Preliminary draft. Do not cite

How Do Nuclear and Extended-Family Households Differ in Labor Allocation Decisions due to Agricultural Technology Adoption? Evidence from Burkina Faso

Aissatou Ouedraogo, Michigan State University, Ouedrao2@msu.edu
Andrew Dillon, Michigan State University, dillona6@msu.edu
Maria Porter, Michigan State University, mporter1@anr.msu.edu

Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2

Preliminary draft. Do not cite

Preliminary draft. Do not cite

How Do Nuclear and Extended-Family Households Differ in Labor Allocation Decisions due to Agricultural Technology Adoption? Evidence from Burkina Faso

Aissatou Ouedraogo
Andrew Dillon
Maria Porter

Michigan State University

May 2016

PRELIMINARY DRAFT FOR CONFERENCE
DO NOT CITE

Abstract: Households adopting new agricultural technologies often face labor constraints influencing the extent to which such technologies are productive and profitable. Such labor constraints differ for nuclear and extended-family households. In a randomized control trial, we estimate the heterogeneous treatment effect of an efficacious fertilization technique called microdosing by differences in household structure. The encouragement design which allocated starter packs and microdosing training to assigned households induced extended family households to reduce labor to agricultural activities, while nuclear households increased such labor activities. These differentiated effects are dominated by households who had previously used fertilizer. Thus, microdosing does not completely relieve the binding labor constraint for extended households who previously used broadcast fertilizer methods. Although nontrivial labor allocation is necessary for both broadcast and microdosing, for extended households, microdosing lowers total person-days to agricultural production by 18% relative to mean labor allocation at baseline, whereas nuclear households increase labor allocation to agricultural production by 36%.

Acknowledgements: The authors gratefully acknowledge funding from the Bill and Melinda Gates Foundation through the GISAIA project, and BASIS-USAID. We also acknowledge, without implicating, Isabelle Diabire, Thom Jayne, Estelle Plat, Ashesh Prasann, Melinda Smale, Nicolo Tomasseli, Adama Traore, Association des grossistes et détaillants d'intrants agricoles, Institut de l'Environnement et de Recherches Agricoles, and Innovations for Poverty Action for their collaboration throughout the project. ,

JEL Keywords: O12, O13, Q12, J22, J12

I. Introduction

Increased agricultural productivity has proven to improve the welfare of many households in developing countries, with one notable example being the Green Revolution in India. As household labor becomes more productive, household income also increases. In addition, children's labor becomes less valuable as an agricultural input into production. For both these reasons, children's schooling increases, human capital investment increases, and infant and child mortality is reduced. With lower mortality rates and a greater potential for investing in child quality, fertility rates decline (Becker 1981). Such demographic changes may encourage economic growth (Galor 2005). While some debate continues on the exact mechanism of the demographic transition in a general model of economic growth (Galor and Weil 2000), productivity changes are central to all of the above mechanisms in explaining household size reduction.

This paper investigates a micro foundation of this macro-development model, the potential labor substitution effects of agricultural technology adoption which could increase labor availability to other productive activities and raise overall labor productivity. When additional adults are available to contribute labor to productive activities, labor constraints in technology adoption and productivity may be alleviated. We explore the potential for such economies of scale in production in the context of household adoption of new agricultural techniques having the potential to augment productivity.

Hence, household structure is an important determinant in explaining productivity changes in a demographic transition model, particularly within countries for which household structure is not uniform. Due to this non-uniformity of household structure within countries, the gains from technology adoption may vary by household type and induce different labor substitution patterns as the change in the marginal product of labor will not respond homogenously across household type.

Despite an increasing fragmentation of households to smaller units in the developing world, there is still evidence of the prevalence of household organization characterized by the cohabitation of extended family members in sub-Saharan African countries (Bongaarts 2001 and West 2010). The majority of these households are rural subsistence-farmers where labor remains a crucial input in their productive activities. Moreover, these regions are characterized by missing labor markets, and consequently, households in these regions heavily rely on family members as the main source of their agricultural labor.

In this article, we examine how nuclear and extended family households differ in their labor responses to the introduction of a new and productive agricultural technology. Extended households, comprised of multiple nuclear families, differ from nuclear households in that they have more adult labor available to them, and coordinate labor activities across family members in ways that nuclear households are unable to. Yet, given their larger size, labor allocation decision-making among extended households could inhibit adoption if coordination problems create high transaction costs compared to nuclear households, given their larger size (Poteete and Ostrom 2004).

As household structure and technology adoption are potentially simultaneously determined, to identify heterogeneous treatment effects of technology adoption across nuclear and extended households, we must exogenously vary the availability of such technology. To do so, we conducted a randomized control trial where the treatment included training in a fertilizer application technique called microdosing, along with a starter kit comprised of certified sorghum seed and fertilizer.

This article contributes to a broader literature investigating whether labor allocation is efficient within extended households (Kazianga and Wahhaj 2013; Guirkinger and Platteau 2014). For example, different household structures lead to differences in efficiency in the allocation of production and consumption resources (Kazianga and Wahhaj 2015). Our study is the first to investigate how labor allocation across households with different structures responds to the adoption of potentially labor-intensive agricultural technology.

We find that the microdosing intervention increased labor allocation to agricultural production among nuclear households, particularly for applying fertilizer, harvesting, and weeding. In contrast, agricultural labor was reduced among extended family households. These differential effects are also greatest at the intensive margin, that is, for those households who already used fertilizer prior to the intervention. Such differences may be attributed to several possible reasons. One possibility is that extended households already allocating more labor to agricultural activities may have a lower marginal product of labor relative to nuclear households. Another possibility is that extended households may have coordination problems in allocating labor to certain activities, so that microdosing substitutes for labor that would have otherwise been used for production but requires potentially significant transaction costs to using such labor.

The remainder of the article is structured as follows. We describe our experimental design in Section II, where we also describe the microdosing technology. In Section III, we explain how we classify households according to nuclear or extended categories. In Section IV, we describe the difference-in-difference methods used to identify the intent to treat effect of the microdosing technology intervention. In Section V, we describe the data and sample restrictions. We also summarize differences in demographic and production characteristics across nuclear and extended households, as well as balancing tests by treatment assignment within each household category. Section VI presents the results, while Section VII concludes.

II. Experimental Design

Sorghum is the main food staple and most widely cultivated dryland crop among rural households in the West African Sahel. Yet, as in much of this region, average sorghum yields in Burkina Faso are estimated at 0.8 tons per hectare, despite the potential to attain over 2 tons per hectare (Ministry of Agriculture, Burkina Faso 2010). One way to improve sorghum yields is to apply a technique called microdosing

In microdosing, farmers apply 2 to 6 grams of fertilizer (about a three-finger pinch) in or near the seed hole. The amount of fertilizer applied is equivalent to about 20 to 60 kg of fertilizer per hectare. Alternatively, the fertilizer can be applied as top dressing from 3 to 4 weeks after the seeded crop begins to emerge. In case of hard soil, farmers dig small holes and fill them with manure before the rain begins. Once the rain starts, the fertilizer and seeds are placed into the moist soil. This technique captures the water, so that it does not run off the hard-crusted soil, thereby encouraging root growth (ICRISAT, Fertilizer Microdosing, January 2009).

When applied to the seeding of improved sorghum varieties, microdosing raises yields considerably. In Burkina Faso, INERA (Institut de l'Environnement et de Recherches Agricoles) has reported grain yields of nearly 2000 kg/ha for improved sorghum varieties with microdosing. The primary drawbacks to microdosing are that it is time-consuming, laborious, and it is difficult to ensure that the correct amount of fertilizer is used for each dose.

Our experimental design used an encouragement design to randomly assign microdosing training and a starter kit which included fertilizer and certified sorghum seed sufficient for one hectare of sorghum production. We worked with AGRODIA, an organization of local agro-dealers in Burkina Faso, to supply these micro packets. The seed was certified by INERA, the public agricultural research institution in the country. INERA also provided training in microdosing to all households in treated villages.

We selected three provinces for our study: Bam and Sanmatenga from the Center-North region and Passoré from the North region. These provinces were selected because there is a high prevalence of sorghum cultivation and little cultivation of cash crops such as cotton. We collected a complete list of all 925 villages in these three provinces. Because this study was part of a larger project which involved collecting social network censuses in many of the villages, we restricted our potential pool of villages to those that were not too large to conduct such censuses. We therefore kept villages where the population size was between 190 and 800, provided that the number of households was no greater than 120 households. The number of households per village varied between 70 and 120 households. From the remaining 226 villages, 80 villages were randomly selected for the treatment group studied here, and 20 villages were randomly selected for the control group. In all these villages, a village enumeration included questions about plot information, sorghum production, and adoption of improved seeds.

Using this village enumeration, in each village, we then randomly sampled approximately 30 households growing sorghum. For these households, we conducted baseline and follow-up household surveys, where we collected detailed production and socio-economic information. Thus, detailed household surveys were conducted for 2400 households in all 80 villages in the treatment group, and for 600 households in all 20 villages in the control group.

In each of 80 treated villages, approximately 15 of the 30 surveyed households were randomly selected to receive free micro-packets of certified sorghum seed and fertilizer. In our analysis here, we compare these 1200 treated households to the 600 households surveyed in control villages which did not receive any micro-packets or any training in micro-dosing. We exclude all households in treatment villages who did not receive free micro-packets, but may have received training in microdosing. We do so to eliminate any potential spillover effects due to possible technological transfer, which in turn may lead to underestimation of the program's impact on treated households.

III. Household Classification

Our objective in this article is to identify the potential heterogeneous impact of our microdosing treatment on labor allocation, depending on differences in household structure which may influence such production decisions. We define a household as "a socio-economic unit within which one or more members, related or not, live in the same house or concession, pool their resources, and jointly meet the bulk of their food and other basic needs under the authority of one of them, called the head of household" (Beaman and Dillon 2012). This definition of the household may include multiple "nuclear" households cohabiting in one "extended" household. Such cohabitation of multiple nuclear households may arise through two possible channels: vertical extension of the household, where married sons and their nuclear family have common residency with their fathers; and horizontal extension, where married brothers and their respective nuclear families cohabitate (Laslett and Wall 1982; West 2010; Kazianga and Wahhaj 2015).

Therefore, we define an "extended" household as a household that meets at least one of the following criteria: households having one married male who is not the household head; or household heads having married sons, married brothers, daughters-in-law, or sisters-in-law living in the household (see Panel B of Table 1). Households that do not meet these criteria are classified as "nuclear" households. According to this definition, 366 of the 1,093 households in our final sample (about 34 percent) are extended households, and remaining households are classified as nuclear households.

The leading criterion for being qualified as an extended household is the household having more than one married male. This condition is met by about 30 percent of the final sample. When classified by relationship to the head, approximately 16 percent of the heads have at least one married son and nearly 9 percent of them live with one or multiple married brothers. The father and married son relationship is mirrored by approximately 15 percent of heads having at least one daughter-in-law. However, while only about 9 percent of the heads cohabitate with married brothers, up to 15 percent of them have at least one sister-in-law.

The definition of an extended household may not be well classified in binary terms. It is possible that labor substitution effects from technology adoption are predicated on household composition rather than meeting any of the criteria listed above. As a robustness check, we also investigate labor substitution effects using a continuous variable to indicate extended family status, namely the number of adult men within the household.

IV. Estimation Methods

Our randomized study design enables us to apply difference-in-differences (DID) methods to identify the causal effect of being given free microdosing packets and training on labor allocation. As the literature suggests both that household structure may be a constraint to adopting technology, as well as changing in response to productivity changes due to technology adoption, technology adoption and household structure are potentially simultaneously determined. Our experimental design permits identification of the direction of causality. Since treatment assignment was randomly allocated within treatment villages, we estimate the Intention to Treat (ITT) effect of receiving microdosing packets and training.

As we are interested in the differential effects of this intervention depending on whether households are comprised of either extended or nuclear family structures (as outlined above), we interact treatment assignment (T_{ij}) with an indicator variable for family structure (E_{ij}), with households indexed by *i* and villages indexed by *j*. Therefore, we estimate OLS for the following set of regressions:

$$(Y_{ij}^1 - Y_{ij}^0) = \beta_1 T_{ij} + \beta_2 E_{ij} + \beta_3 (T_{ij} \text{ x } E_{ij}) + \beta_3 L_{ij}^0 + \mu_j + (\varepsilon_{ij}^1 - \varepsilon_{ij}^0) \text{ ,} \qquad (1)$$

where we difference outcome measures across post- and pre- treatment survey data. Superscripts 1 or 0 refer to follow-up and baseline data respectively. Our primary outcomes are labor allocation in person-days per hectare in total and disaggregated by tasks, including: inorganic and organic fertilizer application, harvesting, and weeding.. Since treatment assignment is allocated by village, we cluster all standard errors by village.

In this specification, we also control for the number of hectares devoted to sorghum as the main crop at baseline (L_{ij}^0) and village fixed effects (μ_j). In addition, we estimate the same regressions without these additional controls. To be specific, in the tables below, Model 1 refers to the base specification that does not include these additional controls; Model 2 includes L_{ij}^0 to control for differences in land holding at baseline, which may result in possible economies of scale in production; and Model 3 also controls for village fixed effects to control for any village-specific unobservables.

Finally, in addition to estimating these regressions for our overall sample of households, we also split our sample into those households who used inorganic fertilizer before the intervention, and those that did not do so. We do so to differentiate between potential effects of our intervention at the extensive and intensive margins. As fertilizer adoption, whether using microdosing or broadcast methods, may require a minimum labor allocation, disaggregating by whether or not households used fertilizer at baseline delineates the intent to treat effect by households who were able to make this investment prior to receiving treatment assignment from those who were unable to do so.

V. Data

We collected detailed household survey data within our study villages, both before and after the intervention. We surveyed all those who received starter kits in treatment villages. In addition, we surveyed approximately 30 households at random from each of the control villages. The baseline survey took place at the end of 2013, just prior to the beginning of the agricultural season. Households received microdosing training and starter kits at planting time in January 2014. Our follow-up survey was conducted one year later, at the beginning of 2015.

Our multi-topic household surveys collected information on various demographic, socio-economic, and agricultural production characteristics. We collected data at the household level as well as at the individual plot manager level. In total, we collected 1,529 household surveys at baseline. With a household attrition rate of 6.7%, we collected household surveys both at baseline and follow-up for 1,426 households.

Sample restrictions

As our interest is in determining the differential impact of the microdosing intervention by household structure, and as male and female headed households are considerably different from one another, we first restrict our sample to male-headed households. Extended households are mostly headed by men (Colson 1962; Kazianga and Wahhaj 2015), and most female headed households are nuclear households.[1] This restriction ensures that in comparing across different household structures, we are not conflating these differences with differences in male or female headed households. This drops about 10 percent of the households.

In addition, to eliminate any potentially differentiated effects specific to gender differences, we also exclude all female-controlled plots from the sample. Preliminary analysis of the sample (results not presented here) indicated that the proportion of female-plot managers among extended households is much higher relative to that among nuclear households. Consequently, comparing labor allocation across the two types of households without eliminating female-controlled plots will likely lead to outcomes being driven by gender-specific effects rather than by differences in household structure.

Given that our identification strategy consists of investigating changes in labor allocation to sorghum production across the pre- and post- treatment periods, the sample is further restricted to male-headed households that had at least one male-controlled sorghum plot in each of the two rounds, resulting in 1,119 remaining households.

Finally, we identified outliers in labor allocation measured in person-days per hectare as those observations with values greater than three times the standard deviation. This

[1] Only about 5 percent of the extended households (in the sample before the headship gender restriction) are headed by a female member.

restriction eliminates 26 households from our sample, resulting in a final sample size of 1,093 households. Table 1 summarizes these sequential, cumulative sample restrictions.

Demographic And Production Characteristics by Household Structure

Table 2 presents summary statistics of demographic and production characteristics across extended and nuclear households prior to our intervention, and shows that the two types of households are very different in terms of their demographic and production characteristics. First, the heads of extended households are on average about six years older than nuclear heads. As expected, the numbers of adult males and females are significantly higher for extended households.

These differences in household composition will likely impact their labor response to the introduction of the microdosing technology. In particular, the larger number of adults in the extended households implies the need for more coordination efforts in their labor allocation decisions. As labor markets are almost nonexistent in the study zone, households rely heavily on family labor for their agricultural production activities (Udry 1996; Kazianga and Wahhaj 2013). As a result, since the microdosing technology is potentially labor-intensive, households may have to readjust their labor allocation if they were already facing labor constraints before the intervention. This possible need for labor allocation readjustment is likely to be higher for extended households relative to nuclear households.

The larger household size of the extended household (in terms of adult members who are more than 14 year-old) is further reflected in larger total land holdings devoted to agricultural production, especially for sorghum. Moreover, the proportion of households that apply fertilizer among extended households exceeds that of nuclear households by 10 percent, and the difference is statistically significant at 5 percent. Finally, relative to nuclear households, labor allocation expressed in number of men-days per hectare is higher among extended households for all activities. In addition, both male and female labor applied to sorghum plots is higher for extended households.

Pre-Treatment Household Demographic and Production Characteristics

In order to attribute any changes in labor allocation among the assigned households to the microdosing treatment, it is important to ensure that households assigned to treatment and control groups share similar pre-intervention characteristics. Since we are interested in the heterogeneous effect of the microdosing treatment by household structure, we conduct balancing tests across treated and control households within each category of household structure.

Table 3 presents summary statistics of pre-intervention household demographic and production characteristics by assignment status for extended and nuclear households respectively (see Panels A and B). Overall, the p-values corresponding to the statistical significance level of the mean differences across the assigned and control households greatly exceed the 10% significance level, indicating that the randomization produced balanced assignment and control groups of households. The only exception is labor application to manure, where on average, nuclear households in the control group allocate six more men-days per hectare to manure application relative to nuclear households in the treatment group.

VI. Results

We summarize estimation results of the ITT effect of receiving the microdosing packets and training on total labor allocation per hectare in Panel A in Tables 4 and 5. The outcome variable is the change in total labor allocation between pre- and post-intervention periods. Table 4 presents the results when treatment assignment is interacted with a binary indicator of household structure (extended versus nuclear), while Table 5 summarizes estimation results when treatment assignment is interacted with the number of adult males in the household, a continuous proxy for household structure. Every panel contains three econometric models and presents results for the overall sample, as well as the subsample of households who used inorganic fertilizer at baseline, and those who did not do so prior to treatment.

The first model presents the specification where we only control for assignment status and household structure. The second specification includes land as a control variable, as variation in household land holdings could affect the labor constraint to microdosing adoption. We include village fixed effects in the third model to account for the potential effect of village-level unobservables, including factors such as access to input, labor and output markets. Standard errors are in parentheses, and are all clustered by village, as treatment assignment has been carried out by village.

The ITT effect of the intervention impact on total labor allocation (Table 4, Panel A) for nuclear households is captured by the coefficients on the variable *Treatment*. The positive sign of the coefficients across all three models indicates that the intervention unambiguously increased total labor allocation to sorghum production among nuclear households. Results for the split sample show that the impact of the program on total labor allocation is stronger among households who did not use inorganic fertilizer at baseline, especially when village fixed effects are included (Table 4, Panel A, Model 3). Specifically, treatment assignment led to an increase of 78 person-days per hectare in total labor allocated to sorghum production among nuclear households who did not apply fertilizer to sorghum at the baseline, and this increase is statistically significant at the 1% significance level. This implies an average increase of 44%, as average total labor allocation to sorghum production at baseline is 176 person-days per hectare.

In contrast, the treatment effect on extended households is negative, and seems to be mainly due to households who used fertilizer at baseline. As the overall effect of treatment on extended households is the sum of coefficient estimates on the treatment variable and the interaction term, the reduction in person-days spent on sorghum production for treated extended households ranges between 15 and 31 person-days per hectare, or 8.5% to 18% on average. This impact is statistically significant at 10%. This can be explained by the fact that extended households may be constrained in terms of how much labor can be allocated to such activities, either because of a lower marginal product of labor at higher labor allocations to begin with relative to nuclear households, or to coordination costs, or to some combination of both.

Since household structure is highly related to the number of adult male household members (based on our household classification criteria as well as the existing literature on household organization, we estimate another set of regressions where treatment is interacted with the number of adult males as a way to check the robustness of the results. The results, shown in Table 5 (Panel A), follow a similar pattern with the ones presented in Table 4, with even higher magnitudes of the coefficients on the variable *Treatment*. This supports our prediction that the assignment of the microdosing package will increase labor allocation to sorghum production among nuclear households. The interaction effects also support prior conclusions, as the treatment effect declines as the number of adult males increases. These results are also consistent across the two sub-samples of households, although coefficient estimates on the interaction terms are not statistically significant.

To understand how the intervention increased total labor allocation among the assigned households, we also present results for specific activities in Tables 4 and 5. The outcome variables presented in panels B through G in both tables are respectively for labor allocation to: inorganic fertilizer application, harvest, organic fertilizer application, and weeding.

Labor allocation results with respect to fertilizer application indicate that the program had a very significant impact for treated nuclear households. Even with village fixed effects, compared to nuclear households in control villages, nuclear households in treatment villages increased their time spent on fertilizer application by 52%, and this effect is statistically significant at 5%. In contrast, treatment effects for extended households are estimated with less precision, and indicate less of an effect of treatment if any, particularly for those who were already using fertilizer at baseline.

That these potentially negative effects are primarily due to extended households who were already using fertilizer makes sense since other households were not devoting any time to fertilizer application to begin with. It is also possible that extended households already applying fertilizer may apply it in a more concentrated way in response to training than they had with the broadcast method. That is, they may be applying it to less cropland, depending on the amount of labor required for microdosing versus broadcast methods.

In the regressions in Table 5, treatment effects are similar, and there is no marginal effect of the interaction term with the number of adult males. Overall, the effects on fertilizer application are very high, ranging from an additional 2 to 9 person-days per hectare, although they are only statistically significant for the overall sample and the subsample of households who did not use fertilizer to begin with. With an average baseline level of 5.6 person-days, these results indicate that the treatment had a very strong impact on time devoted to fertilizer application, particularly at the extensive margin. That is, the intervention encouraged many households to use fertilizer when they had not done so in the prior season, and this holds across different household structures.

The results related to harvest, presented in Panel C (Tables 4 and 5) are also positive for nuclear households. With coefficient estimates ranging between 4.7 and 21.5 person-days, and with average time to harvest at baseline being 32.2 person-days per hectare, this implies an average increase of 15% for households who had not used fertilizer at baseline, to 67% for those who had already been using fertilizer at baseline. Most estimates are also statistically significant (with the exception of estimates on households not using fertilizer at baseline in Models 1 and 2 in Table 4). Since time spent on harvest is likely to be positively correlated with the amount of output produced, these results suggest that the intervention increased sorghum production among nuclear households assigned to treatment, particularly for those who had already been using fertilizer. Combined with the fertilizer results, this also indicates that nuclear households who had been using broadcast methods were able to use their labor more effectively when switching to microdosing.

In contrast to nuclear households, extended households assigned to treatment spent nearly 20% less time on harvesting sorghum, on average (Models 1, 2, and 3, Panel C, Table 4). If time spent on harvest reflects the amount of output produced, then this strong differential impact on harvest labor suggests that the treatment assignment may have led to a decrease in total sorghum production among extended households. In addition, these effects are primarily driven by the extended households who were already using fertilizer at baseline. Yet, when we control for village unobservables, the net effect on extended households is zero. Thus, much of these differences is likely due to village-specific production shocks. What is interesting is that within these same villages, nuclear households were positively impacted by treatment. This is further evidence for extended households being constrained in their ability to gain more labor for microdosing.

Treatment effects on labor allocation to applying manure are similar to those on application of inorganic fertilizer. Labor allocated to manure application significantly increased among nuclear households in intervention villages, especially when we control for village specific unobservables in the split samples (Model 3 in Panel D in Tables 4 and 5). But while extended households who had not used inorganic fertilizer before the intervention are similarly affected, extended households who had used fertilizer previously reduced their time spent on manure application if they received treatment. When controlling of village unobservables, the net average decrease for such households is nearly 42%.

Nuclear and extended households also differ significantly in how treatment influences labor allocation to weeding. One might expect the weeding labor requirement to decrease among assigned households, given that microdosing targets the seed-hole. While this seems to be the case for extended households assigned to treatment, assigned nuclear households significantly increase weeding efforts, with average treatment effects ranging between 18% and 51%, depending on whether village fixed effects are included. In contrast, extended households reduce time devoted to weeding by between 11% and 42% on average. Although, it is important to note that once village fixed effects are included, there is no significant net effect of treatment on extended households who had previously used fertilizer.

VII. Conclusion

Our findings show a significantly differential impact of microdosing on sorghum production by household structure, particularly among households who were already using fertilizer prior to the intervention. This heterogeneous impact of the intervention may be explained by two factors. The first is that extended households, owing to their larger size, may have coordination problems in their labor allocation decisions, and may therefore have difficulty in increasing labor allocation at the extensive margin. Yet, in addition, given their larger pool of available labor compared to nuclear households, the marginal product of labor for extended households may be lower relative to nuclear households.

References

Aune, J.B. and Coulibaly, A., 2015. Microdosing of Mineral Fertilizer and Conservation Agriculture for Sustainable Agricultural Intensification in Sub-Saharan Africa. In Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa (pp. 223-234). Springer International Publishing.

Beaman, L. and Dillon, A., 2012. Do household definitions matter in survey design? Results from a randomized survey experiment in Mali. Journal of Development Economics, 98(1), pp.124-135.

Becker, G. 1981. A Treatise on the Family. Cambridge, Mass.: Harvard University Press.

Bongaarts, J., 2001. Household size and composition in the developing world in the 1990s. Population studies, 55(3), pp.263-279.

Bielders, C.L. and Gérard, B., 2015. Millet response to microdose fertilization in south–western Niger: effect of antecedent fertility management and environmental factors. Field Crops Research, 171, pp.165-175.

Camara, B.S., Camara, F., Berthe, A. and Oswald, A., 2013. Micro-dosing of fertilizer-a technology for farmers' needs and resources. International Journal of AgriScience, 3(5), pp.387-399.

Colson, E., 1962. Family change in contemporary Africa. Annals of the New York Academy of Sciences, 96(2), pp.641-652.

Galor, O., 2005. The demographic transition and the emergence of sustained economic growth. Journal of the European Economic Association, 3(2-3), pp.494-504.

Galor, O. and Weil, D.N., 2000. Population, technology, and growth: From Malthusian stagnation to the demographic transition and beyond. American economic review, pp.806-828.

ICRISAT. 2012. Fertilizer Microdosing, July 2012

Kazianga, H. and Wahhaj, Z., 2015, May. Norms of Allocation within Nuclear and Extended-Family Households. In 2015 AAEA & WAEA Joint Annual Meeting, July 26-28, San Francisco, California (No. 205534). Agricultural and Applied Economics Association & Western Agricultural Economics Association.

Laslett, P., Wall, R., Nakamura, J.I. and Miyamoto, M., 1982. Household and family in past time. Economic Development and Cultural Change, 30(2), pp.229-269.

Ministere de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques. 2010. Diagnostic du secteur Semencier du Burkina Faso. Document final. Ouagadougou, Burkina Faso, November.

Poteete, A.R. and Ostrom, E., 2004. Heterogeneity, group size and collective action: The role of institutions in forest management. *Development and change*, *35*(3), pp.435-461.

Rosenzweig, M.R. and Wolpin, K.I., 1985. Specific experience, household structure, and intergenerational transfers: farm family land and labor arrangements in developing countries. The Quarterly Journal of Economics, pp.961-987.

Udry, C., 1996. Gender, agricultural production, and the theory of the household. Journal of political Economy, pp.1010-1046.

West, Colin Thor. 2010. Household Extension and Fragmentation: Investigating the Socio-Environmental Dynamics of Mossi Domestic Transitions. Human Ecology 38.3, pp 363-76.

Table 1: Sample Restrictions and Household Structure

Sample restrictions	**Number excluded**	**Number remaining**
All households in baseline	0	1,529
All households in follow-up	0	1,428
Households in both surveys	103	1,426
Remaining male-headed HHs	145	1,281
Remaining male-headed HHs with at least one plot managed by male	16	1,265
Remaining male-headed HHs producing sorghum at baseline	63	1,202
Remaining male-headed HHs producing sorghum both at baseline and follow-up	83	1,119
Final sample after dropping outliers	26	1,093
Household structure	**Number of Households**	
HH has at least one additional married male besides the head	324	
HH head has at least one married son	176	
HH head has at least one married brother	96	
HH head has at least one daughter-in-law	166	
HH head has at least one sister-in-law	139	
Extended HHs (HHs that meet at least one of the criteria above)	366	
Nuclear HHs (HHs that meet none of the criteria above)	727	
Total number of HHs	**1,093**	

Note: Observations are at the household level.
Outliers are identified as observations with values more than three times the standard deviation above the mean.

Table 2: Demographic And Production Characteristics Across Extended And Nuclear Households

	Nuclear Households (N=727)		**Extended Households (N=366)**		
VARIABLES	Mean	SD	Mean	SD	P-Value
Household is Assigned Treatment	0.66	0.48	0.65	0.48	0.94
Head Age	46.24	14.08	52.10	15.41	0.00
Number of Adult Males	1.90	1.13	3.61	1.79	0.00
Number of Adult Females	2.21	1.27	4.13	2.23	0.00
Household size (members older than 15 years)	4.51	1.88	8.12	3.45	0.00
Household more than one married male	0.00	0.00	0.88	0.32	0.00
Household head has at least one married son	0.00	0.00	0.48	0.50	0.00
Household head has at least one married brother	0.00	0.00	0.26	0.44	0.00
Household head has at least one daughter-in-law	0.00	0.00	0.45	0.50	0.00
Household head has at least one sister-in-law	0.00	0.00	0.38	0.49	0.00
Household Uses Fertilizer	0.46	0.50	0.56	0.50	0.01
Total Land Holding (ha)	3.83	2.50	5.66	4.16	0.00
Total land where sorghum is main crop (ha)	2.97	2.14	4.40	3.61	0.00
Total land where millet is main crop (ha)	0.71	1.24	0.94	1.41	0.00
Total land where maize is main crop (ha)	0.05	0.22	0.09	0.32	0.02
Total land where rice is main crop (ha)	0.01	0.11	0.09	1.10	0.32
Total land where peanut is main crop (ha)	0.04	0.21	0.03	0.19	0.72
Total Labor Allocation to Fertilizer Application (men-days/ha)	7	18	11	20	0.00
Total Labor Allocation to Manure Application (men-days/ha)	14	22	23	29	0.00
Total Labor Allocation to Weeding (men-days/ha)	110	232	158	464	0.06
Total Labor Allocation to Harvest (men-days/ha)	49	125	81	308	0.05
Total Male Labor (men-days/ha)	111	234	172	608	0.06
Total Female Labor (men-days/ha)	109	231	168	337	0.00
Total Child Labor (men-days/ha)	38	175	45	165	0.48
Total Labor Allocation (men-days/ha)	257	559	385	1086	0.03

Table 3: Balancing Test Results Across Assigned and Control Households By Household Structure

	Panel A: Extended Households					**Panel B: Nuclear Households**				
	Control (N=127)		Assigned (N=239)			Control (N=250)		Assigned (N=477)		
VARIABLES	Mean	SD	Mean	SD	P-Value	Mean	SD	Mean	SD	P-Value
Head Age	52.31	15.61	51.99	15.34	0.87	46.56	14.34	46.08	13.96	0.68
Number of Adult Males	3.61	1.94	3.61	1.71	0.99	1.86	1.01	1.93	1.18	0.46
Number of Adult Females	4.10	1.90	4.15	2.39	0.85	2.24	1.36	2.19	1.22	0.66
Total number of adults	8.13	3.13	8.11	3.62	0.97	4.60	1.90	4.47	1.87	0.46
Household more than one married male	0.86	0.35	0.90	0.31	0.38					
Household head has at least one married son	0.28	0.45	0.26	0.44	0.69					
Household head has at least one married brother	0.48	0.50	0.48	0.50	0.99					
Household head has at least one daughter-in-law	0.49	0.50	0.44	0.50	0.35					
Household head has at least one sister-in-law	0.37	0.49	0.39	0.49	0.80					
Household Uses Fertilizer	0.50	0.50	0.59	0.49	0.32	0.40	0.49	0.50	0.50	0.10
Total Land Holding (ha)	6.24	4.64	5.35	3.85	0.18	3.96	2.65	3.77	2.42	0.53
Total land where sorghum is main crop (ha)	4.67	3.68	4.26	3.57	0.45	3.06	2.11	2.92	2.15	0.53
Total land where millet is main crop (ha)	1.03	1.43	0.89	1.40	0.54	0.73	1.40	0.69	1.15	0.80
Total land where maize is main crop (ha)	0.09	0.33	0.10	0.31	0.75	0.04	0.18	0.06	0.23	0.21
Total land where rice is main crop (ha)	0.23	1.86	0.02	0.13	0.33	0.01	0.07	0.02	0.13	0.40
Total land where peanut is main crop (ha) (ha)	0.03	0.14	0.04	0.21	0.60	0.04	0.24	0.03	0.20	0.74
Total land where niebe is main crop (ha)	0.19	1.81	0.05	0.27	0.35	0.08	0.36	0.05	0.28	0.31
Total Labor Allocation to Fertilizer Application (men-days/ha)	11	23	12	19	0.84	8	24	7	14	0.72
Total Labor Allocation to Manure Application (men-days/ha)	24	29	22	29	0.71	18	32	12	15	0.01
Total Labor Allocation to Weeding (men-days/ha)	140	132	168	566	0.47	121	186	104	253	0.29
Total Labor Allocation to Harvest (men-days/ha)	68	76	87	377	0.45	55	143	46	115	0.37
Total Male Labor (men-days/ha)	145	140	187	745	0.39	124	273	104	210	0.32
Total Female Labor (men-days/ha)	164	169	170	399	0.86	116	171	105	257	0.47
Total Child Labor (men-days/ha)	40	56	48	200	0.56	36	68	38	210	0.85
Total Labor Allocation (men-days/ha)	349	304	405	1,326	0.53	276	444	247	612	0.43

Table 4. Regression Results when Interacting Treatment Allocation and Household Structure

	All Households			No Fertilizer at Baseline			Use Fertilizer at Baseline		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
	N=1,093	N=1,093	N=1,093	N=584	N=584	N=584	N=509	N=509	N=509
	Panel A: Change in Total Labor Allocation (Mean at Baseline=176 men-days/ha)								
Treatment	45.933***	45.664***	31.738**	48.017**	46.742**	76.090***	39.93	40.465	77.778**
	(16.804)	(16.847)	(13.308)	(22.009)	(22.048)	(16.434)	(25.079)	(25.488)	(38.228)
Extended	74.143***	75.899***	67.405**	58.483*	64.533**	65.922*	88.562*	83.992*	50.976
	(27.985)	(27.427)	(28.482)	(32.208)	(30.954)	(34.370)	(45.520)	(45.207)	(56.307)
Treat*Extended	-60.882*	-61.129*	-63.047*	-11.552	-11.172	-53.399	-102.68*	-101.28*	-81.1
	(33.223)	(33.096)	(35.646)	(47.406)	(46.384)	(53.566)	(52.403)	(52.587)	(64.972)
R-squared	0.012	0.012	0.132	0.023	0.026	0.235	0.011	0.012	0.206
	Panel B: Change in Labor Allocation to Fertilizer Application (Mean at Baseline=5.6 men-days/ha)								
Treatment	4.974***	4.988***	2.931**	5.568***	5.536***	0.011	4.946	5.005	8.082**
	(1.670)	(1.711)	(1.221)	(1.703)	(1.709)	(0.972)	(3.185)	(3.262)	(3.882)
Extended	2.676	2.584	2.841	0.26	0.415	0.428	6.13	5.621	6.239
	(1.861)	(1.951)	(2.358)	(1.388)	(1.433)	(1.561)	(4.580)	(4.696)	(5.911)
Treat*Extended	-1.831	-1.818	-2.775	3.941	3.951	3.156	-7.087	-6.931	-7.239
	(2.711)	(2.708)	(3.325)	(3.095)	(3.091)	(3.701)	(5.266)	(5.276)	(6.864)
R-squared	0.011	0.011	0.119	0.049	0.049	0.325	0.006	0.007	0.148
	Panel C: Change in Labor Allocation to Harvest (Mean at Baseline=32.2 men-days/ha)								
Treatment	7.060**	6.855**	7.017***	5.081	4.731	19.662***	8.906**	8.806**	21.585***
	(2.916)	(2.873)	(2.386)	(3.943)	(3.906)	(3.020)	(3.825)	(3.765)	(7.147)
Extended	13.567***	14.903***	13.911**	11.901**	13.565**	12.916**	15.038*	15.890*	13.453
	(4.870)	(4.831)	(5.616)	(5.647)	(5.221)	(6.498)	(8.630)	(8.922)	(11.207)
Treat*Extended	-12.570**	-12.758**	-13.549**	-4.265	-4.161	-10.684	-20.20**	-20.46**	-20.231
	(5.905)	(5.778)	(6.454)	(8.649)	(8.250)	(9.964)	(9.897)	(9.906)	(12.311)
R-squared	0.010	0.013	0.110	0.014	0.022	0.185	0.012	0.013	0.198
	Panel D: Change in Labor Allocation to Manure Application (Mean at Baseline=10.18 men-days/ha)								
Treatment	4.651**	4.652**	-2.553	5.350**	5.299**	10.697***	3.929*	3.974*	12.581***
	(1.938)	(1.937)	(1.654)	(2.496)	(2.500)	(2.084)	(2.302)	(2.329)	(4.311)
Extended	11.839***	11.831***	12.782***	9.555***	9.798***	11.225***	14.560**	14.177**	14.787**
	(3.461)	(3.561)	(3.962)	(3.298)	(3.408)	(4.221)	(6.060)	(6.320)	(7.365)
Treat*Extended	-9.554**	-9.553**	-10.045**	-2.102	-2.087	-7.178	-15.84**	-15.72**	-16.82**
	(4.215)	(4.218)	(4.721)	(5.978)	(5.976)	(5.482)	(6.447)	(6.520)	(7.602)
R-squared	0.017	0.017	0.138	0.027	0.027	0.316	0.024	0.025	0.191
	Panel E: Change in Labor Allocation to Weeding (Mean at Baseline=76.9 men-days/ha)								
Treatment	19.704**	19.704**	31.215***	22.191**	21.774*	22.356**	13.518	13.853	39.405**
	(9.294)	(9.368)	(6.572)	(11.144)	(11.284)	(9.440)	(14.713)	(14.971)	(16.700)
Extended	36.637***	36.637***	30.230***	35.416**	37.397**	37.310**	34.705*	31.840*	11.696
	(11.591)	(11.438)	(11.219)	(15.792)	(16.189)	(17.715)	(19.022)	(18.133)	(22.085)
Treat*Extended	-37.888**	-37.888**	-41.107**	-30.605	-30.48	-54.991*	-42.050*	-41.169*	-28.276
	(15.695)	(15.760)	(16.238)	(25.269)	(24.997)	(28.006)	(22.940)	(22.871)	(27.853)
R-squared	0.009	0.009	0.142	0.011	0.012	0.214	0.008	0.010	0.218

Total sorghum land	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Village FE	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Standard errors in parentheses are clustered by village. * p<0.1 ** p<0.05 *** p<0.01.
Sample is restricted to households with at least one male-controlled sorghum plot in both baseline and follow-up surveys.

Table 5. Regression Results when Interacting Treatment Allocation and Number of Adult Males

	All Households			No Fertilizer at Baseline			Use Fertilizer at Baseline		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
	N=1,093	N=1,093	N=1,093	N=584	N=584	N=584	N=509	N=509	N=509
	Panel A: Change in Total Labor Allocation (Mean at Baseline=176 men-days/ha)								
Treatment	80.472***	80.114***	58.027**	87.122**	84.328**	97.831***	67.035	69.618*	115.941*
	(25.889)	(25.495)	(23.415)	(33.523)	(33.849)	(27.531)	(40.483)	(39.916)	(64.673)
Adult Male	20.905**	21.052**	20.367**	15.585*	16.595*	17.079	25.089	24.033	23.729
	(9.048)	(9.044)	(9.000)	(9.086)	(9.246)	(11.674)	(15.104)	(15.760)	(17.262)
Treat*Adult Male	-22.475**	-22.383**	-21.204*	-18.535	-17.807	-24.114	-25.225	-25.867	-23.113
	(10.757)	(10.672)	(10.870)	(12.580)	(12.499)	(14.543)	(17.208)	(17.355)	(18.988)
R-squared	0.011	0.011	0.132	0.015	0.017	0.234	0.010	0.011	0.209
	Panel B: Change in Labor Allocation to Fertilizer Application (Mean at Baseline=5.6 men-days/ha)								
Treatment	5.495***	5.528***	4.168*	6.831***	6.737***	1.998	4.747	5.015	9.307
	(2.026)	(2.037)	(2.375)	(2.246)	(2.288)	(1.572)	(3.778)	(3.880)	(6.798)
Adult Male	0.859	0.846	1.07	0.6	0.634	0.742	1.245	1.136	1.572
	(0.766)	(0.809)	(0.939)	(0.525)	(0.533)	(0.639)	(1.423)	(1.527)	(1.806)
Treat*Adult Male	-0.472	-0.481	-0.88	-0.094	-0.07	-0.845	-0.943	-1.01	-1.298
	(0.904)	(0.882)	(1.002)	(0.762)	(0.768)	(0.809)	(1.597)	(1.585)	(1.875)
R-squared	0.011	0.011	0.119	0.043	0.043	0.323	0.004	0.005	0.147
	Change in Labor Allocation to Harvest (Mean at Baseline=32.2 men-days/ha)								
Treatment	16.045**	15.418**	13.747**	11.951*	11.142*	22.346***	20.429*	19.920*	33.940*
	(6.537)	(6.374)	(6.346)	(6.059)	(6.147)	(4.314)	(11.811)	(11.391)	(18.981)
Adult Male	4.174	4.430*	4.171	2.195	2.487*	1.694	6.221	6.429	6.474
	(2.544)	(2.529)	(2.711)	(1.456)	(1.429)	(1.710)	(4.808)	(4.821)	(5.243)
Treat*Adult Male	-5.381*	-5.219*	-5.444*	-3.49	-3.279	-4.608*	-7.352	-7.225	-6.761
	(2.772)	(2.712)	(2.913)	(2.143)	(2.143)	(2.462)	(5.137)	(5.008)	(5.496)
R-squared	0.012	0.014	0.112	0.006	0.010	0.184	0.022	0.023	0.208
	Panel C: Change in Labor Allocation to Manure Application (Mean at Baseline=10.18 men-days/ha)								
Treatment	6.311**	6.319**	0.23	4.488	4.387	9.680***	8.524***	8.711***	19.621***
	(2.509)	(2.482)	(2.844)	(2.873)	(2.872)	(2.488)	(3.234)	(3.202)	(6.432)
Adult Male	2.855**	2.852**	3.347***	1.511*	1.548*	2.186**	4.296**	4.220**	4.617***
	(1.180)	(1.188)	(1.181)	(0.765)	(0.781)	(0.889)	(1.647)	(1.677)	(1.752)
Treat*Adult Male	-2.009	-2.012	-2.365*	-0.054	-0.027	-0.644	-4.034**	-4.081**	-4.384**
	(1.303)	(1.303)	(1.346)	(1.213)	(1.220)	(1.314)	(1.813)	(1.817)	(1.888)
R-squared	0.013	0.013	0.136	0.014	0.015	0.310	0.026	0.027	0.195
	Panel D: Change in Labor Allocation to Weeding (Mean at Baseline=76.9 men-days/ha)								
Treatment	28.092**	28.584**	31.955***	44.046**	43.476**	31.948*	4.626	6.347	27.167
	(12.749)	(12.837)	(10.245)	(17.763)	(18.310)	(16.198)	(18.667)	(18.327)	(24.767)
Adult Male	6.545*	6.344*	4.962	8	8.206	7.824	3.717	3.014	1.931
	(3.389)	(3.429)	(3.658)	(5.279)	(5.401)	(7.297)	(4.760)	(4.910)	(6.348)
Treat*Adult Male	-8.604*	-8.731*	-6.746	-13.130*	-12.981*	-15.238*	-2.728	-3.155	-0.454
	(4.624)	(4.601)	(4.915)	(6.825)	(6.770)	(8.456)	(6.260)	(6.213)	(7.576)
R-squared	0.005	0.005	0.137	0.011	0.011	0.213	0.001	0.003	0.215

Total sorghum land	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Village FE	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Standard errors in parentheses are clustered by village. * p<0.1 ** p<0.05 *** p<0.01.
Sample is restricted to households with at least one male-controlled sorghum plot in both baseline and follow-up surveys.
Sorghum land is the total plot size where sorghum is the main crop.