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Impact of soil conservation adoption on intra-household allocations in Zambia

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Abstract: In this paper, we examine the impact of soil conservation adoption on gender-specific resource allocations within households in Zambia. The extension of funding of conservation farming (CF) training sessions in 2007 in specific districts in Zambia provides variation in CF take-up. We use this variation to implement a difference-in-differences strategy on a number of datasets. We show that expansion of funding for CF training sessions increased take-up of CF, increased female labour hours, and shifted household expenditures towards goods associated more strongly with female preferences than male preferences. These results stress the importance of understanding the impact of development programmes, specifically promotion of agricultural technologies, on household gender dynamics.

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1 Introduction

According to the Zambian Central Statistics Office, agriculture accounted for 60 percent of employment and 10.1 percent of GDP in Zambia in 2012. Women comprised 52.8 percent of the agricultural workforce. However, large gender gaps in productivity and investment persist in Zambia and throughout Sub-Saharan Africa (O'Sullivan et al., 2014). Existing economic literature does not fully explore the causes of these gaps and corresponding interventions that could decrease gender production inequality. This production gap is particularly important, since it is likely that, as women become more productive, they will increase their decision-making power over household resources.[1] An increase in female decision-making power could then lead to significant improvements for future generations, as previous research has shown that women have a stronger preference for child investment than men.[2] This study aims to explore these relationships by evaluating the impact of an intervention that increases female agricultural productivity in Zambia on household outcomes.

Development programs aimed at increasing agricultural productivity in Sub-Saharan Africa often promote agricultural technology adoption, but do not evaluate the impact of adoption on decision-making within the agricultural household. Evaluations of such programs have previously limited the outcomes of interest to overall agricultural productivity measures, while focusing on gender only as a barrier to adoption (Jack, 2011). We add to existing studies by evaluating the impact of adoption of a production technology, particularly one that increases the substitutability of male and female labor, on gender-specific resource allocations and gender roles within the agricultural household. The impact of technology adoption on intra-household resource allocations and household gender dynamics can vary greatly depending on

[1] This is demonstrated in Duflo and Udry (2004).

[2] For one example, see Quisumbing et al. (2000).

the fundamental characteristics of the technology. For example, one would expect a gender-neutral technology to have little impact on intra-household allocations because it will not impact the relative productivity of males and females within the household. However, it is possible that a gender-biased technology could lead to a change in how resources are allocated by changing the relative productivity of males and females. While it may not be clear ex ante whether a technology is gender neutral or gender biased, it is important that development agencies and non-governmental organizations (NGOs) promoting technology adoption understand these nuances and how they may impact households.

We specifically contribute to the literature by testing the impact of a gender biased agricultural technology shift in Zambia on the gender division of labor at the household level, as well as household expenditures and behavioral outcomes. The specific gender biased agricultural technology that we study is conservation farming (CF). In order to identify the impact of conservation farming, we use a difference-in-differences strategy exploiting the regional variation in the conservation farming training expansion that took place in 2007. We find that CF training increased the take-up of CF, increased the agricultural labor hours of females relative to males, improved child outcomes, and shifted household expenditures away from goods associated with male consumption preferences. Overall, we show that technologies exist which both improve productivity and also empower women, providing a "win-win" scenario.

The rest of the paper is organized as follows. Section 2 explains conservation farming in Zambia, the agricultural technology of interest. In Section 3, we place our analysis within existing literature. We model the impact of conservation farming on labor supply by gender in Section 4. In Sections 5 and 6, respectively, we outline the data and empirical strategy utilized throughout our analyses. In Section 7, we present the results of these analyses. Finally, Section 8 concludes with a discussion of our findings and their importance.

2 Conservation Farming in Zambia

The technology we focus on in our analysis is conservation farming in Zambia. The Zambian government has been working with the Conservation Farming Unit (CFU), an NGO, since 1999 to introduce a set of soil conservation practices called conservation farming, which includes zero-till techniques, to farmers all over the country. Specifically, CFU has focused on training maize farmers to adopt conservation techniques. While CFU held trainings prior to 2007, they greatly expanded their training sessions and also began collecting data on farmers beginning in 2007. We exploit this expansion of CFU trainings as well as the availability of data on the location of the CFU sessions to implement our identification strategy. Figure 1 shows the growth in conservation farming knowledge in treated districts and control districts, as measured by whether a respondent has received any advice on practicing minimum tillage. While there is knowledge of CF practices in both treated districts and control districts, the knowledge in only treated districts increases following the expansion of CFU training sessions in 2007.

Similar NGOs and programs have been introduced in a number of other African countries including Tanzania, Senegal, and Malawi. These programs were developed because farmers in Africa use the plough as the main method of tillage for their fields every year. The continued use of the plough has resulted in soils that are degraded to the point that large portions of land are no longer arable. Additionally, the expansion of funding to CFU for the expansion of training sessions into more districts in Zambia in 2007 allows for the use of a difference-in-differences empirical strategy to estimate the impacts of CF adoption on intra-household allocations.

The definition of what constitutes conservation farming varies, but in general it requires adopters to complete their land preparation well before the first rains. Farmers do not burn crop residues, but rather use them as field cover. Another component of the technology is the use of a chaka hoe, an oversized gardening hoe, to dig basins evenly spread throughout fields, finishing land preparation by July or August, well before the planting season. This allows farmers to plant immediately following the first rains in their basins, where they use fertilizer and lime to regenerate the soil. A small percentage of farmers use a magoye ripper to rip shallow lines through their fields to achieve the same effect as digging basins. Finally, during the growing season, farmers who have adopted soil conservation will have to deal with an increased amount of weeds. The household can use herbicides, but most of the weeding is done by hand and herbicides are not commonly used.

Classification of a conservation farmer can be difficult, as they may adopt some of the prescribed practices while not adopting others. The literature uses the following five key practices to understand the overall adoption level by farmers: (1) reduced tillage, farmers do not plough a certain percentage of their land, (2) digging of permanent basins or ripping of soil with as little soil disturbance as possible, (3) use of crops residues as soil cover and no burning of crop residues, (4) crop rotation of cereals and legumes, and (5) dry season land preparation.[3] Given this complex criteria, it can be extremely difficult to classify farmers into adopters and non-adopters.

There are two significant benefits of adopting conservation farming. The first is early land preparation, which guarantees planting is done on time. Ploughing requires access to a draft animal, which can be difficult to obtain following the first

[3] The Conservation Farming Unit, 2010. "MT-CT-CF-CA Definitions CFU Zambia." CFU Zambia

rains when a demand bottleneck occurs. This bottleneck results in farmers ploughing their fields late and as a result planting their maize late. Planting maize even a week late can result in a 10 percent decrease in yields. The second main benefit of conservation farming is the conservation of soil nutrients as a result of decreased tillage. Ploughing results in unnecessary soil disturbance that leads to increased levels of erosion, restricted infiltration of water, and general land degradation. The adoption of conservation farming, of which minimum tillage is the main recommendation, leaves soils intact so that they can be utilized in the following years.

In addition to the short-run and long-run production benefits of conservation farming in Zambia, the potential positive impacts on the well-being of women are quite promising. In traditional agricultural households in rural Sub-Saharan African, men have historically performed soil preparation using the plough. Women contribute both to small-scale farming tasks and domestic production. Women in these settings, for cultural reasons or other reasons related to labor division, rarely participate in field preparation using the plough. Thus, their perceived limited participation in the main agricultural production of the household, tends to result in them not having significant control over resource allocation within the household. This specific gender productivity gap related to the use of the plough is discussed in detail in O'Sullivan et al. (2014). Additionally, Alesina et al. (2013) have hypothesized that the use of the plough is a driving force behind the development of gender roles throughout the world. While the main reasons that conservation farming discourages the use of the plough are unrelated to gender, there could be significant gender spillovers as female labor becomes more substitutable for male labor in adopting households. In fact, Teklewold et al. (2013) find evidence that females do increase their workload more than males after take-up of conservation farming in Ethiopia.

There are benefits to be had by increasing the marginal productivity of females by shifting away from the use of traditional agricultural and the plough. As a result of increased productivity, and possible increased bargaining power, women will have more educational and political opportunities and become less physically vulnerable. The gains could be large, as over 70 percent of the nations in the bottom quartile of the 2013 United Nations Gender Inequality Index are African. Zambia itself falls at 135 out of 152 ranked countries. Moreover, the 2007 Zambian Demographic and Health Survey data indicates that 47 percent of all Zambian women have experienced physical violence since the age of 15. Of these cases, 77 percent of the perpetrators were a current or former husband or partner. The hope is that when women are more involved in household agricultural productivity, the gender dynamics within the household will change, resulting in increased gender equality.

3 Literature Review

There have been an extensive number of published articles studying barriers to farming technology adoption. Jack (2011) provides an overview of the agricultural technology adoption literature and focuses on market inefficiencies in land, labor, credit, risk and information as the main barriers to adoption. The study also explores a gender component of these market inefficiencies, suggesting gender norms may be a barrier to adoption. Knowler and Bradshaw (2007) also reviewed and synthesized a large portion of the empirical studies of conservation agriculture adoption and other farming techniques globally. Their findings show that only a few key variables impacted the adoption decision over all studies and that, once they controlled for background factors, such as location and model specification, there were not any universal variables that effectively predicted adoption. They concluded that the promotion of conservation agriculture must be examined on a case-by-case basis, as previous studies had measured adoption and control variables in different ways. The cultural context, especially gender norms, in Zambia is extremely important.

Other papers have focused particularly on the costs and benefits of soil conservation adoption. Haggblade and Tembo (2003) examine the benefits of conservation farming in Zambia for small-scale cotton farmers. They found that yields significantly increase when conservation techniques are used compared to traditional tilling, but that adoption is costly in the first few years, specifically because of the increased amount of labor needed for weeding.

Our paper also contributes to the literature on gender roles in the household and the gender effects of agricultural technologies. Alesina et al. (2011) and Alesina et al. (2013) examine the long-run impacts of the use of the plough as the main agricultural technology. Exploiting cultural differences in agricultural technology, they are able to show that areas where the plough was used have less equal gender norms compared to areas that used a different agricultural technology. The authors also explore fertility, an important measure of gender roles, and find that areas that historically used the plough actually have lower fertility rates. This is due to the fact that children, like women, are less useful for plough agriculture. These results are long-run gender effects of using plough technology. This paper explores short-run gender effects that drive long-run trends.

Voigtländer and Voth (2013) also examine the importance of historical labor provision by men and women. Specifically, they study the impact of the Black Death in Europe on land scarcity and the shift toward the pastoral sector. The authors use data from Britain to show that movement toward the pastoral sector benefited women, who have a comparative advantage compared to the grain sector due to the physical differences between genders. The results support the hypothesis that the shift in agricultural technology from cereal production to animal husbandry led to an increase in female labor options and a move to later marriages. The shift in age at marriage helped close the enormous gender gap that existed during the Middle Ages. While the authors of this paper use a two-sector agricultural model, our model instead focuses on an increase in substitutability between male and female labor and an increase in the share of female labor relative to male labor once conservation farming is adopted.

The last area of literature relevant to this paper examines differences in female and male consumption goods within the household. Duflo and Udry (2004) use exogenous rainfall shocks that impact male and female crop production differentially in West Africa. These gender specific productivity changes cause a shift in resource allocations. Specifically, variation in female-controlled and male-controlled cash crops is correlated with expenditures on alcohol, tobacco, and prestige goods. When female income increases relative to male income expenditures on alcohol decrease. Other papers in the development literature, including Haddad et al. (1997), Haddad (1999), and Quisumbing et al. (2000) have found that the more influence women have over resource allocations within the household, the higher the share of household income spent on food, health, education and children's nutrition. Additionally, Lundberg et al. (1997) use a natural experiment in the United Kingdom that exogenously increased female income, but not male income, within a household to identify female consumption goods. The authors find that females tend to spend more income on children's clothing compared to men. This type of household analysis provides an empirical framework on which to test female influence on resource allocation within the household.

4 Agricultural Production Technology Model

Consider a farmer faced with a technology adoption decision. The farmer can either continue to use a traditional production technology (ploughing) and produce using the following simplified constant elasticity of substitution agricultural production technology that is a function of male labor L_M, and female labor L_F that have prices w_M and w_F respectively and are used to produce an output crop Q (maize) with a price $p = 1$.

$$f_o(L_M, L_K) = Q_o = ((L_M)^{\frac{\sigma_o - 1}{\sigma_o}} + (L_F)^{\frac{\sigma_o - 1}{\sigma_o}})^{\frac{\sigma_o}{1-\sigma_o}} \tag{1}$$

However, the farmer may also adopt a new production technology (conservation farming) that is a constant elasticity of substitution agricultural production technology that is a function of male labor L_M, and female labor L_F that are used to produce an output crop Q.

$$f_n(L_M, L_K) = Q_n = \gamma((L_M)^{\frac{\sigma_n - 1}{\sigma_n}} + (L_F)^{\frac{\sigma_n - 1}{\sigma_n}})^{\frac{\sigma_n}{1-\sigma_n}} \tag{2}$$

Additionally, each household, i, faces a cost of adoption $c_i > 0$ for the new technology which can be seen as an information cost and/or a stigma cost. Finally, the new technology is more productive i.e. $\gamma > 1$.

Assuming that households are utility maximizers and there are complete markets, then the separability property between production and utility holds and we can focus solely on the profit-maximizing decision of the household. The only additional assumptions necessary for our model is that male labor and female labor are more substitutable when the new technology is adopted, tasks are less gender specific, or $\sigma_n > \sigma_o > 0$, and the male wage rate, w_M, is higher than the female wage rate,

w_F. Given these assumptions, households will maximize the following unconstrained profit equation:

$$\underset{\beta, L_M, L_F}{\text{Max}} \Pi_i(\beta, L_M, L_F) = \beta[\gamma f_n(L_M, L_K) - w_M L_M - w_F L_F - c_i] + (1-\beta)[f_o(L_M, L_K) - w_M L_M - w_F L_F] \quad (3)$$

$$\text{subject to } \beta \in \{0,1\}, L_M \geq 0, L_F \geq 0$$

where the household chooses the optimal allocations of male labor, L_M, and female labor, L_F, under both technologies. Then the household chooses to adopt the technology if $\Pi_i^*(1, L_M^*, L_F^*) \geq \Pi_i^*(0, L_M^*, L_F^*)$ and they do not adopt otherwise. If we assume that c_i is normally distributed we will have a set of households that will always adopt the new technology and a set of households that will never adopt the new technology. Our empirical strategy is centered on an intervention that significantly lowers c_i for treatment households. In our model this will induce certain households to adopt the new technology that previously did not.

Additionally, the profit-maximizing household will choose labor inputs for the old technology accordingly:

$$L_o^* = \frac{L_F^*}{L_M^*} = \left(\frac{w_M}{w_F}\right)^{\sigma_o} \quad (4)$$

Similarly, the household will choose labor inputs for the new technology:

$$L_n^* = \frac{L_F^*}{L_M^*} = \left(\frac{w_M}{w_F}\right)^{\sigma_n} \quad (5)$$

Combining the two ratios of optimal allocations we can see the following:

$$\left(\frac{w_M}{w_F}\right)^{\sigma_n} > \left(\frac{w_M}{w_F}\right)^{\sigma_o} \quad (6)$$

because $\sigma_n > \sigma_o$ and $w_M > w_F$. This result suggests that adopting households will use relatively more female labor compared to male labor than households that do not adopt the new technology. The model explicitly tells us that households that adopt will substitute toward the less expensive input, female labor, away from the more expensive input, male labor. We can test this theoretical result empirically by studying whether households in districts that received conservation farming training significantly increased the share of female labor relative to male labor.

5 Data

In order to estimate the impact of conservation farming training and adoption on labor hours and household resource allocation, we use a number of data sources. First, we use the CFU training dataset, which is a record of whether training in conservation farming techniques was conducted by CFU in district post 2007. Figure 2 shows the geographical variation of treatment districts. We then merge the CFU dataset on to a number of other primary source survey datasets in Zambia that were administered both before and after 2007, when CFU expanded their training sessions. This variation at the district level allows for the implementation of a difference-in-differences strategy to estimate causal effects of conservation farming.

We use the Rural Agricultural Livelihoods Surveys (RALS) to measure the impact of CF training sessions on CF adoption, CF knowledge, household investment in children's education, women's fertility decisions, and child illness. The Zambian RALS data was conducted in 2001, 2004, and 2008 by the Zambian Central Statistical Office with support from the Zambia Food Security Project and the Agricultural, Food, and Resource Economics Department at Michigan State University. Topics covered by the survey include individual and household characteristics, farming practices, and productivity measures. Summary statistics for the RALS data are shown in Table 1. Throughout our analysis, we define CF as any mention of conservation farming or the use of CF techniques.[3]

Additionally, in order to study the impact of conservation farming on household labor allocation, we use the Zambian Labor Force Surveys (LFS) that were conducted in 2000, 2005, and 2008 by the Zambian Central Statistical Office and Ministry of Labour and Social Security with support from the International Labour Organization (ILO). The surveys are cross-sectional and geographically comprehensive data collected during the months of November and December. Topics covered by the survey include individual and household characteristics, labor force participation, and time use. Summary statistics for the LFS are shown in Table 2.

Finally, we use both the Zambian Living Conditions and Monitoring Surveys (LCMS) to measure household consumption and expenditures. The LCMS datasets were administered in 2004 and 2010 and contain household characteristics, as well as detailed information of household consumption and expenditures, including items such as clothing, education and alcohol. Summary statistics for the LCMS are shown in Table 3.

6 Empirical Analysis

All of the primary survey data sources mentioned above, as well as the CFU geographic and training data allow for the use of a difference-in-differences estimation of the causal effect of soil conservation training on household resource allocations. Assigning households to treatment based on whether they are in a district where CFU held trainings in the period of interest, the following equation can be estimated to identify how the training and adoption of conservation farming impacts household

[3] In addition to respondent reporting of farming techniques that fall under CF, we additionally define a respondent as a user of CF if they directly self-report that they are conservation farmers. We find that users often report that they are conservation farmers even if they do not report usage of CF techniques.

allocations.

$$Y_{idt} = \beta_0 + \beta_1 S_t + \beta_2 T_d + \beta_3 S_t \cdot T_d + \mathbf{X}'_{idt}\gamma + \varepsilon_{idt} \tag{7}$$

where Y_{idt} is an outcome of interest at the household level, S_t is an indicator for year (pre-treatment or post-treatment), T_d is an indicator for whether a farm is in a treated district, $\mathbf{X}_{idt}$ is a vector of household characteristics, and ε_{idt} is an error term clustered at the district level. The empirical analysis is applied to three main sets of outcomes. These include the impact of CF training on CF adoption, female labor supply relative to male labor supply, and a variety of household behavior and resource allocation measures.

Identification hinges on the assumption that prior to treatment, treatment and control districts were on parallel trends. To examine the validity of the difference-in-differences identification strategy we can use the RALS dataset to test the pre-trends assumption for the take-up of conservation farming. Additionally, we control for key demographic variables in our empirical analysis, accounting for demographic changes within districts during the period of interest. Finally, we also test whether treated districts, in addition to receiving conservation farming training in 2007 and later, received other sources of aid during this time that could pose a threat to identification. Table 4 shows a difference-in-differences estimation of additional sources of aid at the household level. The results suggest that there was not an increase in access to other aid for treated districts that corresponded with the CF training.

7 Results

There are several main findings. First, CF prevalence increased as a result of CF trainings. Second, female labor supply increased as a result of a CF trainings, presumably due to CF adoption. Finally, a variety of household resource allocation measures suggest that women may have increased decision-making power within the household.

7.1 Conservation Farming Adoption

We first test the impact of conservation farming training on adoption of CF methods. In order to ensure that districts treated with conservation farming training are not different from control districts prior to treatment, we test whether districts are different across a set of key demographic observables in the 2004 RALS data. The results in Table 1 show that the only characteristic for which there is a difference is household size. However, it is not clear why larger household would face different trends in CF adoption. Moreover, we also can test for pre-trends in our CF prevalence analysis.

The difference-in-differences regression results in Table 5 show that training increases the likelihood of adoption by 12 and 13 percentage points. This equates to a 109-113 percent increase in CF.[4] The result is robust to the addition of household controls. While previous studies, such as Arslan et al. (2014), have shown lower levels of adoption, as mentioned in Section 5, we use a broader definition of conservation farming than such studies. Our adoption results are similar to those observed by CFU.

In addition to the regression analysis, the RALS data from 2001 allows for a direct test of the pre-trends assumption on conservation farming between treatment and control districts prior to treatment. Figure 3 shows that the pre-trends are fairly flat and the difference in means in 2001 is not statistically significant. This result provides evidence that our difference-in-differences estimate of CF adoption is causal.

[4] Percent effect calculated as coefficient/mean dependent variable

Even though treatment districts were chosen by CFU in order to reach as many maize farmers as possible, in the sample of only farmers planting maize, the treatment and control groups look fairly similar in terms of demographics and tillage techniques prior to treatment.

7.2 Female Labor Supply

We next explore the impact of CF training on labor hours by gender within the household. In order to ensure that districts treated with conservation farming training are not different from control districts prior to treatment, we test whether districts are different across a set of observable characteristics in the 2005 LFS. The results in Table 2 show that there are no significant differences in the treatment and control households across these demographics.

The results of the difference-in-differences regression analysis are displayed in Table 6. The first two columns are from a difference-in-differences estimation with the outcome Y_i defined as number of hours worked daily by females in the household. The pre-treatment year is 2005 and the post-treatment year is 2008. The number of hours worked prior to treatment is not significantly different across treatment and control districts. However, in the post period, females in both treatment and control districts worked significantly less. This could be due to the change in the timing of the survey collection. The difference-in-differences estimate on female labor supply supports our earlier hypothesis, as females in treated districts are working significantly more in the post treatment period compared to females in control districts. Females are specifically working about 1 more hour per day, or 16-19 percent more hours, as a result of the CF training. Additionally, the estimates are robust to the inclusion of additional control variables and province fixed effects.

The theoretical model suggests that treated households with lower costs of adoption c_i will increase their adoption probability and also increase female labor hours relative to male labor hours. We can test this by estimating a difference-in-differences regression on the ratio of female labor supply to male labor supply. The results are shown in Columns (3) and (4) of Table 6. Again, we can see that the ratio of household female labor supply to male labor supply in treatment districts is significantly higher compared to control districts. The results suggest that, relative to men in their household, women are working significantly more in treatment districts. This result supports the prediction from the theoretical model that training and increased adoption leads to increased female labor supply relative to male labor supply.

Moreover, we can test the model assumptions that the off-farm wage for males and females does not change due to training. To do this we estimate a difference-in-differences regression on total wages earned by household members in the RALS dataset. The results in Table 7 show that households in treated districts were not bringing in higher off-farm wages after treatment when compared to control districts. This result, which holds when broken down by gender, suggests that training did not impact off-farm wages in treated districts, thus supporting the assumptions of the theoretical model.

7.3 Household Female Empowerment

We next test the impact of CF take-up on household female empowerment. To do so, we examine the impact of CF training on fertility in the RALS data. The existing literature suggests that women in Zambia prefer to have fewer children than men, thus we would expect an increase in female decision-making power to decrease fertility (Salem, 2004). However, Alesina et al. (2011) found that the use of the plough resulted in lower fertility levels in the long run. Therefore, the short-run empirical prediction of CF adoption on fertility is ambiguous. Table 8 suggests that there is indeed a decrease in fertility when defined as having an infant present in the household. While this result could be considered an increase in empowerment, we cannot rule out that the decrease is caused by an increase in female labor.[5]

7.4 Household Child Investment

Table 9 examines the impacts of CF training on household child investment. The literature suggests that women favor expenditures on children, we expect an increase in women's decision-making power to increase school attendance and child health.[6] We are able to test household child investment outcomes in the RALS data. The results of the difference-in-differences regressions testing changes in household child investment as measured in the RALS data are in Table 9. The outcome variables are percent of household children currently in school, the highest level of education obtained by children in the household, and whether a child is chronically ill. Conservation farming training led to a significant increase in school attendance by children. This means treatment households increased their investment in children's human capital, which is often preferred by females more than males. The average level of education and the probability of child being sick are not significantly different, but do have the correct sign. These latter two null results may be explained by the fact that the outcomes are cumulative and unlikely to be impacted during such a short

[5] Additionally, we examine the impact of CF training on the election of female parliament members. A similar outcome was used by Alesina et al. (2013) to measure female empowerment. We use a unique dataset with the gender of each district level parliament member to examine the impact CF training on the election of female delegates. Table 8 shows the results of the difference-in-differences regression. While the results are positive, they are not significant, which suggests that the long-run outcomes examined in other papers may not be impacted in the short run.

[6] See O'Sullivan et al. (2014) for a list of studies that link women's preferences to child health and education outcomes.

period.

7.4.1 Household Expenditures

Finally, we use the LCMS data to explore household expenditures. Table 3 suggests that there is balance in demographic characteristics between treatment and control districts in this survey. Table 10 and Table 11 show the results of difference-in-differences analysis estimating the impact of conservation farming training on household consumption of a male-preferred good, alcohol and a female-preferred good, clothing. In Table 10, for a variety of specifications, we find that CF training led to a decrease in expenditures on alcohol as a share of total household expenditures by about 0.55-0.58 percentage points, or about 39-40 percent. Table 11 suggests that CF training led to an increase in expenditures on clothing as a share of total household expenditures by about 1.5 percentage points, or 17-18 percent. In both sets of regressions we control for overall expenditures so that the likely explanation for changes in the share of expenditures is a shift in household decision-making power.

8 Conclusion

Low and unsustainable agriculture productivity in Africa is an important issue for the development of the economy. Soil conservation technologies are a viable way to increase sustainable productivity, especially in the face of climate change. However, NGOs, aid agencies, and other players in the development field need to understand the role of gender and gender norms when attempting to implement soil conservation technologies. This paper has shown that soil conservation adoption can lead to changes in household allocations in the short run. Combined with the long-run results estimated by Alesina et al. (2011) and Alesina et al. (2013), we are confident that soil conservation technologies have significant impacts on gender norms. These benefits should be accounted for when evaluating training programs.

Specifically, we find a number of results. First, we use the RALS data to show that there was a significant increase in both knowledge and adoption rates of conservation farming practices. Second, we use the LFS to show that in areas that received conservation farming training female labor hours increased relative to male labor hours. Finally, we use the RALS and LCMS data to explore household allocations for which we find increases in school attendance and clothing expenditures and decreases in fertility and alcohol expenditures.

These overall results suggest that there are positive gender equality spillovers associated with gender-biased agricultural technology adoption. However, this gender aspect of soil conservation technologies could also be a barrier to adoption in these traditional household settings. A man in a traditional household may be unwilling to give up bargaining power to the female in the household, resulting in low initial levels of adoption and/or high rates of eventual dis-adoption. Moreover, weather fluctuations are important inputs that are not accounted for in the theoretical models or empirical analysis of this paper. Understanding how weather shocks impact adoption decisions is imperative to understanding the true gender effects of conservation farming adoption.

Ideally, this study would benefit from additional survey data with questions aimed at understanding take-up of conservation farming, as well as time and expenditure allocations by gender. A randomized controlled trial or an additional natural experiment or quasi-experiment could offer more insights into the mechanisms through which conservation farming impacts gender-related outcomes. We hope that this paper provides a launching point for research measuring the gender impacts of similar agricultural technologies and the promotion of these technologies throughout the developing world.

References

Alesina, A., Giuliano, P., and Nunn, N. (2011). Fertility and the plough. *The American Economic Review*, 101(3):499–503.

Alesina, A., Giuliano, P., and Nunn, N. (2013). On the origins of gender roles: Women and the plough. *The Quarterly Journal of Economics*, 128(2):469–530.

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., and Cattaneo, A. (2014). Adoption and intensity of adoption of conservation farming practices in Zambia. *Agriculture, Ecosystems & Environment*, 187:72–86.

Duflo, E. and Udry, C. (2004). Intrahousehold resource allocation in Cote d'Ivoire: Social norms, separate accounts and consumption choices. Cambridge, MA: Working Paper 10498, National Bureau of Economic Research.

Haddad, L. (1999). The income earned by women: Impacts on welfare outcomes. *Agricultural Economics*, 20(2):135–141.

Haddad, L., Hoddinott, J., Alderman, H., et al. (1997). *Intrahousehold resource allocation in developing countries: Models, methods, and policy.* Baltimore, MD: Johns Hopkins University Press.

Haggblade, S. and Tembo, G. (2003). *Conservation farming in Zambia.* Washington, DC: International Food Policy Research Institute.

Jack, K. (2011). *Market inefficiencies and the adoption of agricultural technologies in developing countries.* Cambridge, MA: White paper, Agricultural Technology Adoption Initiative, Abdul Latif Jameel Poverty Action Lab/MIT.

Knowler, D. and Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy*, 32(1):25–48.

Lundberg, S. J., Pollak, R. A., and Wales, T. J. (1997). Do husbands and wives pool their resources? Evidence from the United Kingdom child benefit. *Journal of Human Resources*, Jul 1:463–480.

O'Sullivan, M., Rao, A., Banerjee, R., Gulati, K., and Vinez, M. (2014). *Levelling the field: Improving opportunities for women farmers in Africa.* Washington, DC: World Bank.

Quisumbing, A. R., Maluccio, J. A., et al. (2000). *Intrahousehold allocation and gender relations: New empirical evidence from four developing countries*. Washington, DC: International Food Policy Research Institute.

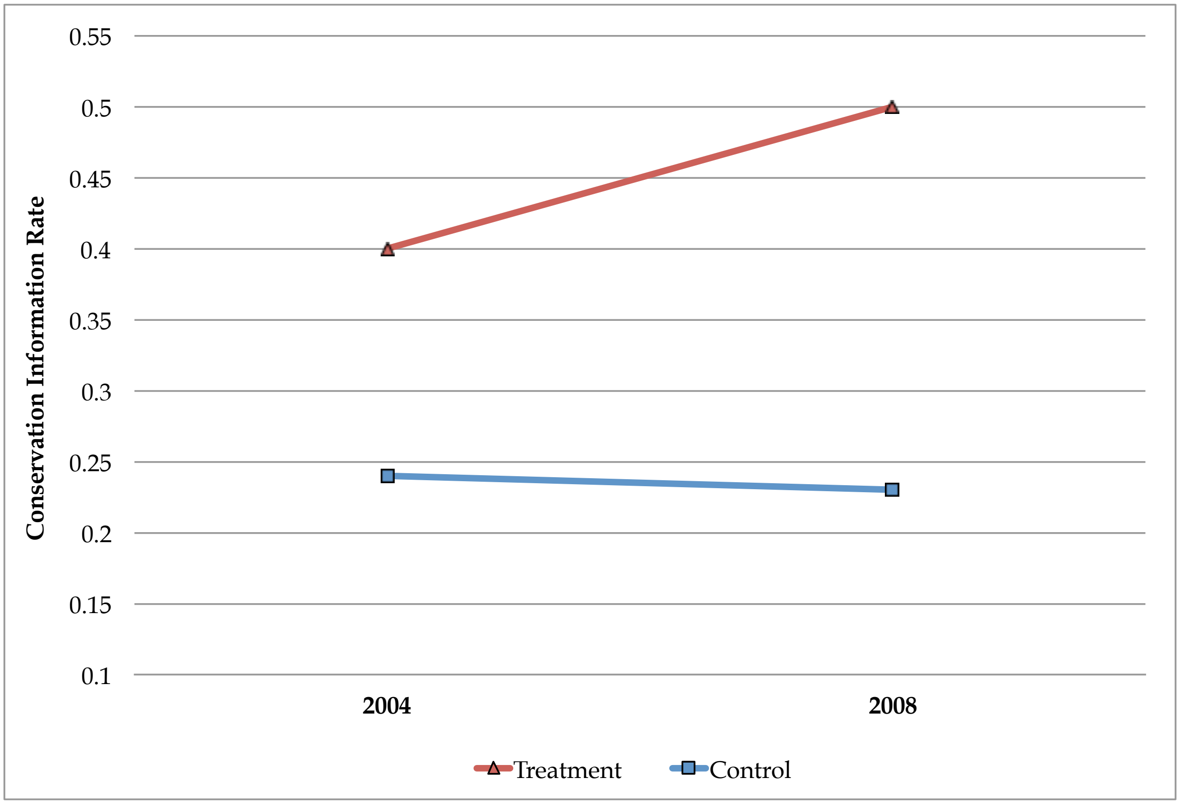
Salem, R. M. (2004). Mens surveys: New findings. *Population Reports. Series M: Special Topics*, (18):1–23.

Teklewold, H., Kassie, M., and Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural ethiopia. *Journal of Agricultural Economics*, 64(3):597–623.

Voigtländer, N. and Voth, H.-J. (2013). How the West 'invented' fertility restriction. *The American Economic Review*, 103(6):2227–2264.

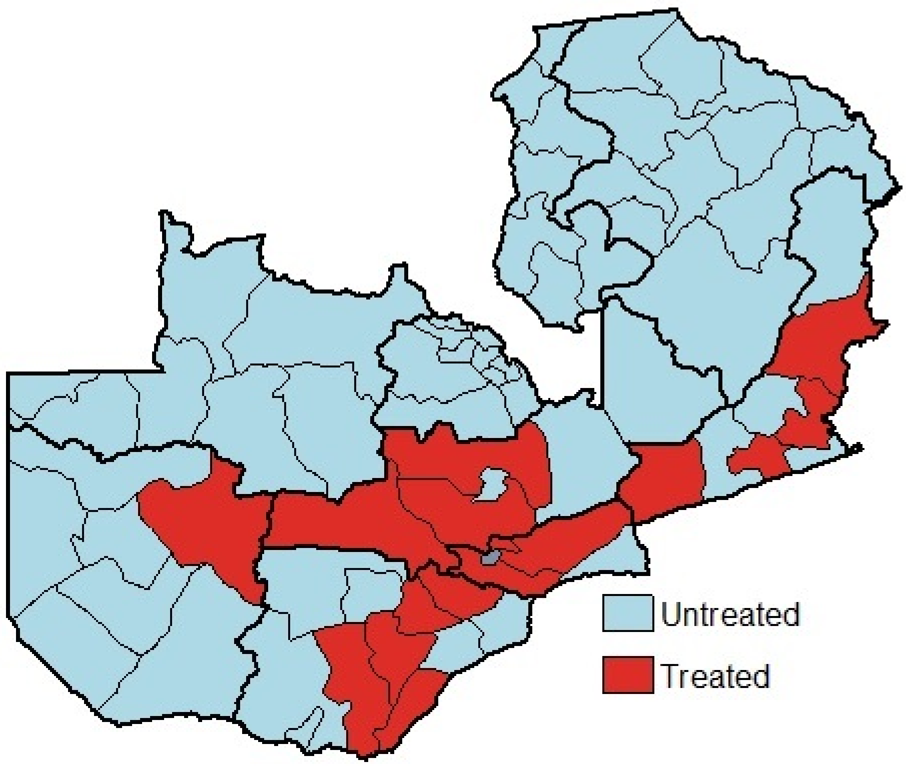
9 Figures

Figure 1: Trends in Conservation Farming Knowledge



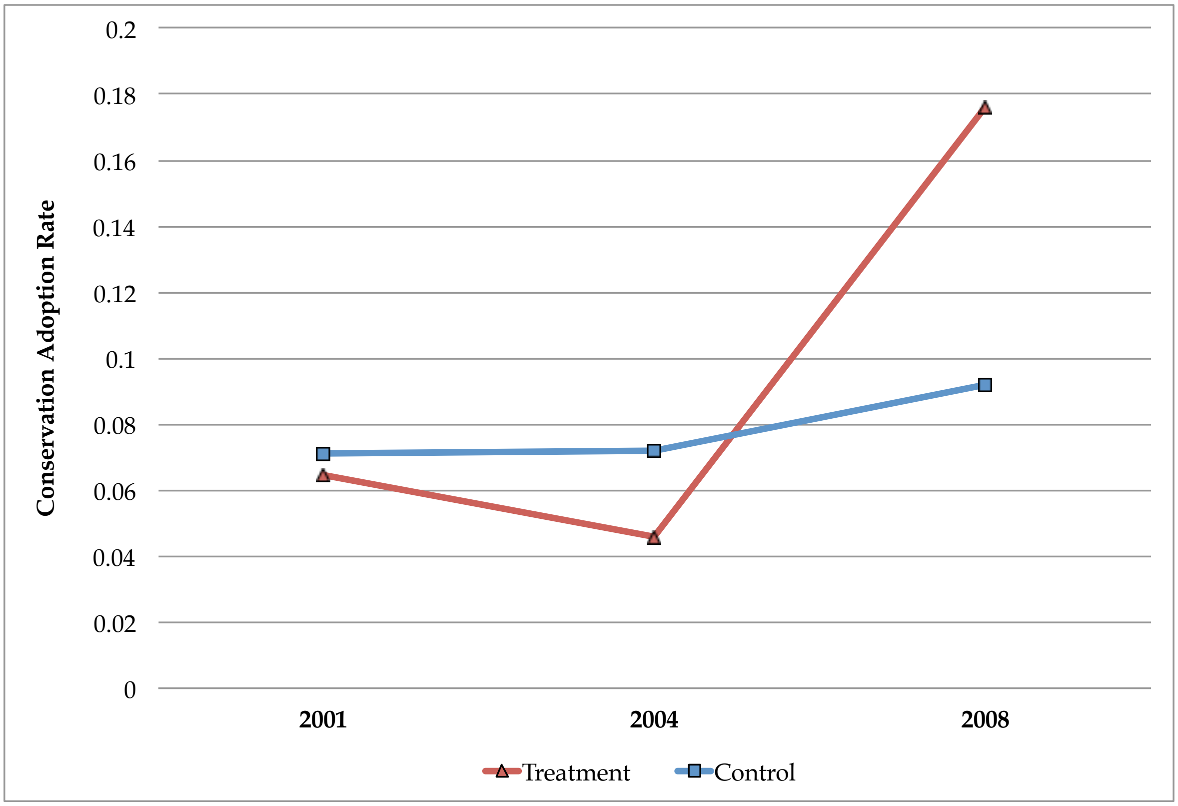
Note: Trends calculated using Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys.

Figure 2: Conservation Farming Training Treatment by District in Zambia



Note: Treatment districts received training in 2007. Data provided by CFU.

Figure 3: Trends in Conservation Farming Adoption



Note: Trends calculated using Zambia 2001, 2004, and 2008 Rural Agricultural Livelihoods Surveys.

10 Tables

Table 1: Balance Table of Baseline Demographic Variables by Treated and Control Districts: Rural Agricultural Livelihoods Survey

	(1) Treatment Districts	(2) Control Districts	(3) Treated-Control
Age	34.959	34.627	0.332
			(0.315)
Female	0.516	0.508	0.008
			(0.006)
Marital Status	0.594	0.582	-0.012
			(0.017)
Sick	0.006	0.007	0.001
			(0.001)
Education	5.495	5.516	0.021
			(0.336)
Household Size	5.271	4.458	-0.813***
			(0.256)

Data Source: Zambia 2004 Rural Agricultural Livelihoods Surveys

Notes: Robust standard errors in parentheses clustered at the district level. Education is defined as number of years of formal education. Sick is an indicator for whether the household head is ill.

Table 2: Balance Table of Baseline Demographic Variables by Treated and Control Districts: Labor Force Survey

	(1) Treatment Districts	(2) Control Districts	(3) Treated-Control
Age	35.146	35.458	-0.312
			(0.995)
Female	0.490	0.481	0.009
			(0.005)
Marital Status	0.639	0.631	0.007
			(0.033)
Literate	0.739	0.741	-0.002
			(0.061)
Education	0.842	0.850	-0.008
			(0.040)
Household Size	5.871	5.849	0.022
			(0.229)

Data Source: Zambia 2005 Labor Force Survey

Notes: Robust standard errors in parentheses clustered at the district level. Education is defined as any formal education.

Table 3: Balance Table of Baseline Demographic Variables by Treated and Control Districts: Living Conditions Monitoring Survey

	(1) Treatment Districts	(2) Control Districts	(3) Treated-Control
Age	34.581	35.274	0.693
			(0.646)
Female	0.501	.510	0.009
			(0.005)
Marital Status	0.504	0.502	-0.002
			(0.030)
Disabled	0.014	0.014	-0.000
			(0.001)
Poor	0.628	0.556	-0.072
			(0.067)
Education	7.548	7.253	-0.296
			(0.640)
Household Size	6.636	6.258	-0.378
			(0.303)

Data Source: Zambia 2004 Living Conditions Monitoring Survey

Notes: Robust standard errors in parentheses clustered at the district level. Education is defined as number of years of formal education. Poor is a self-reported indicator variable denoting perceived poverty. Disabled is an indicator for whether the household head is disabled.

Table 4: Impact of CF Training on Receipt of Other Aid Programs

	(1)	(2)	(3)
Treated*Post 2007	-0.0426	-0.0392	-0.0408
	(0.0519)	(0.0518)	(0.0520)
Post 2007	0.0905***	0.0857***	0.0864***
	(0.0320)	(0.0313)	(0.0316)
Treated District	-0.0450	-0.00927	-0.00607
	(0.0356)	(0.0340)	(0.0344)
Province FE	NO	NO	YES
Controls	NO	YES	YES
Observations	10,682	10,682	10,682

Data Sources: Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys

Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female headed household, total expenditures, and age.

Table 5: Impact of CF Training on CF Prevalence

	(1)	(2)
	Probability of Conservation Farming	
Treated*Post 2007	0.130***	0.126***
	(0.0279)	(0.0281)
Post 2007	0.0203	0.0214
	(0.0213)	(0.0215)
Treated District	-0.0260	-0.0271
	(0.0171)	(0.0174)
Mean Dependent Variable	0.1150	0.1150
Percent Effect	113.04%	109.57%
Controls	NO	YES
Observations	7,979	7,979

Data Sources: Zambia 2004 and 2008 RALS

Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, and age.

Table 6: Impact of CF Training on Labor Supply

	(1)	(2)	(3)	(4)
	Female Labor Supply		Female Labor Share	
Treated*Post 2007	0.901**	1.105***	0.0323*	0.0307*
	(0.392)	(0.386)	(0.0171)	(0.0172)
Post 2007	-0.491**	0.0476	-0.0204*	0.0173
	(0.188)	(0.226)	(0.0109)	(0.0139)
Treated District	-0.233	-0.430	-0.0155	-0.0170
	(0.382)	(0.399)	(0.0113)	(0.0122)
Mean Dependent Variable	5.7267	5.7267	0.4956	0.4956
Percent Effect	15.73%	19.30%	6.52%	6.19%
Province FE	NO	YES	NO	YES
Controls	YES	YES	YES	YES
Observations	5,336	5,336	7,947	7,947

Data Sources: Zambia 2005 and 2008 Labor Force Surveys

Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, and age.

Table 7: Impact of CF Training on Off-Farm Wages

	(1)	(2)	(3)
Treated*Post 2007	-3,449	-14,837	-16,639
	(33,112)	(39,183)	(37,761)
Post 2007	88,919***	77,605***	76,692***
	(15,866)	(17,710)	(17,314)
Treated District	3,452	28,553	17,820
	(25,022)	(22,723)	(36,649)
Province FE	NO	NO	YES
Controls	NO	YES	YES
Observations	63,520	57,308	57,308

Data Sources: Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys

Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female headed household, total expenditures, and age.

Table 8: Impact of CF Training on Female Empowerment Outcomes

	(1)	(2)	(3)	(4)	(5)
	Fertility		Female Politicians		
Treated*Post 2007	-0.0671**	-0.0633**	0.0281	0.0483	0.0595
	(0.0285)	(0.0267)	(0.0563)	(0.0679)	(0.0708)
Post 2007	-0.110***	-0.105***	-0.0318	-0.0362	-0.0751
	(0.0158)	(0.0150)	(0.0442)	(0.0537)	(0.0674)
Treated District	0.0338	0.0337	-0.0203		
	(0.0238)	(0.0213)	(0.0762)		
Mean Dependent Variable	0.2473	0.2473	0.1144	0.1144	0.1144
Percent Effect	-27.13%	-25.59%	24.55%	42.25%	52.04%
Province FE	NO	YES	YES	NO	NO
District FE	NO	NO	NO	YES	YES
Controls	YES	YES	NO	NO	YES
Observations	6,262	6,262	188	188	188

Data Sources: Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys

Notes: Robust standard errors are clustered at the district level. Regressions (1) and (2) control for education, household size, an indicator for female headed household, and age. Regressions (4) and (5) control for year, number of politicians in a district, and political party affiliation. Female politician regressions include parliamentary election results for 2001, 2006, and 2011 and are weighted by number of politicians in each district.

Table 9: Impact of CF Training on Child Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	School		Education		Sick	
Treated*Post	0.0560*	0.0585**	0.0606	0.0311	-0.00660	-0.00642
	(0.0293)	(0.0248)	(0.0867)	(0.0770)	(0.00874)	(0.00877)
Post	-0.0171	-0.0261	-0.0585	-0.0100	-0.0229***	-0.0223***
	(0.0197)	(0.0186)	(0.0652)	(0.0565)	(0.00538)	(0.00533)
Treated District	-0.0258	-0.0281	0.0102	0.0194	0.00223	0.00227
	(0.0406)	(0.0393)	(0.104)	(0.0895)	(0.00879)	(0.00878)
Province FE	NO	YES	NO	YES	NO	YES
Controls	YES	YES	YES	YES	YES	YES
Observations	9,795	9,795	8,302	8,302	16,615	16,418

Data Sources: Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys

Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female headed household, and age.

Table 10: Impact of CF Training on Alcohol Expenditures as a Share of Total Household Expenditures

	(1)	(2)	(3)
	Household Alcohol Expenditures Share		
Treated*Post 2007	-0.00552**	-0.00576**	-0.00556**
	(0.00252)	(0.00250)	(0.00255)
Post 2007	-0.000163	-0.000713	-0.000644
	(0.00171)	(0.00174)	(0.00174)
Treated District	0.00223	0.00219	0.00155
	(0.00237)	(0.00217)	(0.00251)
Mean Dependent Variable	0.0140	0.0140	0.0140
Percent Effect	-39.30%	-41.01%	-39.58%
Province FE	NO	NO	YES
Controls	NO	YES	YES
Observations	20,036	19,990	19,990

Data Sources: Zambia 2004 and 2010 LCMS

Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female headed household, total expenditures, and age.

Table 11: Impact of CF Training on Clothing Expenditures as a Share of Total Household Expenditures

	(1)	(2)	(3)
	Household Clothing Expenditures Share		
Treated*Post 2007	0.0154*	0.0158*	0.0166*
	(0.00830)	(0.00830)	(0.00837)
Post 2007	-0.00813*	-0.00998**	-0.0105**
	(0.00428)	(0.00430)	(0.00426)
Treated District	-0.0150**	-0.0162***	-0.0126*
	(0.00709)	(0.00608)	(0.00715)
Mean Dependent Variable	0.0907	0.0907	0.0907
Percent Effect	16.98%	17.42%	18.30%
Province FE	NO	NO	YES
Controls	NO	YES	YES
Observations	19,990	19,990	19,990

Data Sources: Zambia 2004 and 2010 LCMS

Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female headed household, total expenditures, and age.