harvesting, the quantity of inputs used on the plot, and the rights to the output from that plot. This individual control over inputs and outputs often leads husbands and wives to plant the same crop in the same year on different plots.

## 2.1 ICRISAT Data

There are several differences between the ICRISAT and DEP datasets which may confound comparisons. ICRISAT collected the data between 1981 and 1985 in three provinces of Burkina Faso (Udry only uses the 1981 to 1983 data because those are the years that contain detailed plot-level agricultural information). The survey period comprises both good and poor harvests, with 1984 and 1985 being particularly bad drought years (Reardon, Delgado, and Matlon, 1992; Reardon, Kelly, Crawford, Jayne, Savadogo, Clay, 1996).

In 1980, prior to the survey, ICRISAT conducted qualitative interviews with small groups of farmers in 30 villages in western Burkina Faso (between Dori and Bobo-Dioulasso) to determine which provinces and villages should be selected. ICRISAT combined the data from these qualitative interviews with secondary data to select provinces that met their program objectives, and the three provinces were chosen to be representative of the different agroecological zones of Burkina Faso (Matlon, 1988).[3] Within each province, ICRISAT used a number of criteria to select one village situated on a main road and one more remotely located village. Villages had to be cooperative during the initial 1980 qualitative survey, accessible year-round, not have unusual soils or crops, not have been involved in a major development project, have the modal soil type for villages in that study zone, and have the modal village population for that study zone. In addition, ICRISAT tried to select at least one village in each province which satisfied all of the above criteria and also had a significant fraction of farmers using animal traction (Matlon, 1988). Within each selected village, households were stratified based on animal traction use and then randomly selected. Approximately every ten days, survey enumerators living in the six villages collected information on farm operations, inputs, and outputs on each of the households' plots. Summary statistics for the variables in this dataset can be found in Udry (1996), Table 1.

## 2.2 DEP Data

DEP collected the data during the 1990-1991 crop season in order to examine the implementation of a training and visit-based agricultural extension program. DEP selected a random, nationally representative sample of 2,406 households from all 30 provinces of Burkina Faso,

[3]The northern province, Soum, represents the agroclimatic zone of the Sahel. This region is characterized by low rainfall and sandy soils. Because of the land's low productivity potential and because large parts of the Sahel are suitable only for livestock grazing, there are significant population pressures on the remaining arable land. The central province, Passore, represents the Sudan-Savanna climatic zone. Rainfall is higher than in the Sahel but still low. Soils have a low natural fertility, but production yields tend to be higher than in the Sahel. This region is also more densely populated than the northern province. The southern province, Mouhan, represents the northern Guinea-Savanna climatic zone. It has relatively high annual rainfall, good agricultural potential with soils of intermediate depth and fertility, and low population pressures.

covering different agroclimatic zones. The sampling of households was carried out in two steps. First, villages were randomly selected from each province with the probability of selection proportional to the size of the village. Second, in each of the 401 villages, six households were randomly chosen and interviewed (Bindlish, Evenson, and Gbetibouo, 1993). To minimize potential bias, the Burkina Faso extension agency involved in providing training and visit-based extension did not participate in the sample or questionnaire design phases and did not collect the data (Bindlish, Evenson, and Gbetibouo, 1993). Summarizing the differences between the datasets, the DEP data are nationally representative and have a larger sample of interviewed households, but there is less detailed information about production inputs and less plot-level information about soil quality and plot topography that is one of the strengths of the ICRISAT data.

There are also significant differences in the DEP data between those provinces located proximate to the ICRISAT provinces (I will label these provinces near-ICRISAT) and those provinces in the rest of the country.[4] The near-ICRISAT provinces contain households with larger average plot sizes, greater wealth, and a higher percentage of households in areas with rainfall above the long-run province average. Panel A of Table 1 shows that average plot size is 0.71 hectares in the near-ICRISAT region but only 0.64 hectares in the rest of the country, a difference that is significant at the 1 percent level. Total household land holdings, a measure of wealth, are significantly higher in the near-ICRISAT region (6.00 versus 5.11 hectares) and the result is significant at the 1 percent level. Using the ICRISAT data, total

[4] The near-ICRISAT provinces include the three provinces surveyed by ICRISAT (Soum, Passore, and Mouhoun) as well as Bam and Oudalan in the northern zone, Kadiogo, Kossi, Oubritenga, and Sourou in the central zone, and Bougouriba and Komoe in the southern zone.

landholdings are 6.39 hectares. In addition, with the DEP data in the near-ICRISAT region, 24.97 percent of plots experienced rainfall above the long-run average for that province but only 7.11 percent of plots in the rest of the country experienced a positive rainfall shock. This difference is significant at the 1 percent level. With the ICRISAT data, 54.99 percent of plots experienced a positive rainfall shock.

There are also important differences in the type of crops that are grown in the near-ICRISAT region compared with the rest of Burkina Faso. Panel B of Table 1 shows that this region has a higher percentage of plots planted with cash crops (cotton) or crops that require large inputs of fertilizer (maize) or labor (rice, fonio, and earthpeas) and subsequently fewer plots planted with millet, sorghum or groundnuts. These differences are all significant at the 1 percent level (with the exception of millet which shows no difference between regions). The ICRISAT data show a similar pattern to the near-ICRISAT region in the DEP data, with an even larger percentage of plots planted to cotton and rice and fewer plots planted to millet, sorghum, or groundnuts.

# 3 Household Model and Empirical Strategy

Udry (1996) develops a theoretical model of household behavior to derive a test for Pareto efficiency in the allocation of productive resources within the household. He argues that if the household allocates the factors of production efficiently, then within a given household, in the same year, plots planted to the same crop should have similar yields regardless of whether the plot is controlled by the husband or wife. He estimates the following household-year-crop fixed effects regression to test whether the gender of the individual who controls the plot influences plot yields:

$$Q_{htci} = X_{htci}\beta + \gamma G_{htci} + \lambda_{htc} + \varepsilon_{htci} \tag{1}$$

where $Q_{htci}$ is the yield on plot $i$ planted with crop $c$ at time $t$ by a member of household $h$, $X_{htci}$ is a vector of characteristics for the plot (which includes the plot area), $G_{htci}$ is the gender of the individual who controls the plot, $\lambda_{htc}$ is a household-year-crop fixed effect, and $\varepsilon_{htci}$ is an error term that captures any unobserved plot quality variation and plot-specific production shocks on yields. Based on Udry's model, the exclusion restriction that the gender of the individual controlling the plot should not have any impact on plot output, yields a test of whether $\gamma = 0$.

To examine how rainfall shocks influence the intrahousehold allocation of resources, I modify the household-year-crop fixed effects regressions to include an interaction of rainfall shocks with the gender of who controls the plot, as follows:

$$Q_{htci} = X_{htci}\beta + \gamma_1 G_{htci} + \gamma_2 (G_{htci} * \mathit{Rain\ Shock}_{ht}) + \lambda_{htc} + \psi_{htci} \tag{2}$$

where $Q_{htci}$, $X_{htci}$, $G_{htci}$, and $\lambda_{htc}$ are as previously defined, $\mathit{Rain\ Shock}_{ht}$ is an indicator for whether household $h$ experiences rainfall at time $t$ above the long-run average for the province, and $\psi_{htci}$ is a random, idiosyncratic error term.[5] In the empirical section, I employ several alternative measures of rainfall shocks including looking at extreme variations in rainfall (in which rainfall is more than 0.5 standard deviations above or below the long-run

[5] In Equation 2, I do not include the $\mathit{Rain\ Shock}_{ht}$ main effect because it will be absorbed by the fixed effects.

province average of rainfall) because these extremes are both more observable to household members and might have larger costs associated with them.

# 4 Empirical Results

## 4.1 Baseline Household-Year-Crop Fixed Effects Regressions

In Table 2a, I estimate the household-year-crop fixed effects regression from Equation 1 to examine the impact on yields due to the gender of the person who controls the plot. In Column 1, I use the ICRISAT data to replicate the results from Udry (1996) Table 7, Column 2. I find that within a household if a women manages a plot, yields are 28.5 percent lower than if a man manages a plot planted with the same crop in the same year. The gender results hold even after controlling for observable characteristics of the plot, such as plot size.[6] The results show a strong pattern in which smaller plots are farmed more intensively and have higher yields than larger plot sizes. In the ICRISAT data, there are additional observable plot characteristics, such as soil type, topography, and distance from the compound, and Udry shows that the gender results are unchanged even after including those variables (Table 7, column 3). Since the DEP data do not contain these additional characteristics, I restrict the ICRISAT regressions to only control for plot size.

In columns 2 and 3 of Table 2a, I estimate the fixed effects regressions using the DEP data restricted to the near-ICRISAT provinces (column 2) and all other provinces in Burkina Faso (column 3).[7] When the data are restricted to the near-ICRISAT provinces, there is a large

[6] Following Udry (1996), for the ICRISAT data, I omit the 5th decile of plot size and with the DEP data, I omit the plot size category Size 4.

[7] Since the DEP data are only from one agricultural season, I cannot include year fixed effects, so the

negative impact of gender on plot yields with women having 50.0 percent lower yields than men in the same household planting the same crop, and the gender results are significant at the 5 percent level. However, in the other provinces of Burkina Faso, there is not a negative relationship between the gender of the plot manager and yields. In fact, having a female plot manager leads to 32.5 percent higher yields for plots planted with the same crop in the same household and this result is significant at the 10 percent level. The DEP data show similar results regarding plot size, with smaller plots having larger yields, although the coefficients for the larger plot size variables are imprecisely measured.[8]

In Table 2b, I estimate the same household-year-crop fixed effects regressions as above, but I restrict the data to only include plots planted with millet or sorghum. Results in column 1 using the ICRISAT data show there is still a negative impact of gender on plot yields with women having 19.7 percent lower yields on plots planted with these staple crops but the impact is reduced compared with the regression using all crops. Using the DEP data restricted to the near-ICRISAT region shows women have 41.1 percent lower yields compared to men in the same household planting staple crops and the result is significant at the 10 percent level. This impact is also reduced compared to the regression using all crops that showed a 50.0 percent reduction in yields for women. In the other provinces of Burkina

estimated regressions are household-crop fixed effects regressions.

[8]In the DEP data, plot size is coded in 0.1 hectare increments and 27.1 percent of all plots are coded as 0.1 hectares. Due to this, I code the first three deciles of plot size into one plot size variable called Size 1. The other plot size variables (Size 2 to Size 8) roughly correspond to the fourth to tenth deciles as shown in the table, although there is some rounding due to plot size not being continuous. Size 2 is for plots that are 0.2 hectares and contains 15.6 percent of all plots. Size 3 is for 0.3 hectare plots and contains 10.0 percent of all plots. Size 4 is for plots that are 0.4 and 0.5 hectares and contains 12.8 percent of plots while Size 5 is for plots 0.6 and 0.7 hectares and represents 8.0 percent of all plots. Size 6 is for plots between 0.8 and 1.1 hectares inclusive and represents 9.7 percent of all plots. Size 7 is for plots between 1.2 and 2.1 hectares and contains 10.7 percent of all plots, while Size 8 is for plots larger than 2.2 hectares and contains 6.1 percent of all plots. Results are robust to alternative plot size category codings.

Faso, similar to the fixed effects regression with all crops, gender has a positive impact on plot yields with women having 45.1 percent higher yields than men from the same household planting staple crops.[9] The results indicate that Udry's finding of Pareto inefficiency within the household can be replicated using the DEP data, but only when the data are restricted to the same geographical location as the ICRISAT provinces. Extending the analysis to the rest of Burkina Faso shows that the Pareto inefficient results are not robust.

## 4.2 Impact of Rainfall Shocks

Having analyzed the regional heterogeneity of which households exhibit Pareto inefficient outcomes, I explore possible explanations for this variation and find that in regions experiencing negative rainfall shocks the amount of Pareto inefficiency is reduced. In Table 3, I present household-year-crop fixed effects regressions that estimate Equation 2 and include two alternative measures of rainfall shocks interacted with the gender of the plot manager to determine if Pareto inefficient outcomes are correlated with rainfall shocks. The first measure is a dummy variable taking the value one if the household is located in a province that experienced rainfall greater than the long-run province average.[10] The second measure

[9] The ICRISAT data contain price information in the six surveyed villages so I can calculate the value of plot output per hectare for each crop harvested and use this as the dependent variable in the regressions. However, the DEP data do not contain localized price information and so the regressions are estimated using plot output per hectare as the dependent variable. For the fixed effects regressions focusing on a specific crop, including price information would not change the results. For the regressions combining all crops, I re-estimated the regressions using Burkina Faso Ministry of Agriculture and Animal Resources data on national crop prices for 1991 and the results do not change (see International Monetary Fund (1998) for data on the principal crop producer prices).

[10] For the ICRISAT data, the long-run province average is calculated using the 1981 to 1983 province level rainfall measured in the six ICRISAT villages. With this data, 54.99 percent of household plots are in regions that experienced rainfall greater than the long-run province average. For the DEP data, the long-run province average is calculated using the Burkina Faso National Meteorological Service (Direction de la Meteorologie Nationale) annual 1977 to 1990 rainfall amounts from weather stations in each province. With the DEP data, only 13.75 percent of household plots are in regions that experienced rainfall greater

tries to capture extreme positive and negative rainfall variations and examines provinces that either had rainfall more than one-half standard deviation below the long-run province average or more than one-half standard deviation above the long-run province average.[11] Appendix Tables 1 and 2 provide robustness checks to test if the results vary with cut-off levels other than one-half standard deviation above or below the long-run province average.

In column 1 of Table 3, using the ICRISAT data, I find that if households experienced a positive rainfall shock, women's yields, on plots planted with the same crop in the same year within the same household, are 24.3 percent lower than men's yields. The result is significant at the 1 percent level. The net impact of gender on yields in areas with positive rainfall shocks is 39.9 percent lower yields for women, compared with only 15.6 percent lower yields in areas that experienced negative rainfall shocks. Column 2 presents results using the second shock measure which incorporates extreme variations in rainfall. Individual and household behavior might be more responsive to large rainfall variations that are more easily observed. Compared to regions that had average rainfall, if a household experiences rainfall greater than one-half standard deviation above the long-run province average, women had 31.7 percent lower yields than men and the coefficient is significant at the 10 percent level. In those regions that experienced negative rainfall shocks (rainfall greater than one-half standard deviation below the long-run province average), women's yields were 3.2 percent higher but the coefficient is not significantly different from zero.

than the long-run province average.

[11] For the ICRISAT data, the extreme rainfall measure shows that 28.70 percent of household plots had rainfall more than one-half standard deviation below the long-run province average, and 27.67 percent of household plots had rainfall more than one-half standard deviation above the long-run province average. For the DEP data, this measure shows that 58.11 percent of household plots had rainfall levels more than one-half standard deviation below the long-run province average, while only 6.68 percent of household plots had rainfall more than one-half standard deviation above the long-run province average.

Using the DEP data, in column 3, in areas with a positive rainfall shock, women's yields are 34.6 percent lower than men's yields although the coefficient is not precisely measured. The net impact of gender on yields in those areas with negative rainfall shocks is positive but not significantly different from zero. However, using the measure of extreme rainfall shocks shows that women's yields are 208.6 percent lower than men's in areas that experience a large positive rainfall shock and the coefficient is significant at the 10 percent level. In addition, in areas experiencing negative rainfall shocks, the net impact of gender on crop yields is only 3.6 percent lower yields for women, which is not significantly different from zero. Overall, these results indicate that in areas experiencing negative rainfall shocks in which the cost of being inefficient is larger, the impact of gender on yields is greatly reduced. This contrasts with positive rainfall shock areas in which households are more likely to be Pareto inefficient and women's yields are significantly lower than men's yields for the same crop planted in the same household in the same year.

To test the robustness of these results, I use different cut-off levels in measuring rainfall shocks (alternative standard deviations above or below long-run average rainfall) to see if the observed link between Pareto inefficiency and shocks varies. Appendix Table 1 presents results using ICRISAT data and in columns 1 and 2, I define alternative specifications of rainfall shocks as, respectively, more than 1.5 or 1 standard deviation below the long-run province average.[12] The results are unchanged from Table 3. Column 3 presents regressions

[12] Rainfall shock specifications focusing on rainfall levels greater than one standard deviation above the long-run province average are not possible with the DEP data because the largest positive rainfall shock is 0.61 standard deviations above the long-run province average. However, in the ICRISAT data, there are households experiencing rainfall shocks as high as 1.39 standard deviations above the long-run province average. Regression results with the ICRISAT data are similar using a rainfall shock measure looking at rainfall shocks one standard deviation below or above the long-run province average.

using a rainfall shock measure that captures finer gradations of rainfall variation, including large negative rainfall shocks (rainfall greater than one-half standard deviation below the long-run province average), moderate negative rainfall shocks (rainfall less than one-half standard deviation below the long-run province average), moderate positive rainfall shocks (rainfall less than one-half standard deviation above the long-run province average), and large positive rainfall shocks (rainfall greater than one-half standard deviation above the long-run province average). The results are qualitatively similar with women experiencing a large negative impact in regions with large positive rainfall shocks, although only the coefficient for the largest positive rainfall shock is precisely measured. Finally, in column 4, I interact the plot manager's gender with total rainfall in that province and find that for each additional millimeter of rainfall, plot yields decrease by an insignificant 0.065 percent. This indicates that the impact of rainfall and gender on yields is not a linear function of rainfall amounts, but rather depends on extreme variations above or below the province long-run average. Appendix Table 2 presents similar robustness checks with alternative rainfall shock specifications using the DEP data, and the results are consistent with those in Table 3.

## 4.3 Impact of Rainfall Shocks By Crop

To further examine the link between rainfall shocks and Pareto inefficiency, in Table 4, I estimate household-year-crop fixed effects regressions comparing the staple crops, millet and sorghum, with the cash and labor intensive crops, cotton, rice, and fonio. The results indicate that rainfall shocks and gender have a significantly different impact on yields for the two types of crops. With the ICRISAT data, in areas experiencing rainfall above the long-run province average, women's yields are 15.1 percent lower than men's yields for staple crops but are 143.6 percent lower for cotton, rice, and fonio. The same pattern is seen in the DEP data for areas with positive rainfall shocks. Women's yields on staple crops are 16.7 percent higher than men's yields (although the coefficient is not significantly different from zero), but for cotton, rice, and fonio, women's yields are 634.8 percent lower than men's yields.

Appendix Table 3 presents results for the fixed effects regressions broken down by crop using the alternative rainfall shock specification (large positive and negative rainfall shocks). Results are consistent with Table 4, but some of the coefficients are no longer statistically significant when using this alternative rainfall shock. With the ICRISAT data, in areas experiencing large positive rainfall shocks, women's yields on cotton, rice, and fonio are 233 percent lower than men's yields, while for staple crops, women's yields are only 7.9 percent lower. With the DEP data, for households facing large positive rainfall shocks, the net impact of gender on yields for staple crops is 133.1 percent lower for women than men, but for the cash and labor intensive crops, yields are 321.2 percent lower for women.

## 4.4 Impact of Rainfall Shocks by Wealth Levels

In Table 5, I analyze the role wealth plays in the intrahousehold allocation of resources and the link between wealth and rainfall shocks. Columns 1 and 4 present baseline specifications interacting a measure of household wealth (whether the household owns above or below the median amount of land) with the plot manager's gender.[13] Household wealth does not explain

[13] Alternative measures of wealth, including livestock holdings, use of animal traction, or the number of non-family members employed on the farm are used and results are robust. Results are also robust to using mean landholdings instead of median levels.

plot yields as evidenced by a statistically insignificant coefficient on the variable for gender interacted with a dummy for households with below the median amount of landholdings.

However, when the sample is split into rich and poor households (based on household landholdings) and the plot manager's gender is interacted with rainfall shocks, I find a differential impact of rainfall shocks depending on the household's wealth. For rich households (those with landholdings above the median level), the net impact of gender on yields is significantly more negative in areas experiencing positive rainfall shocks. Using the ICRISAT data, females in rich households with a positive rainfall shock have 75.6 percent lower yields than men in those same households planting the same crop in the same year, but females in rich households with a negative rainfall shock only have 27.7 percent lower yields than men. However, females in poor households facing a positive rainfall shock have 22.0 percent lower yields than men, while females in poor households with a negative rainfall shock only have 9.7 percent lower yields. The results using the DEP data are even more stark. Females in rich households with positive rainfall shocks have 191.3 percent lower yields than men in those same households, while females in rich households with negative rainfall shocks harvest only 7.2 percent less than men. For females in poor households experiencing a positive rainfall shock, yields are 130.3 percent lower than men's yields, while females in poor households facing a negative rainfall shock have 2.6 percent higher yields than men.

### 4.5 Impact of Rainfall Shocks On Productive Inputs

Having analyzed the impact of rainfall shocks on Pareto inefficient outcomes within the household, in Table 6, I use the ICRISAT data to estimate household-year-crop fixed effects

Tobit regressions to consider the mechanisms a household uses to adjust its behavior in response to rainfall shocks, particularly focusing on adjustments to labor and fertilizer inputs (male labor, female labor, child labor, non-family labor, and fertilizer).[14] I estimate baseline specifications controlling for the plot manager's gender, and results indicate plots managed by women have 632 hours less male labor, 248 hours less child labor, 356 hours less non-family labor, and 15,070 kilograms less manure. The male labor result is significant at the 1 percent level and the child labor and fertilizer results are significant at the 5 percent level, but the non-family labor result is not significant at standard levels. However, in households that face negative rainfall shocks, plots managed by women garner an extra 135 hours of male labor, an amount which significantly differs from zero at the 10 percent level. Women in these households also receive an additional 115 hours of non-family labor, 27 hours of child labor, and 6050 kilograms of manure, although the coefficients are not statistically significant at standard levels. In addition, in households facing negative rainfall shocks, women work 239 fewer hours on their plots, presumably switching labor to other tasks that are more productive such as home production or marketing.[15]

# 5 Conclusion

Given the significant finding of Pareto inefficiency in intrahousehold allocations in the paper by Udry (1996), the results of this paper are surprising. Using the nationally representative

[14] I estimate the fixed effects Tobit regressions using Honoré's (1992) fixed effects Tobit estimator. I use the Broyden-Fletcher-Goldfarb-Shanno optimization method, but similar results are obtained using the Polak-Ribiere Conjugate Gradient Method, the Simplex Method, or Powell's Method.

[15] Unfortunately, the DEP data do not contain information about productive inputs, so I cannot replicate this analysis using that data.

Burkina Faso National Directorate for Studies and Planning (DEP) data, I find that regions which are geographically close to the ICRISAT provinces exhibit the same Pareto inefficient allocations that Udry found with the ICRISAT data. However, no evidence of inefficiency is found in the other provinces of Burkina Faso. Results indicate that this regional heterogeneity is correlated with rainfall shocks. Households in regions experiencing negative rainfall shocks are less likely to have inefficient intrahousehold allocations, possibly because the cost of being inefficient is greater in the face of a negative rainfall shock. Households facing a negative rainfall shock are also more likely to allocate additional labor resources to the wife's plots in the household, further verifying that, in bad years, they try to avoid the losses due to being inefficient.

These results portray a story of how households are efficiently responding to changes in relative productivity shocks. In areas that experience positive rainfall shocks, male labor and resources are shifted to crops that men predominantly control (cotton, rice, and fonio) and for which prices are determined at a national or international level. However, for women who are growing predominantly staple crops for which the price is determined locally (millet and sorghum), there are fewer benefits of a positive rainfall shock, and it is likely these women shift their time to other home production or trading activities. There is also evidence that in bad rainfall years, husbands shift resources to growing staple crops to ensure household consumption. Once the role of rainfall shocks is accounted for, it is no longer clear that households are behaving in a Pareto inefficient manner.

The results also indicate that Pareto efficiency is not an exogenous outcome, but rather that it might be caused by the household's behavioral decisions and is therefore an endogenous decision. Understanding the implications of that decision merits additional future research, both to measure whether similar patterns are found in other countries and to measure the impact of the decision on labor supply, health, and human capital investment outcomes. However, the data requirements to test the hypothesis that rainfall shocks are correlated with the decision of a household to be efficient or inefficient are quite high. The data must include plot-level information, including yields, and who managed the plot. In addition, there must be enough geographical variation in the data (several regions or an entire country) to have differential rainfall shocks across regions or there must be variation over time. Few datasets satisfy these requirements suggesting that additional data collection may be necessary to adequately test these hypotheses of whether or not households are behaving efficiently.

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Table 1: Summary Statistics Comparing ICRISAT and DEP Data

| | ICRISAT Data | DEP Data | | |
|---|---|---|---|---|
| | (1) | Near-ICRISAT Provinces (2) | All Other Provinces in Burkina Faso (3) | Difference (3) – (2) |
| Panel A: | | | | |
| Average Plot Size (hectares) | 0.51 | 0.71 | 0.64 | -0.07*** [0.018] |
| Wealth Measure: | | | | |
| Total HH land holdings (hectares) | 6.39 | 6.00 | 5.11 | -0.89*** [0.083] |
| Percentage of plots in which Rainfall > Long-run Province Average | 54.99 | 24.97 | 7.11 | -17.86*** [0.63] |
| Panel B: | | | | |
| Percentage of plots planted to a given crop [column percent] | | | | |
| Millet | 17.64 | 26.00 | 25.60 | -0.40 [0.83] |
| Sorghum | 29.52 | 28.56 | 35.77 | 7.21*** [0.89] |
| Maize | 13.02 | 15.78 | 11.93 | -3.85*** [0.64] |
| Rice | 3.39 | 2.14 | 1.29 | -0.85*** [0.24] |
| Fonio/ Earthpeas | 10.59 | 10.86 | 6.59 | -4.27*** [0.52] |
| Cotton | 7.37 | 4.40 | 2.42 | -1.98*** [0.33] |
| Groundnut | 8.85 | 12.26 | 16.39 | 4.13*** [0.67] |
| Others | 9.62 | | | |
| Observations | 4655 | 4430 | 7492 | |

Note: Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. ICRISAT data are from 3 provinces in Burkina Faso. DEP data are from all 30 provinces in Burkina Faso. Column 2 uses DEP data and is restricted to 11 provinces (including the 3 ICRISAT provinces) that are geographically proximate to the 3 ICRISAT provinces. Column 3 uses DEP data restricted to the other 19 provinces of Burkina Faso.

Table 2a: Household-Year-Crop Fixed Effects Regressions of the Determinants of Plot Yield (All Crops)

| | ICRISAT Data | DEP Data | |
|---|---|---|---|
| | | Near-ICRISAT Provinces | All Other Provinces in Burkina Faso |
| | (1) | (2) | (3) |
| Female | -28.535*** | -50.040** | 32.459* |
| | [6.575] | [21.933] | [17.188] |
| Plot Size: | | | |
| 1st decile/Size 1 | 133.305*** | 179.432*** | 95.168*** |
| | [41.122] | [40.048] | [25.533] |
| 2nd decile | 69.612*** | | |
| | [20.356] | | |
| 3rd decile | 64.087*** | | |
| | [13.738] | | |
| 4th decile/Size 2 | 34.178** | 64.446 | 39.907 |
| | [13.563] | [39.409] | [28.920] |
| 6th decile/Size 3 | -1.966 | 39.288 | 5.466 |
| | [8.914] | [44.735] | [30.376] |
| 7th decile/Size 5 | -13.484 | -32.765 | -11.748 |
| | [9.602] | [43.749] | [39.661] |
| 8th decile/Size 6 | -18.001** | -67.530 | -2.616 |
| | [8.668] | [50.468] | [37.207] |
| 9th decile/Size 7 | -26.894*** | 41.772 | 10.415 |
| | [8.520] | [45.555] | [34.448] |
| 10th decile/Size 8 | -33.170*** | 17.148 | 75.570 |
| | [8.691] | [59.475] | [52.963] |
| Constant | 78.441*** | 600.232*** | 592.723*** |
| | [8.225] | [28.544] | [20.980] |
| Observations | 4655 | 4430 | 7492 |

Notes: Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ICRISAT data are from 3 provinces in Burkina Faso. DEP data are from all 30 provinces in Burkina Faso. Column 2 uses DEP data and is restricted to 11 provinces (including the 3 ICRISAT provinces) that are geographically proximate to the 3 ICRISAT provinces. Column 3 uses DEP data restricted to the other 19 provinces of Burkina Faso. The dependent variable is value of plot output/hectare for the ICRISAT data and plot output/hectare for the DEP data. The omitted land size category is the 5th decile for the ICRISAT data and Size 4 for the DEP data.

Table 2b: Household-Year-Crop Fixed Effects Regressions of the Determinants of Plot Yield
(Only Millet & Sorghum)

| | ICRISAT Data | DEP Data | |
|---|---|---|---|
| | | Near-ICRISAT Provinces | All Other Provinces in Burkina Faso |
| | (1) | (2) | (3) |
| Female | -19.673*** | -41.116* | 45.091*** |
| | [3.120] | [22.513] | [15.753] |
| Plot Size: | | | |
| 1st decile/Size 1 | 35.248 | 168.802*** | 108.229*** |
| | [38.380] | [38.327] | [25.470] |
| 2nd decile | 37.028*** | | |
| | [11.928] | | |
| 3rd decile | 29.553*** | | |
| | [6.885] | | |
| 4th decile/Size 2 | 18.473*** | 22.726 | 41.413 |
| | [5.508] | [38.479] | [29.893] |
| 6th decile/Size 3 | -2.418 | 36.634 | 11.517 |
| | [4.415] | [40.282] | [29.492] |
| 7th decile/Size 5 | -11.230** | -47.137 | -35.445 |
| | [4.646] | [39.472] | [30.848] |
| 8th decile/Size 6 | -23.029*** | -18.571 | 12.670 |
| | [5.113] | [42.060] | [31.800] |
| 9th decile/Size 7 | -27.532*** | 50.915 | 13.321 |
| | [4.600] | [43.240] | [28.883] |
| 10th decile/Size 8 | -32.352*** | 43.882 | 29.904 |
| | [4.871] | [49.375] | [44.238] |
| Constant | 56.596*** | 510.991*** | 527.915*** |
| | [3.973] | [27.239] | [19.192] |
| Observations | 2195 | 2417 | 4598 |

Notes: Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ICRISAT data are from 3 provinces in Burkina Faso. DEP data are from all 30 provinces in Burkina Faso. Column 2 uses DEP data and is restricted to 11 provinces (including the 3 ICRISAT provinces) that are geographically proximate to the 3 ICRISAT provinces. Column 3 uses DEP data restricted to the other 19 provinces of Burkina Faso. The dependent variable is value of plot output/hectare for the ICRISAT data and plot output/hectare for the DEP data. The omitted land size category is the 5th decile for the ICRISAT data and Size 4 for the DEP data.

Table 3: Household-Year-Crop Fixed Effects Regressions of the Determinants of Plot Yield Including the Impact of Rainfall Shocks

| | ICRISAT Data | | DEP Data | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Female | -15.608*** | -21.988*** | 12.735 | 40.581 |
| | [5.380] | [5.548] | [13.274] | [26.271] |
| Female * (Rainfall > Long-run Province Average) | -24.340*** | | -34.578 | |
| | [9.130] | | [73.201] | |
| Female * (Rainfall > 0.5 Standard Deviations BELOW Long-run Province Average) | | 3.164 | | -44.160 |
| | | [7.015] | | [30.146] |
| Female * (Rainfall > 0.5 Standard Deviations ABOVE Long-run Province Average) | | -31.726* | | -208.581* |
| | | [17.099] | | [107.098] |
| Plot Size: | | | | |
| 1st decile/Size 1 | 130.948*** | 131.728*** | 126.139*** | 124.752*** |
| | [41.096] | [41.118] | [21.851] | [21.820] |
| 2nd decile | 67.400*** | 68.533*** | | |
| | [20.577] | [20.430] | | |
| 3rd decile | 62.896*** | 62.571*** | | |
| | [13.792] | [13.833] | | |
| 4th decile/Size 2 | 33.544** | 33.320** | 48.810** | 48.538** |
| | [13.538] | [13.503] | [23.336] | [23.279] |
| 6th decile/Size 3 | -2.369 | -3.213 | 17.994 | 18.219 |
| | [8.906] | [9.021] | [25.187] | [25.174] |
| 7th decile/Size 5 | -14.443 | -14.709 | -21.068 | -21.717 |
| | [9.601] | [9.714] | [29.644] | [29.579] |
| 8th decile/Size 6 | -19.058** | -19.518** | -26.538 | -28.028 |
| | [8.708] | [8.891] | [30.062] | [30.045] |
| 9th decile/Size 7 | -27.472*** | -27.353*** | 20.940 | 20.417 |
| | [8.552] | [8.590] | [27.585] | [27.555] |
| 10th decile/Size 8 | -33.594*** | -33.967*** | 52.769 | 50.303 |
| | [8.722] | [8.831] | [39.721] | [39.585] |
| Constant | 79.502*** | 80.024*** | 595.443*** | 595.746*** |
| | [8.345] | [8.551] | [16.983] | [16.936] |
| Observations | 4655 | 4655 | 11922 | 11922 |

Notes: Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is value of plot output/hectare for the ICRISAT data and plot output/hectare for the DEP data. The omitted rainfall shock category in columns 2 and 4 is rainfall amounts less than 0.5 standard deviations above or below the province long-run average rainfall. The omitted land size category is the 5th decile for the ICRISAT data and Size 4 for the DEP data.

Table 4: Household-Year-Crop Fixed Effects Regressions of the Determinants of Plot Yield Broken Down by Crop

| | ICRISAT Data | | DEP Data | |
|---|---|---|---|---|
| | Millet-Sorghum (1) | Cotton-Rice-Fonio (2) | Millet-Sorghum (3) | Cotton-Rice-Fonio (4) |
| Female | -11.396*** | 27.585 | 20.409 | 38.734 |
| | [3.402] | [23.671] | [12.854] | [101.398] |
| Female * (Rainfall > Long-run Province Average) | -15.107*** | -143.639* | 16.654 | -634.788** |
| | [4.317] | [73.694] | [69.938] | [289.507] |
| Plot Size: | | | | |
| 1st decile/Size 1 | 37.423 | 230.296** | 129.190*** | 177.650 |
| | [37.851] | [99.584] | [21.280] | [126.833] |
| 2nd decile | 35.991*** | 120.972*** | | |
| | [11.754] | [46.053] | | |
| 3rd decile | 29.056*** | 128.493*** | | |
| | [6.836] | [43.706] | | |
| 4th decile/Size 2 | 17.820*** | 64.943* | 35.800 | 58.301 |
| | [5.503] | [35.103] | [23.791] | [131.078] |
| 6th decile/Size 3 | -2.853 | 3.612 | 18.933 | 47.230 |
| | [4.369] | [43.246] | [24.054] | [151.446] |
| 7th decile/Size 5 | -12.099*** | 18.164 | -39.478 | 76.595 |
| | [4.562] | [30.960] | [24.442] | [207.624] |
| 8th decile/Size 6 | -23.656*** | 6.989 | 3.943 | -202.338 |
| | [5.069] | [31.196] | [25.443] | [220.428] |
| 9th decile/Size 7 | -27.870*** | -6.122 | 24.759 | 109.793 |
| | [4.576] | [29.932] | [24.123] | [198.628] |
| 10th decile/Size 8 | -32.564*** | -15.234 | 35.112 | 177.683 |
| | [4.867] | [32.525] | [33.789] | [271.772] |
| Constant | 56.920*** | 44.407 | 521.349*** | 841.580*** |
| | [3.963] | [37.884] | [15.791] | [104.945] |
| Observations | 2195 | 994 | 7015 | 1543 |

Notes: Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is value of plot output/hectare for the ICRISAT data and plot output/hectare for the DEP data. The omitted land size category is the 5th decile for the ICRISAT data and Size 4 for the DEP data.

Table 5: Household-Year-Crop Fixed Effects Regressions of the Determinants of Plot Yield Including the Impact of Rainfall Shocks and Wealth

| | ICRISAT Data | | | DEP Data | | |
|---|---|---|---|---|---|---|
| | All Households | Below Median Land Holdings | Above Median Land Holdings | All Households | Below Median Land Holdings | Above Median Land Holdings |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Female | -32.089*** | -15.767** | -27.813*** | 15.532 | 9.673 | 57.991* |
| | [9.340] | [7.774] | [7.926] | [19.613] | [39.830] | [33.910] |
| Female * Below Median Land Holdings | 7.875 | | | -12.714 | | |
| | [8.916] | | | [27.375] | | |
| Female * (Rainfall > 0.5 Standard Deviations BELOW Long-run Province Average) | | 6.045 | 0.139 | | -7.102 | -65.172* |
| | | [11.343] | [8.767] | | [46.330] | [39.050] |
| Female * (Rainfall > 0.5 Standard Deviations ABOVE Long-run Province Average) | | -6.230 | -47.805* | | -139.959 | -249.257** |
| | | [11.356] | [27.791] | | [206.223] | [120.194] |
| Plot Size: | | | | | | |
| 1st decile/Size 1 | 133.544*** | 44.981 | 199.173*** | 125.388*** | 116.539*** | 129.634*** |
| | [41.176] | [38.356] | [59.060] | [22.013] | [30.862] | [29.830] |
| 2nd decile | 69.614*** | 73.050** | 70.757*** | | | |
| | [20.341] | [33.077] | [25.584] | | | |
| 3rd decile | 63.610*** | 47.151** | 74.980*** | | | |
| | [13.830] | [18.293] | [20.155] | | | |
| 4th decile/Size 2 | 34.049** | 28.599 | 37.085** | 48.222** | 39.434 | 53.680* |
| | [13.561] | [22.000] | [17.188] | [23.440] | [33.052] | [31.187] |
| 6th decile/Size 3 | -1.885 | -10.782 | 2.490 | 15.875 | 2.965 | 25.356 |
| | [8.910] | [16.071] | [10.729] | [25.343] | [36.142] | [34.056] |
| 7th decile/Size 5 | -13.304 | -7.757 | -18.088 | -21.541 | -23.059 | -21.608 |
| | [9.591] | [13.324] | [13.367] | [29.839] | [40.232] | [40.588] |
| 8th decile/Size 6 | -17.873** | -8.263 | -26.829** | -27.839 | -16.397 | -37.292 |
| | [8.647] | [11.327] | [12.747] | [30.378] | [42.591] | [40.026] |
| 9th decile/Size 7 | -26.905*** | -20.762** | -32.227** | 18.730 | 24.491 | 17.037 |
| | [8.531] | [10.428] | [12.649] | [27.678] | [38.683] | [35.372] |
| 10th decile/Size 8 | -33.629*** | -27.706** | -39.760*** | 46.730 | 17.941 | 47.598 |
| | [8.856] | [10.809] | [12.992] | [39.845] | [129.433] | [41.623] |
| Constant | 78.430*** | 81.802*** | 83.438*** | 595.990*** | 574.161*** | 618.762*** |
| | [8.226] | [10.990] | [12.457] | [16.991] | [23.154] | [23.040] |
| Observations | 4655 | 2325 | 2330 | 11816 | 5682 | 6134 |

Notes: Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is value of plot output/hectare for the ICRISAT data and plot output/hectare for the DEP data. The omitted rainfall shock category is rainfall amounts less than 0.5 standard deviations above or below the province long-run average rainfall. The omitted land size category is the 5th decile for the ICRISAT data and Size 4 for the DEP data.

Table 6: Household-Year-Crop Fixed Effects Tobit Estimates of the Determinants of Plot Input Intensities Including the Impact of Rainfall Shocks

| Dependent Variables: | Male Labor Per Hectare | | Female Labor Per Hectare | | Child Labor Per Hectare | | Non-Household Labor Per Hectare | | Manure (1000kg) per Hectare | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Female | -631.80*** | -669.00*** | 116.40*** | 152.50*** | -248.10** | -261.90** | -355.70 | -400.40 | -15.07** | -19.87*** |
| | [67.42] | [67.92] | [40.06] | [46.74] | [102.20] | [110.0] | [254.90] | [255.70] | [6.27] | [6.84] |
| Female * (Rainfall > 0.5 Standard Deviations BELOW Long-run Province Average) | | 134.80* | | -239.00*** | | 27.12 | | 114.70 | | 6.05 |
| | | [76.85] | | [59.96] | | [65.20] | | [103.50] | | [5.97] |
| Female * (Rainfall > 0.5 Standard Deviations ABOVE Long-run Province Average) | | 57.41 | | 39.01 | | 104.00 | | 103.80 | | 12.14 |
| | | [116.00] | | [89.61] | | [111.40] | | [121.30] | | [8.06] |
| Plot Size | | | | | | | | | | |
| 1st decile/Size 1 | 1201.00*** | 1195.00*** | 1069.00*** | 1057.00*** | 835.40 | 837.40 | 121.10 | 110.10 | 23.53** | 23.61** |
| | [460.2] | [446.00] | [231.30] | [228.00] | [534.20] | [535.00] | [325.80] | [309.50] | [11.29] | [9.97] |
| 2nd decile | 511.70*** | 512.70*** | 872.50*** | 867.60*** | 270.10* | 273.50* | 397.50 | 393.50 | 1.44 | 1.875 |
| | [149.1] | [142.40] | [194.20] | [188.00] | [149.60] | [148.10] | [413.10] | [411.80] | [7.33] | [7.54] |
| 3rd decile | 192.20** | 192.60** | 641.80*** | 646.00*** | 188.80** | 188.30** | 272.30 | 264.60 | -2.52 | -2.66 |
| | [82.21] | [81.31] | [101.20] | [97.68] | [90.86] | [93.87] | [267.80] | [287.30] | [5.83] | [5.96] |
| 4th decile/Size 2 | 69.04 | 67.65 | 354.00*** | 360.00*** | 98.06 | 98.37 | 409.30 | 418.70 | -12.77* | -12.56* |
| | [63.85] | [62.39] | [70.13] | [69.00] | [143.10] | [143.90] | [518.00] | [575.80] | [7.35] | [7.43] |
| 6th decile/Size 3 | -0.32 | 3.23 | -78.79 | -75.95 | -58.85 | -54.68 | -20.29 | -20.13 | -6.22 | -5.78 |
| | [51.58] | [50.44] | [48.40] | [48.20] | [81.05] | [84.29] | [87.29] | [85.45] | [9.53] | [8.35] |
| 7th decile/Size 5 | -164.10*** | -160.50*** | -279.40*** | -272.50*** | -82.21 | -78.89 | 50.92 | 56.08 | -15.68* | -15.53* |
| | [58.66] | [58.35] | [51.27] | [51.34] | [99.75] | [101.50] | [90.95] | [89.61] | [9.02] | [9.03] |
| 8th decile/Size 6 | -372.70*** | -366.50*** | -358.80*** | -354.50*** | -290.00* | -285.20* | -71.39 | -66.50 | -14.46* | -14.02 |
| | [61.99] | [61.15] | [59.80] | [59.83] | [155.10] | [159.80] | [158.80] | [161.90] | [7.87] | [8.53] |
| 9th decile/Size 7 | -408.40*** | -401.40*** | -369.20*** | -374.30*** | -342.00** | -339.40* | -290.00 | -279.20 | -18.33** | -18.15** |
| | [60.43] | [58.72] | [65.25] | [65.37] | [174.20] | [178.90] | [325.30] | [314.30] | [7.78] | [7.56] |
| 10th decile/Size 8 | -485.60*** | -478.70*** | -420.20*** | -425.10*** | -340.60** | -336.90** | -233.00 | -215.60 | -20.53*** | -21.17*** |
| | [61.96] | [60.47] | [66.68] | [66.80] | [153.60] | [157.80] | [257.90] | [244.40] | [7.62] | [7.55] |
| Observations | 4655 | 4655 | 4655 | 4655 | 4655 | 4655 | 4655 | 4655 | 4655 | 4655 |

Note: Standard errors are in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. This table is estimated using Honore's (1992) fixed effects Tobit estimator. The estimation was done in Gauss using Honore's Pantob program using the Broyden-Fletcher-Goldfarb-Shanno optimization method. Similar results were obtained using the Polak-Ribiere Conjugate Gradient Method, the Simplex Method, and Powell's Method. The omitted rainfall shock category is rainfall amounts less than 0.5 standard deviations above or below the province long-run average rainfall. The omitted land size category is the 5th decile.

Appendix Table 1: Household-Year-Crop Fixed Effects Regressions of the Determinants of Plot Yield Including the Impact of Rainfall Shocks (Alternative specification of rainfall shocks)

| ICRISAT Data | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Female | -21.864*** | -22.596*** | -18.867*** | 9.083 |
| | [5.151] | [5.433] | [6.974] | [29.310] |
| Female * (Rainfall > 1.5 Standard Deviations BELOW Long-run Province average) | 5.788 | | | |
| | [8.660] | | | |
| Female * (Rainfall > 1 Standard Deviation BELOW Long-run Province average) | | 6.514 | | |
| | | [7.272] | | |
| Female * (Rainfall < 0.5 Standard Deviations BELOW Long-run Province average) | | | 6.218 | |
| | | | [7.031] | |
| Female * (Rainfall < 0.5 Standard Deviations ABOVE Long-run Province average) | | | -10.699 | |
| | | | [8.878] | |
| Female * (Rainfall > 0.5 Standard Deviations ABOVE Long-run Province average) | -31.831* | -31.149* | -34.887** | |
| | [16.961] | [17.015] | [17.252] | |
| Female * Total Rainfall | | | | -0.065 |
| | | | | [0.051] |
| Plot Size: | | | | |
| 1st decile/Size 1 | 131.511*** | 131.582*** | 130.657*** | 131.557*** |
| | [41.165] | [41.112] | [41.179] | [41.239] |
| 2nd decile | 68.409*** | 68.477*** | 67.380*** | 68.838*** |
| | [20.448] | [20.433] | [20.541] | [20.522] |
| 3rd decile | 62.481*** | 62.475*** | 62.441*** | 63.540*** |
| | [13.856] | [13.838] | [13.834] | [13.790] |
| 4th decile/Size 2 | 33.195** | 33.191** | 33.289** | 33.737** |
| | [13.542] | [13.517] | [13.510] | [13.493] |
| 6th decile/Size 3 | -3.223 | -3.211 | -3.217 | -2.378 |
| | [9.014] | [9.016] | [9.016] | [8.903] |
| 7th decile/Size 5 | -14.742 | -14.792 | -14.951 | -14.286 |
| | [9.711] | [9.712] | [9.689] | [9.581] |
| 8th decile/Size 6 | -19.557** | -19.629** | -19.733** | -19.543** |
| | [8.888] | [8.887] | [8.867] | [8.701] |
| 9th decile/Size 7 | -27.336*** | -27.451*** | -27.789*** | -27.648*** |
| | [8.588] | [8.582] | [8.582] | [8.532] |
| 10th decile/Size 8 | -33.996*** | -34.091*** | -34.105*** | -33.259*** |
| | [8.829] | [8.830] | [8.829] | [8.670] |
| Constant | 80.188*** | 80.015*** | 80.461*** | 78.121*** |
| | [8.555] | [8.546] | [8.569] | [8.157] |
| Observations | 4655 | 4655 | 4655 | 4655 |

Notes: Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is value of plot output/hectare. In column 1, the omitted rainfall shock category is rainfall amounts between 1.5 standard deviations (SD) below the province long-run average rainfall and 0.5 SD above long-run average rainfall. Column 2 omits the rainfall category between 1 SD below long-run average and 0.5 SD above long-run average. Column 3 omits the rainfall category greater than 0.5 SD below long-run average rainfall. The omitted land size category is the 5th decile for the ICRISAT data.

Appendix Table 2: Household-Year-Crop Fixed Effects Regressions of the Determinants of Plot Yield Including the Impact of Rainfall Shocks (Alternative specification of rainfall shocks)

| DEP Data | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Female | 14.990 | 15.455 | -3.580 | 49.419 |
| | [14.118] | [18.722] | [14.880] | [71.484] |
| Female * (Rainfall > 1.5 Standard Deviations BELOW Long-run Province average) | -17.587 | | | |
| | [73.169] | | | |
| Female * (Rainfall > 1 Standard Deviation BELOW Long-run Province average) | | -3.317 | | |
| | | [26.802] | | |
| Female * (Rainfall < 0.5 Standard Deviations BELOW Long-run Province average) | | | 45.249 | |
| | | | [29.595] | |
| Female * (Rainfall < 0.5 Standard Deviations ABOVE Long-run Province average) | | | 38.772 | |
| | | | [92.107] | |
| Female * (Rainfall > 0.5 Standard Deviations ABOVE Long-run Province average) | -182.969* | -183.420* | -164.422 | |
| | [104.763] | [105.495] | [104.857] | |
| Female * Total Rainfall | | | | -0.063 |
| | | | | [0.121] |
| Plot Size: | | | | |
| 1st decile/Size 1 | 125.280*** | 125.274*** | 124.774*** | 126.127*** |
| | [21.830] | [21.850] | [21.809] | [21.859] |
| 4th decile/Size 2 | 48.285** | 48.364** | 48.562** | 48.719** |
| | [23.269] | [23.290] | [23.251] | [23.321] |
| 6th decile/Size 3 | 17.742 | 17.835 | 18.253 | 17.880 |
| | [25.187] | [25.187] | [25.155] | [25.201] |
| 7th decile/Size 5 | -21.400 | -21.345 | -21.755 | -20.720 |
| | [29.610] | [29.608] | [29.618] | [29.628] |
| 8th decile/Size 6 | -28.087 | -28.002 | -28.014 | -26.516 |
| | [30.099] | [30.090] | [30.054] | [30.051] |
| 9th decile/Size 7 | 21.057 | 20.944 | 20.458 | 20.325 |
| | [27.557] | [27.568] | [27.572] | [27.531] |
| 10th decile/Size 8 | 51.514 | 51.511 | 50.385 | 52.496 |
| | [39.640] | [39.650] | [39.676] | [39.639] |
| Constant | 596.463*** | 596.304*** | 595.737*** | 595.980*** |
| | [16.946] | [16.927] | [16.923] | [17.111] |
| Observations | 11922 | 11922 | 11922 | 11922 |

Notes: Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is plot output/hectare. In column 1, the omitted rainfall shock category is rainfall amounts between 1.5 standard deviations (SD) below the province long-run average rainfall and 0.5 SD above long-run average rainfall. Column 2 omits the rainfall category between 1 SD below long-run average and 0.5 SD above long-run average. Column 3 omits the rainfall category greater than 0.5 SD below long-run average rainfall. The omitted land size category is Size 5 for the DEP data.

Appendix Table 3: Household-Year-Crop Fixed Effects Regressions of the Determinants of Plot Yield Broken Down by Crops (Alternative Rainfall Shock Specification)

| | ICRISAT Data | | DEP Data | |
|---|---|---|---|---|
| | Millet-Sorghum (1) | Cotton-Rice-Fonio (2) | Millet-Sorghum (3) | Cotton-Rice-Fonio (4) |
| Female | -19.076*** | -38.603 | 57.260** | -128.627 |
| | [3.730] | [42.897] | [24.778] | [157.237] |
| Female * (Rainfall > 0.5 Standard Deviations BELOW Long-run Province Average) | 5.171 | 73.036 | -54.571* | 169.604 |
| | [5.474] | [47.566] | [28.794] | [195.176] |
| Female * (Rainfall > 0.5 Standard Deviations ABOVE Long-run Province Average) | -7.879 | -232.955 | -190.329* | -192.576 |
| | [5.637] | [182.579] | [106.304] | [318.546] |
| Plot Size: | | | | |
| 1st decile/Size 1 | 35.843 | 226.614** | 127.990*** | 188.054 |
| | [38.437] | [100.079] | [21.275] | [127.280] |
| 2nd decile | 36.728*** | 122.011*** | | |
| | [11.966] | [46.401] | | |
| 3rd decile | 29.125*** | 117.863*** | | |
| | [6.877] | [44.150] | | |
| 4th decile/Size 2 | 17.968*** | 58.843 | 35.713 | 62.744 |
| | [5.509] | [35.697] | [23.752] | [130.753] |
| 6th decile/Size 3 | -2.812 | 8.787 | 18.837 | 49.428 |
| | [4.471] | [41.493] | [24.023] | [152.326] |
| 7th decile/Size 5 | -11.710** | 20.955 | -40.685* | 81.504 |
| | [4.672] | [31.384] | [24.295] | [210.977] |
| 8th decile/Size 6 | -23.544*** | 6.975 | 2.079 | -196.090 |
| | [5.141] | [31.325] | [25.429] | [224.076] |
| 9th decile/Size 7 | -27.649*** | -5.045 | 23.935 | 126.562 |
| | [4.615] | [29.676] | [24.108] | [199.922] |
| 10th decile/Size 8 | -32.649*** | -12.350 | 32.365 | 189.533 |
| | [4.894] | [32.180] | [33.646] | [278.504] |
| Constant | 56.781*** | 68.416 | 521.316*** | 828.957*** |
| | [3.999] | [46.646] | [15.706] | [105.577] |
| Observations | 2195 | 994 | 7015 | 1543 |

Notes: Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is value of plot output/hectare for the ICRISAT data and plot output/hectare for the DEP data. The omitted land size category is the 5th decile for the ICRISAT data and Size 4 for the DEP data.