Bargaining-Power and Biofortification: The Role of Gender in Adoption of Orange Sweet Potato in Uganda*

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Abstract

We examine the role of gender in adoption and diffusion of orange sweet potato, a biofortified crop being promoted to increase dietary intakes of vitamin A in Uganda. Intrahousehold gender dynamics and female bargaining power may play an important role in crop choice, child feeding practices and technology diffusion through information networks in this intervention. Using data from an experimental evaluation, we find that the share of assets controlled by women does not affect the probability that a household adopts OSP. Within households, plots of land exclusively controlled by women are not more likely to contain OSP, but plots under joint control of men and women, in which a woman has primary control over decisionmaking are significantly more likely to contain OSP. The share of nonland assets controlled by women increases dietary intakes of vitamin A, but does not increase the impact of the OSP project on vitamin A intakes.

Keywords: gender, technology adoption, biofortification
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1. Introduction

Biofortification is emerging as a potentially significant strategy in the fight against micronutrient malnutrition. It involves breeding staple food crops to be a rich source of one or more key micronutrients, such as iron, zinc, vitamin A, and iodine, and disseminating these crops in areas where the rate of micronutrient deficiency is high and where poor households consume a large share of calories from staple foods (Bouis 2002; Bouis et al. 2011). Often, poverty and high prevalence of micronutrient malnutrition coincide. The success of biofortification as a public health intervention relies on having a large share of households in these areas to substitute conventional varieties of the low-nutrient staple food crop in their diet for the biofortified nutrient-dense variety. In many areas in rural Africa and South Asia, poor households operate near subsistence, growing most of their own food. In these settings, getting the biofortified food into the diet means fostering broad adoption of the new crop varieties by households in their fields (Gilligan, 2012). For many seed crops, adoption can be encouraged through marketing campaigns for biofortified seeds, but for crops like cassava and sweet potato, planting material in the form of vine cuttings cannot be stored, making marketing ineffective as a primary dissemination strategy. Instead, most households obtain planting material for these crops through interaction with other households. This raises a number of important questions about the role of social interaction, intrahousehold division of labor, and gender in the success of adoption and diffusion of these biofortified crops.

We study the role of gender in the adoption and diffusion of biofortified orange sweet potato (OSP) during a biofortification project that disseminated OSP to 10,000 households in Uganda from 2007 to 2009. Starting in 2007, the HarvestPlus "Reaching End Users" (REU) project introduced OSP to households in Uganda with the goal of increasing dietary intakes of vitamin A and reducing the prevalence of vitamin A deficiency. OSP is a dense source of vitamin A. It is moderately higher yielding than conventional white or yellow sweet potato varieties, but is more vulnerable to rot during dry periods. The REU project involved a multi-pronged intervention, including: a one-time distribution of 20 kg of free OSP vines each to members of selected project farmer groups; trainings of farmer group members on OSP cultivation; trainings of adult female members of households in the project on the nutritional benefits of consuming OSP and other vitamin A sources; and trainings of farmer group members on marketing plus limited coordination to support marketing of OSP roots. The experimental impact evaluation of the REU project, from which this paper is drawn, was designed to compare the cost-effectiveness of two strategies to distribute and promote OSP. Model 1 consisted of vine distribution plus two years of intensive trainings; Model 2 was identical to Model 1 in year one with the elimination of training activities in year two. This design enabled a cost-effectiveness study comparing the impacts of Model 1 to Model 2, which was expected to be 30 percent cheaper to implement. The impact evaluation showed that the REU project successfully promoted OSP adoption. The combined intervention led to adoption of OSP by 65 percent of project households, compared to just four percent in the control group (de Brauw et al., 2012). There was also substantial diffusion of the biofortified crop; each beneficiary household gave OSP planting material to one additional household, on average. The project also led to improvements in diet and nutritional status: the interventions, reduced the prevalence of inadequate dietary intakes of vitamin A by children under 3 years by 32 percentage points (from a base of 48% dietary inadequacy) and reduced the prevalence of low serum retinol (retinol<1.05 μmol/L) among children age 3-5 years with low serum retinol at baseline by 9.5 percentage points (Hotz et al., 2012).

This study examines the roles of male and female household members in the decision to adopt the OSP crop, to continue growing it over the four seasons of the project, and to distribute the crop to other households. We also explore the role of gender as a variable mediating the impacts of the intervention on dietary intakes of vitamin A by young children. In the project areas in Uganda, men play a leading role in crop choice decisions within the household, but our survey data show that women also play an active role in crop selection, particularly for food crops for household consumption, and that women commonly supply labor on household farms. The evaluation household survey data, collected in two rounds before the distribution of OSP vines in 2007 and at the end of the project in 2009, as well as complementary qualitative interviews (Behrman, 2011) confirm that women take the lead in deciding what food is prepared and consumed within the household, particularly for children. Because of this familiar pattern of gender-based specialization in managing child diets, the REU project implementation team decided only to target women for the nutrition trainings on the grounds that this would be most cost-effective. Although the biofortified OSP varieties were expected to achieve somewhat higher yields than conventional white and yellow sweet potato varieties, the project's promotional messages emphasized the relative health benefits of OSP, particularly for children and women, compared to conventional varieties.[1] This suggests that, although men and women likely coordinated efforts on the decision to adopt the OSP crop, women may have played an essential role in fostering OSP adoption.

Although there is some gender-based specialization of tasks within the households in the sample, the degree of specialization or level of control over decision-making may be affected by the relative bargaining power of men and women within the household, particularly as it relates to crop and food choices. There is now a substantial pool of empirical evidence from developed and developing countries rejecting the unitary model of the household, which assumes that household members share the same preferences and pool household resources (Haddad et al. 1997; Schultz 2001; Quisumbing, ed. 2003). An alternative, the collective model, allows for the possibility of disagreement between household members, raising the possibility that when there is disagreement, how it is resolved may depend on the relative bargaining power of individuals within the household (Manser & Brown, 1980; McElroy & Horney, 1981). While bargaining power has been measured in different ways in empirical work (see Quisumbing and Maluccio 2003 for a review), control over economic resources, such as land and assets, are likely to be major determinants. We use two measures of female bargaining power to examine how intrahousehold gender relations affect OSP adoption decisions. The first measure is the share of nonland assets controlled by women at baseline. Women who own a larger share of household assets may have greater discretion over household decisions or stronger bargaining power to win concessions from their male partners. The second measure is the share of household land area at baseline that is under female control. This measure directly relates to the relative control of female household members in making crop choice decisions. Using these measures of bargaining power, we estimate the role of gender in a household-level model of the determinants of OSP adoption. This model allows us to conduct tests of the theory of the unitary household decision model (Becker, 1965, 1981). We also use data on gender of control over plots of land to estimate plot-level models of OSP adoption, accounting for the correlation in crop choice decisions across plots. In these models, we differentiate the effects of gender on crop choice by whether the plot is under the sole control of a male household member, whether it is solely

[1] An efficacy trial conducted in South Africa (van Jaarsveld et al. 2005) had already demonstrated that consumption of OSP increases dietary intakes of vitamin A and increases serum retinol concentrations, a measure of vitamin A status.

controlled by a female household member, or whether the plot is under joint control, often with one individual taking the lead in making decisions regarding that plot.

We also explore the relative contributions of men and women to OSP crop diffusion. Only a small amount of OSP planting material is needed for a household to start a small plot, so project households could share planting material with several other households without significantly affecting their productivity. However, the vine cuttings must be transplanted within a day or they will wither and die. This feature discourages large commercial operations selling OSP planting material. Rather, most households at baseline reported receiving their white/yellow sweet potato planting material from neighbors and friends. The potential for this exchange is shaped by the patterns of interactions between households in a community. Women and men have overlapping, but often different social or information spheres within a community. An important question is how these gender-differentiated spheres of interaction play a role in OSP crop diffusion. In related work, McNiven and Gilligan (2012) show that information networks within communities play a substantial role in first providing access to OSP planting material and later in supporting sustained OSP adoption by households outside the project. Here, we explicitly examine how gender facilitates or restricts the diffusion of this agricultural technology.

This research makes a number of novel contributions. First, it begins to explain the vital role of gender in promoting adoption and diffusion of OSP as a strategy to increase vitamin A intakes and reduce vitamin A deficiency. Vitamin A deficiency causes night blindness and contributes to child morbidity and mortality. In Uganda, vitamin A deficiency is a significant public health problem, affecting 28 percent of children under age 5 (UBOS and ORC Macro 2001). Globally, vitamin A deficiency afflicts 127 million young children (West, 2002) and is responsible for six percent of deaths of children under five (Black et al., 2008). Second, a substantial recent literature has provided new evidence on the information, resource and market constraints to adoption of seemingly profitable agricultural technologies in developing countries (see Jack 2011 for a review). However, insufficient attention has been paid to addressing the potentially important role of gender in the promotion and adoption of agricultural technologies. A review of empirical studies (Peterman et al., forthcoming) found that female farmers tend to use modern inputs (inorganic fertilizer, insecticides, improved seed varieties, amechanical power) less intensively than men. However, most studies (e.g. Doss and Morris 2001 for Ghana) find that once differences in land, labor, and education are controlled for, there are no significant difference in rates of modern seed variety adoption between male and female farmers. Similarly, Tiruneh and colleagues' (2001) study of households in Ethiopia found that a significantly higher proportion of male than female heads of household use improved wheat;[2] in male-headed households, farm size and extension service contact significantly and positively affected adoption, whereas farm size and asset ownership are associated with adoption in female-headed households. In the case of OSP and other biofortified crops, women may play a larger role in the crop choice decision because of the importance of these crops for the nutritional status of children and adult women in the household. However, if production of staple food crops had been the purview of male household members, introduction of biofortified crops may lead to complex changes in gender roles for crop choice decisions and crop production that will be shaped by intrahousehold bargaining power. Ultimately, the result of these changes may have important implications for the success of biofortification.

This paper is organized as follows. Section 2 presents the HarvestPlus REU OSP project. Section 3 describes the impact evaluation and survey design. Section 4 presents the results and Section 5 concludes.

2. The HarvestPlus REU OSP Project

The Reaching End Users Orange Sweet Potato project disseminated OSP from 2007-2009 in Uganda, where vitamin A deficiency is a public health problem. During the project, roughly 10,000 farm households were provided OSP planting material (vines) and complementary trainings.[3] This was the first time that a biofortified crop with a visibly different trait (color) had been deployed on such a large scale. The project ran from August 2007 – August 2009, covering four agricultural seasons. In Uganda, there are two agricultural seasons each year, with the first

[2] Improved wheat seed is artificially produced by cross-pollination to improve yield, uniformity, and resistance to disease.

[3] A complementary OSP intervention was conducted and studied at the same time in Mozambique, in order to provide evidence of the generalizability of study findings to context. The impacts of the REU project on OSP adoption and diet in Mozambique are also reported in de Brauw et al. (2012). The present research paper only reports the role of gender and bargaining power for Uganda, where gender-disaggregated data on control over land and household assets were collected.

season (February-July) characterized by heavier rains and the second season (August-December) having lighter rains. Through pre-intervention (baseline) and post-intervention (endline) surveys, the project assessed OSP adoption rates and whether adoption resulted in improved vitamin A intakes among young children and their mothers.

Two dissemination strategies were implemented: a more intensive and costly Model 1, and a less costly, less intensive Model 2. Both models had four primary components:

(i) conduct a one-time free OSP vine distribution to project households in August 2007,
(ii) provide extension services to men and women who were members of project farmer groups on OSP production practices and marketing opportunities,
(iii) provide nutritional knowledge, in particular about vitamin A deficiency, to women in these same households (either the female farmer group member or the female spouse of the farmer group member), and
(iv) develop markets for OSP roots and processed products made from OSP roots.

Component (i) was identical across the two intervention arms; Model 1 and Model 2 households received 20 kg of OSP vines on average during the same period in 2007. Components (ii) and (iii) were provided for two years in Model 1 and for one year in Model 2, at a savings of roughly 30 percent of total model costs. These trainings were accomplished through the use of a pyramidal structure of extensionist trainers working for nongovernmental organizations (NGOs) and promoters trained by these extensionists who, in turn, instructed fellow members of pre-existing farmers' groups or community organizations.

Several other aspects of the project and the sample could shape the role of gender in OSP adoption. For example, at baseline, nearly sixty percent of farmer group members in the project were women (Table 1). Also, all households in the evaluation sample included at least one household member age 3-5 years old to serve as the primary reference group for dietary assessment.[4] Because all households in the sample have young children, the age distribution of

[4] The sample is unbalanced, with fewer farmer groups in Model 2, because it was determined that the large samples required for biochemical assessment to measure serum retinol were too costly to include in all three intervention arms. Blood samples were only taken in households in the Model 1 and Control groups. Children age 3-5 years at baseline comprised the primary reference group for dietary assessment. A smaller second reference group of children age 6-35 months old was included in the sample for dietary assessment primarily by selecting younger siblings of the first reference group.

adult household members is also younger than the overall population. However, fertility rates in Uganda are high and many young couples reside with the husband's parents, so the age distribution of women involved in crop choice decisions in the sample is wide. Average age of the female spouse of the household head or of the female head of the household is 34.9 years (Table 1).

3. The Evaluation Design and Survey Data

The sample for the impact evaluation includes 84 farmer groups from three districts: Kamuli, Bukedea, and Mukono. These districts were selected for the REU project because white and yellow sweet potato is commonly grown and consumed there and these districts are relatively close to potential markets for orange sweet potato. There are 36 farmer groups in Model 1 (M1), 12 in Model 2 (M2), and 36 in the Control (C) group. These farmer groups and the village that is home to the largest number of its members represent the sample clusters in the data. Farmer groups were sampled from a list of active farmer groups in each district obtained from the nongovernmental organization (NGO) implementing partners based on consultation with local leaders. Farmer group sampling was stratified by district. Farmer groups were then randomly assigned into the three evaluation arms (M1, M2, C) within districts (in proportions 12:4:12) to assure even spatial coverage.

Households were selected for the sample from among households with children 3-5 years of age (36-71 months). Statistical power calculations suggested that 14 households per cluster in Model 1 and Control farmer groups would be needed to detect the minimum effect size desired for serum retinol measured in blood samples, after allowing attrition of two households per farmer group. In Model 2 farmer groups, the required household sample size per cluster was determined by the desired minimum effect size for dietary intake of vitamin A, measured in µg of retinol activity equivalent (RAE) per day. That analysis indicated that 12 households would be needed in Model 2 groups. We sampled 14 households in Model 2 groups to maintain comparability with the other groups and to allow for some attrition in the sample. The sample also needed to include a smaller number of young children, age 6-35 months, in order to assess the impact of the interventions on their dietary intake of vitamin A. In most farmer groups, the children in this age range were sampled from among the younger siblings of the primary reference children. In some farmer groups, an additional household was added to the sample to reach the target number of children age 6-35 months.

Based on the needed number of individuals in each reference population, a sample of 14 households was drawn from each farmer group. In addition, another five households that were not members of the sample farmer groups were added to the sample from each village that was the primary location of the sample farmer groups in order to measure spillover effects of the program in terms of diffusion of the OSP vine technology. In some farmer groups, additional interviews were conducted as additional insurance against attrition, providing a baseline sample of 1,594 households.

Data collection took place in two survey rounds, a baseline survey in 2007 and an endline survey in 2009. The survey included a detailed socioeconomic survey and a nutrition survey, including a detailed 24-hour dietary recall module. Each survey round also included a farmer group survey conducted with the farmer group chairperson or other leader, a community survey, and a price survey. In total, 1,473 of the 1,594 households in the baseline survey were re-interviewed in 2009. This represents an attrition rate of 7.6 percent over the two-year period, which is reasonably low relative to other panel surveys.

The profile of OSP adoption over the four seasons of the project among participant households is shown in Table 1. Adoption rates of the crop were very high (89.8%) in the first season of the project when 20 kg of free planting material was distributed to all project households.[5] However, average adoption rates declined in each of the next 3 seasons. Farmers listed a number of reasons for why they disadopted OSP, including that their vines dried up and they were unable to obtain new planting material, that they did not have sufficient labor to continue to grow the crop (which may reflect the demands of participating in the project or the labor needed to implement the new cropping techniques), or that they decided they did not like the crop. Despite this pattern, the crop remained very popular in Kamuli and Mukono districts, where 80-85 percent of project households continued to grow OSP in the fourth season of the project. It was in Bukedea district where most of the disadoption took place; the OSP adoption rate fell to 41.4

[5] The 20kg of planting material distributed would have been enough to plant one quarter of an acre of OSP under the planting guidelines taught by the project.

percent in season 4 in Bukedea. This is also the district with the lowest share of female farmer group members, so we control for both district of residence and share of female members in the farmer group in our models of OSP adoption.

Measures of intrahousehold bargaining power were constructed using gender-differentiated data from the survey on asset ownership and control over land. This is consistent with other studies using land and assets as measures of bargaining power (e.g. Doss 1999; Quisumbing and Maluccio 2003; Fafchamps et al. 2009). For each asset in the baseline asset module, respondents were asked what proportion of the value of the asset was jointly owned, owned only by the household head, or owned only by the spouse of the household head.[6] Similarly, respondents were asked which household member made the crop choice decisions on each plot, allowing for up to two responses. These data were used to create estimates of the share of land and nonland assets exclusively owned by women, exclusively owned by men or jointly owned. We use values of these variables at baseline so that our measures of bargaining power would be exogenous, or at least predetermined, in the decision to adopt OSP. These measures of relative bargaining power within the household are summarized in Table 1. Women have exclusive control of only 16 percent of land assets and 22 percent of other assets. Respondents reported that 25 percent of land assets and 31 percent of nonland assets were jointly owned by men and women. By district, there is considerable variation, with a clear pattern of much higher share of land (59 percent) and nonland assets (62 percent) under exclusive control of men in Bukedea.

4. Results

We first test for the role of bargaining power in a household-level model of the determinants of OSP adoption over seasons 2-4 of the project, from February 2008 – August 2009. Results are

[6] Information on the value of assets owned by the household was collected during the baseline survey in 2007. However, the questions on what proportion of these assets owned at baseline was under the control of the household head, spouse, or joint control were not asked until the endline survey in 2009. During the endline survey interview in 2009, enumerators reminded respondents of the value of each asset the household reported owning in 2007, and then asked the questions about control of the asset at that time. Although there may be some recall bias in remembering who controlled the asset two years before, we believe that in most cases this gender disaggregation in control is fairly stable, which would limit the degree of recall bias. Also, when we use these variables as control variables for OSP adoption decisions we assume that any bias in the recall on gender disaggregated control over these assets is not correlated with the treatment.

presented in Table 2. In a random effects model estimated on all households in the REU project (column 1), there is no effect of the share of the value of land or nonland assets under exclusive female control on the probability of the household growing OSP that season. This result is consistent with the unitary household model; the relative bargaining position of household members has no effect on the probability of OSP adoption. The pattern of declining adoption rates over seasons in the project is also apparent, with disadoption occurring at an accelerating rate. As expected, there is considerable persistence in adoption decisions across seasons. Adopters in the previous season are roughly 30 percentage points more likely to be growing OSP this season. Also, the small number of households that had grown OSP before the start of the project in 2007 were weakly significantly more likely to grow it in the current season. The probability of growing OSP is declining in the number of years that the household has had a member in the farmer group, suggesting that newer members may be more willing to try new agricultural technologies. Relatively few other factors are associated with probability of adoption. However, pooling all households without attention to sex of the household head or intrahousehold decisionmaking over specific plots may mask the extent to which gender roles affect the adoption decision.

We first examine whether the sex of the household head affects the decision to adopt OSP. Female-headed households make up 11 percent of the sample of project beneficiary households. These households, which may include a male partner, show larger effects of bargaining power. The probability of OSP adoption is positively associated with the share of baseline land value exclusively controlled by an adult female household member and this effect is weakly significant. However, the probability of OSP adoption is declining in the share of nonland assets exclusively controlled by women. This may reflect that women controlling a large share of nonland assets have substantial nonfarm activities and so may not be engaged in farming or in crop choice decisions. Also in female-headed households, the probability of OSP adoption is increasing in the share of area under sweet potato cultivation at baseline. This suggests that farmers with a comparative advantage in growing sweet potato or a revealed preference for the crop are more likely to adopt the new biofortified varieties, at least among female-headed households. Although this pattern is only present in a small subsample, it demonstrates that, as a public health intervention to promote consumption of vitamin A rich foods, the REU OSP project is shaped by the link between crop production practices and dietary patterns. The pattern of effects for male-headed households is similar to that of all households in the project.

As mentioned above, the results of the household level models may mask a more complex decision-making process occurring within households, even if the household-level analysis differentiates between male- and female-headed households.. Most households have access to two or more parcels of land for farming and may have worked out an implicit agreement over which household members control crop choice and farming decisions on each parcel. For a particular parcel, the crop choice decision may be joint, between the household head and spouse, for example, or a particular household member may maintain sole control over the parcel. However, a household member with sole control over a parcel may still consider the crops being grown on other parcels when making crop choice decisions for that parcel. Our data allow us to differentiate the gender dimensions of the control over decision making at the parcel level.

Next, we examine the role of gender differentiation in control over crop choice decisions on land parcels the household owns or controls for cultivation. Figure 1 shows the response from the survey to the question, “Who decided what to grow on this parcel?” in first season of 2009. Respondents were allowed to give up to two responses. We interpret the order of household members listed as indicating which household member played a larger role in the crop choice decision. The figure shows that the most common arrangement, on nearly 60 percent of parcels, is one in which control over crop choice is joint, but that a male takes the lead in making this decision. On 20 percent of parcels only women make decisions on crop choice, which in part reflects the number of single-headed households headed by females. However, only 4.5 percent of parcels are reported to be under exclusive male control, while the remaining 16.5 percent of parcels are under joint control with a woman taking the lead in the decision making. The figure also shows that in Bukedea, the pattern of male dominance of control over crop choice decisions is magnified, with more than 80 percent of parcels under join control, but where the male takes the lead in the decision.

At the parcel level, the probability of adoption of OSP in 2009 is higher for parcels under exclusive female control than for parcels under exclusive male control or under joint control but with a male taking the lead, as shown in Table 3. Similarly, OSP adoption is significantly more likely on parcels under joint control but in which a female takes the lead in decisionmaking than on parcels under joint control with a male leading the crop choice decision. This pattern of behavior is quite different when considering land area devoted to OSP. The share of area planted under OSP is highest on parcels under joint control, but with a male leading decision making (at 9.9% of cultivated area). However, this share of area under OSP is not significantly different for parcels with joint control in which a female leads decision making. In fact, area under OSP is lowest on parcels with exclusive male control. These patterns are informative, but they do not control for a variety of factors that account for selection into parcel control within the household or the joint decision of the household concerning what to grow on all of its parcels.

Table 4 presents a model of the determinants of the decision to grow OSP at the parcel level by season, controlling for baseline responses on control over parcel decision making by gender. In a model without other control variables (column 1), OSP is significantly more likely to be grown on parcels in which only women make crop choice decisions (by 5.5 percentage points), or when crop choice decisions are joint but a woman takes the lead (by 11.2 percentage points), compared to parcels with joint control but where a man leads decision making. In this model, the probability that OSP is grown on the parcel is significantly higher under joint decision making with a woman taking the lead than on parcels under sole female control. However, these estimates may be misleading because the model does not control for other contextual factors that affect OSP adoption and does not adjust for possible correlation in decisions across parcels within households. After controlling for a large set of observable variables (column 2), OSP is significantly more likely to be planted on parcels with joint control, but where a woman was listed first in order of control than on parcels under joint control but where a man is listed first (the omitted category). Also, parcels under exclusive male control are significantly less likely to include OSP than those under joint control. In a model conditional on whether the household is growing OSP on any parcel (column 3), parcels controlled only by a women are not significantly more likely to have OSP than those with joint control in which men have primary control, but parcels controlled only by men are significantly less likely to have OSP.

These models also provide evidence of other factors shaping the OSP adoption decision. In the model with other control variables in column 2, the probability of adopting OSP on this parcel increases significantly with household head age. Mother’s nutrition knowledge also affects OSP adoption. The probability of OSP adoption increases significantly with the number of nutrition facts related to vitamin A that the mother of the reference child knew at baseline and with the number of such facts that she learned during the REU project. The probability of adopting OSP also increases significantly with the share of land area that the household had planted with sweet potato (white, yellow or orange) on all of its parcels at baseline. This suggests that households are substituting area under production with white or yellow sweet potato with OSP, as anticipated by the biofortification program. OSP adoption is less likely on farms with larger land holdings, but conditional on total landholdings, OSP is more likely to be grown on parcels with more land area. There is limited evidence that land tenure may be affecting crop choice decisions. Parcels under the free hold land tenure status are less likely to be selected for adopting OSP, although this relationship is only weakly significant. Free hold tenure arrangements provide greater security of land tenure than the more common customary or *mailo* arrangements. *Mailo* is a form of land tenure that provides rights to occupants of land owned by someone else; it is common in the Buganda region of Uganda (Mukono district). Consistent with other evidence from Uganda that more secure tenure creates incentives to plant permanent crops (Deininger et al. 2008), farmers may be selecting crops that require more investment in land or take longer to mature on free hold parcels, given that OSP vines can be easily transplanted to other parcels.

None of the models presented so far account for the fact that decisions on what to grow are correlated across parcels within the household. When we account for this in estimation (column 4) using a conditional logit model, the pattern of effects is weaker. Results in column 4 present the odds ratio of the probability of adopting OSP compared to parcel under joint control with a male leading decision making. The point estimates suggest that the probability of adopting OSP is highest on parcels with joint control and a female leading decision making and lower on parcels under control of a single gender, but none of these estimates is significant. In another approach to accounting for correlated decisions across parcels, we use the specification in column 2 of Table 4 and add control variables for the number of other parcels under each type of gender control over decision making (Table 5). In this model, the probability that OSP is grown is significantly higher (9.1 percentage points) on parcels under joint control with a female in the lead than on parcels under joint control with a male in the lead. Parcels under exclusive male control are significantly less likely to contain OSP (by 29.2 percentage points) compared to parcels under joint control with male leading decision making. The estimates on number of other parcels under each form of control all have negative point estimates and all but "male only" are significant. This indicates considerable joint decision making across parcels. In particular, the probability that OSP is grown on any given parcel is declining in the number of other parcels under any other form of control (except "male only").

When bargaining power is introduced into the parcel-level models, a more nuanced picture emerges. We separate the sample by the share of nonland assets under exclusive female control, characterizing a situation of low bargaining power by those households where the share of nonland assets under exclusive female control is less than 3 percent (the sample median). Table 6 shows that households in which women have weaker bargaining power (column 1) are more likely to grow OSP on joint plots with women in primary control. Where female bargaining power is higher (column 2), decision making on joint plots appears more egalitarian but OSP adoption is significantly less likely on plots under exclusive male control. It may be that in these households women have other income earning activities that provide greater access to assets and so they are less concerned with the adoption of this new healthy technology. Alternatively, women with stronger bargaining power may have access to other nutritious foods as a result of their stronger control over household assets. We revisit this issue in our results on dietary intake of vitamin A among young children.

Next we address the question, in Table 7, about how the effect of gender dimensions of control over parcels on OSP adoption varies with farm size. Qualitative research that accompanied this study suggested that agriculture decision making may be more egalitarian on small farms (Behrman, 2011). For OSP adoption, evidence does not support a 'small but equal' hypothesis. Gender control over parcels has a larger effect on OSP adoption in small farms than in large farms.

The cost-effectiveness of the REU project as a biofortification strategy to improve dietary intakes of vitamin A would be greatly improved if households in the project share OSP planting material with other households. On average, each household in the project gave OSP planting material to 1.2 other households during the two years of the project. Here, we examine the role of female and male farmer group members as well as the role of female bargaining power in the household's decision to participate in OSP diffusion. Results are presented in Table 8. Among households participating in project farmer groups, whether a household has at least one female farmer group member does not affect the probability of the household undertaking any diffusion during the project. Although the estimate of the effect of female farmer group membership is large in Kamuli, it is not significant. In Bukedea, having a female farmer group member in the household is associated with a decline in the probability of conducting diffusion. Interestingly, the share of nonland assets controlled by women in the household does not have a significant effect on the probability of conducting diffusion in the full sample, but, in Kamuli, it leads to a large and significant increase in the probability that a household shares the OSP crop.

Also in the full sample, farmers with better soils are significantly less likely to undertake diffusion. However, the probability of sharing the OSP crop increases significantly if the mother has some knowledge about vitamin A at baseline and if one of the household members is a leader in the farmer group. Overall, diffusion was significantly higher in Mukono district than in Kamuli (17 percentage points) and was weakly significantly higher in Bukedea than Kamuli (14.5 percentage points).

Finally, we examine the effect of female bargaining power on dietary intake of vitamin A by children in the reference group of 3-5 year olds. Improving dietary intakes of vitamin A for this group of reference children was a major objective of the project. The impacts of the project on dietary intake of vitamin A are reported in Hotz et al. (2012). Here we examine how gender roles shape this result. Dietary intake of the reference children was measured in the survey through a comprehensive dietary recall interview of their mothers. Respondents were asked to list each food consumed by the child in the day before the interview and then were asked about the composition of the foods consumed, for complex dishes. The weight (or volume) of each food consumed by the child was recorded and these were then converted into nutrient values using a detailed food composition table constructed for this study. Table 9 reports that the impact of the REU project on average dietary intake of vitamin A was 445.5 μg RAE/day, a very large effect. The average requirement for children age 4-8 years old is 275 μg RAE/day. Panel A of Table 9 shows that the share of nonland assets exclusively controlled by women had a large and significant independent effect on child dietary intake of vitamin A. Children of women who controlled more nonland assets had higher vitamin A consumption on average. In Panel B, we report the results of a model that interacts the treatment effect with and indicator for whether adult women in the household controlled a relatively high share (above the median of 5 percent) of nonland assets. In this case, it does not appear that women with relatively higher control of nonland assets were able to use their bargaining power to increase the impact of the REU project on child consumption of vitamin A.

5. Conclusions

We find a complex relationship of female bargaining power and control over household assets to the impact of the Uganda OSP biofortification program on OSP adoption, diffusion and dietary intakes of vitamin A. Female bargaining power, measured by the share of land and nonland assets exclusively controlled by female household members, does not unambiguously increase the probability that a household adopts OSP in response to the project. Also, land parcels over which women have sole control are not those most likely to contain OSP. Rather, the probability of adoption of OSP is highest on parcels for which there is joint control, but where women take the lead in deciding which crops are grown. However, the probability of adopting OSP is also lowest on parcels exclusively controlled by men. As expected, we find evidence that crop choice decisions are correlated across parcels. Nonetheless, the evidence indicates that women play an important role, and often a leading role, in the decision to adopt OSP, but that this decision is often jointly made with their husbands. Because of the jointness of these decisions, the current strategy of targeting only women with nutritional trainings may be missing an opportunity to create an awareness of the benefits of OSP among men. The evaluation of the REU project found no evidence of impact on fathers' knowledge of child feeding practices in Uganda (de Brauw et al. 2010), but the contribution of nutrition messages received by women on the impact of the project on OSP adoption and dietary intakes of vitamin A appears to be relatively small (de Brauw et al. 2012). Nonetheless, in this setting, our results suggest that engagement of the project with adult household members of both genders may be the best strategy to promote adoption.

We acknowledge that these estimates do not identify whether the observed effects are due to gender-based differences in preferences, in information or in specialization of activities within households. We find no effect on average of female bargaining power or farmer group participation in diffusion of the OSP crop technology. However, effects do vary by district, suggesting that extension efforts to disseminate OSP and other biofortified crops may need to be tailored to local context. The result that the female share of control of nonland assets independently increases dietary intake of vitamin A for young children in project households, but does not mediate the overall impact of the project implies that women's bargaining power may play an important and independent role in allocating resources to improve child nutrition. However, the insignificance of the interaction effect between the treatment and women's initial bargaining power implies that the project has been effective in reaching women with different degrees of bargaining power within the household.

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Figure 1: The distribution of control over crop choice decisions on household parcels

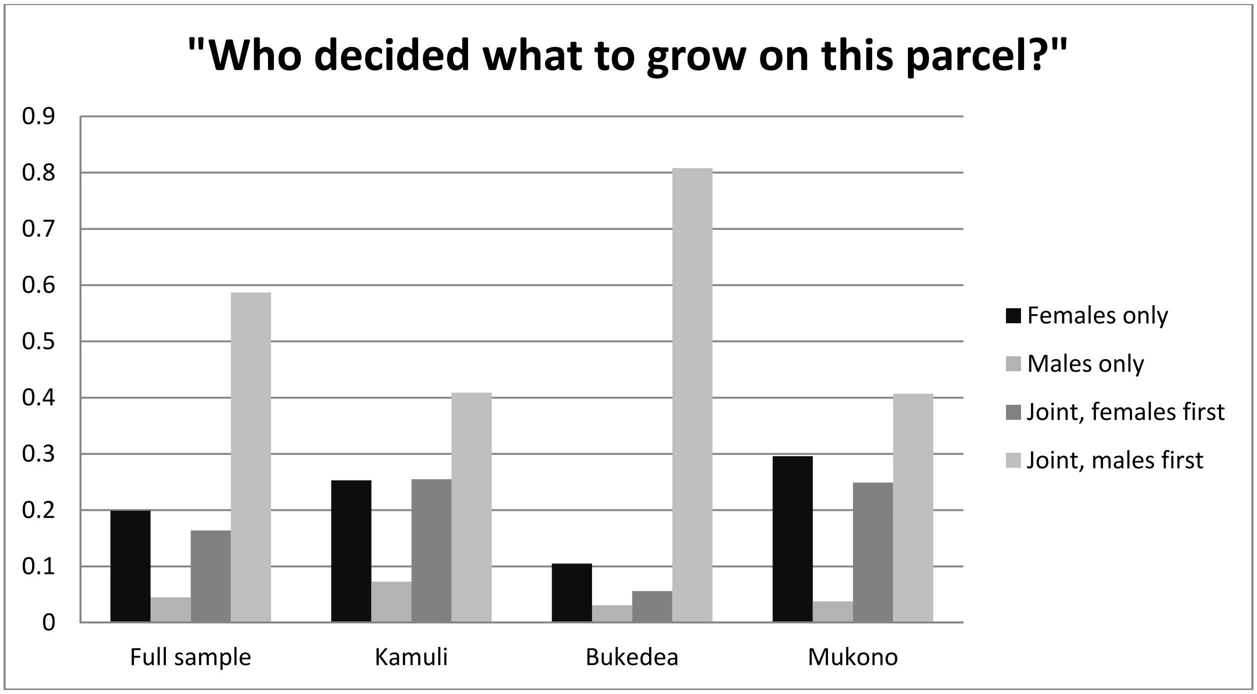

Table 1: Gender composition of the sample and asset ownership at baseline, 2007

	Overall	by District		
		Kamuli	Bukedea	Mukono
Gender composition of the sample				
Female share of farmer group members, 2007	0.594	0.568	0.520	0.693
	(0.256)	(0.241)	(0.287)	(0.218)
Age of female head of household or female spouse of head, 2007	34.9	35.7	33.0	36.4
	(10.8)	(11.0)	(9.2)	(11.8)
OSP adoption patterns over time				
Share of project households adopting OSP				
season 1	0.898	0.955	0.889	0.851
season 2	0.858	0.968	0.673	0.942
season 3	0.780	0.904	0.543	0.903
season 4	0.685	0.854	0.414	0.799
Intrahousehold bargaining variables				
Share of value of land owned in 2007 under…				
…exclusive female control	0.160	0.204	0.103	0.183
	(0.334)	(0.329)	(0.292)	(0.374)
…exclusive male control	0.591	0.457	0.742	0.547
	(0.468)	(0.441)	(0.429)	(0.489)
…joint control	0.253	0.349	0.155	0.269
	(0.434)	(0.475)	(0.362)	(0.445)
Share of value of nonland assets in 2007 under…				
…exclusive female control	0.218	0.215	0.160	0.282
	(0.332)	(0.319)	(0.295)	(0.368)
…exclusive male control	0.489	0.402	0.626	0.422
	(0.411)	(0.380)	(0.417)	(0.394)
…joint control	0.310	0.400	0.228	0.314
	(0.408)	(0.439)	(0.386)	(0.384)

Notes: Estimates are means (standard deviations) over farmer group member households in treated farmer groups.

Table 2: Determinants of OSP adoption by season, 2008-09

	REU Project Households	Female-headed REU Project Households	Male-headed REU Project Households
	(1)	(2)	(3)
Adopted OSP last season	0.310***	0.141	0.307***
	(0.031)	(0.103)	(0.033)
Fraction of the value of land exclusively owned by female household members, 2007	0.038	0.365*	-0.011
	(0.070)	(0.217)	(0.076)
Fraction of the value of nonland assets exclusively owned by female household members, 2007	-0.029	-0.540**	0.032
	(0.069)	(0.232)	(0.074)
Female-headed household, 2007	-0.013	--	--
	(0.068)		
Household size, 2007	-0.001	0.005	-0.001
	(0.004)	(0.014)	(0.004)
Household head education	-0.005	0.006	-0.006*
	(0.003)	(0.015)	(0.003)
Quintile 2: Total expenditure per adult eq.	0.005	0.092	-0.010
	(0.031)	(0.138)	(0.033)
Quintile 3: Total expenditure per adult eq.	0.026	0.024	0.030
	(0.032)	(0.105)	(0.034)
Quintile 4: Total expenditure per adult eq.	0.018	-0.098	0.023
	(0.034)	(0.150)	(0.036)
Quintile 5: Total expenditure per adult eq.	0.017	0.101	0.008
	(0.034)	(0.130)	(0.037)
Total land area, 2007	0.003	-0.010	0.005
	(0.004)	(0.009)	(0.004)
Female share of land area, 2007	-0.006	-0.064	-0.003
	(0.031)	(0.153)	(0.033)
Whether had access to lowland parcel, 2007	0.017	0.139	0.008
	(0.021)	(0.105)	(0.022)
Share of 'good' soils, 2007	-0.041	-0.082	-0.035
	(0.025)	(0.091)	(0.027)
Ever grew OSP before second season 2007	0.070*	0.359**	0.064
	(0.042)	(0.150)	(0.045)
Ever changed farming practices as a result of advice received	0.013	-0.068	0.010
	(0.022)	(0.094)	(0.023)
Mother knows what vitamin A is, 2007	-0.016	0.000	-0.020
	(0.072)	(0.000)	(0.072)
Mother has access to any radio	0.020	-0.043	0.022
	(0.021)	(0.084)	(0.022)

Farmer group leader	0.027	-0.020	0.037
	(0.027)	(0.098)	(0.029)
Number of years as a farmer group member	-0.002**	0.021	-0.002**
	(0.001)	(0.025)	(0.001)
Share of sweet potato in planted area, 2007	0.105	1.208***	0.084
	(0.069)	(0.417)	(0.071)
Ever give advice on farming, 2007	0.036	0.184	0.026
	(0.024)	(0.119)	(0.025)
Bukedea	-0.253***	-0.172	-0.264***
	(0.029)	(0.127)	(0.030)
Mukono	0.003	-0.008	-0.003
	(0.028)	(0.106)	(0.030)
Second season 2008	-0.064***	-0.103	-0.060**
	(0.024)	(0.072)	(0.026)
First season 2009	-0.178***	-0.152**	-0.184***
	(0.024)	(0.074)	(0.026)
Constant	0.669***	0.708*	0.690***
	(0.094)	(0.363)	(0.096)
Observations	1305	138	1167
Number of households	435	46	389

Notes: Models are random effects household panel data models estimated over 3 seasons from 2008-09. Sample is farmer group member households in treated farmer groups. *significant at the 10% level; . **significant at the 5% level; ***significant at the 1% level.

Table 3: Mean probability of OSP adoption and area planted by sex of decision maker and type of decision making

"Who decided what to grow on this parcel?"	Females only	Males only	Joint, females first	Joint, males first
	(1)	(2)	(3)	(4)
Grow OSP on this parcel	41.6[a,c]	28.7 [b]	47.4 [c]	35.9
Share of parcel area planted with OSP	0.073[c]	0.054[b,c]	0.092	0.099

Notes: Estimates are averages over all four seasons for farmer group member households in treated farmer groups. [a] Significantly different from (2) "Males only". [b] Significantly different from (3) "Joint, females 1st". [c] Significantly different from (4) "Joint, females 1st".

Table 4: Effect of gender in control over parcel decisions on OSP adoption

Dep Var: Grow OSP on this parcel	Unconditional	Conditional on observables	Conditional on household adopting OSP	Conditional logit model
	(1)	(2)	(3)	(4)
Parcel control: female only	0.055***	0.005	-0.025	0.884
	(0.021)	(0.029)	(0.030)	(0.205)
Parcel control: male only	-0.080	-0.132**	-0.211***	0.519
	(0.055)	(0.052)	(0.053)	(0.235)
Parcel control: joint, female listed first	0.112***	0.063***	0.032	1.261
	(0.025)	(0.023)	(0.027)	(0.197)
Household size		-0.002	0.001	
		(0.004)	(0.004)	
Female headed household		-0.011	-0.008	
		(0.038)	(0.039)	
Household head age		0.003***	0.001	
		(0.001)	(0.001)	
Household head education		0.002	0.002	
		(0.003)	(0.003)	
Log of monthly expenditure per adult equ.		0.020*	0.020	
		(0.012)	(0.015)	
Mother's knowledge of vitamin A, 2007		0.046***	0.016	
		(0.017)	(0.020)	
Change in mother's knowledge of vitamin A, 2007-2009		0.041***	0.024*	
		(0.013)	(0.014)	
Share of sweet potato in land area, 2007		0.226***	0.085	
		(0.060)	(0.052)	
Total land area operated in this season, acres		-0.062***	-0.066***	0.675***
		(0.008)	(0.011)	(0.037)
Household member is farmer group leader		0.041	0.038	
		(0.025)	(0.030)	
Distance to FG meeting place		0.001	0.002*	
		(0.001)	(0.001)	
Ln of farmer group size, 2007		-0.114*	-0.014	
		(0.067)	(0.063)	
Parcel area, acres		0.135***	0.151***	1.432***
		(0.015)	(0.021)	(0.098)
Parcel has good soil, 2009		-0.02	-0.024	1.066
		(0.018)	(0.023)	(0.167)
Parcel tenure status, freehold, 2009		-0.169*	-0.305	0.657
		(0.088)	(0.340)	(0.532)
Season 2		0.029*	0.083***	1.153*
		(0.017)	(0.021)	(0.092)
Season 3		-0.017	0.039*	0.895
		(0.017)	(0.022)	(0.073)
Season 4		-0.131***	0.025	0.547***
		(0.017)	(0.019)	(0.048)
Observations	5,723	5,032	3,138	4,490

Notes: Dependent variable is 1 if OSP grown on this parcel in this season, 0 otherwise. Estimates in columns (1)-(3) are marginal effects at the mean of the data from logit models. Column (4) presents odds ratios from a conditional logit model. Household-level variables drop from this model as do parcel observations from households in which OSP is grown on all parcels or none of the parcels. Sample is farmer group member households in treated farmer groups. Omitted category for Parcel Control is joint, male listed first. Standard errors adjusted for stratification by district and clustering at the farmer group level. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 5: OSP adoption, correlated decisions across parcels

Dep Var: Grow OSP on this parcel	Including Other Parcel Controls
Parcel control: female only	-0.077
	(0.052)
Parcel control: male only	-0.292***
	(0.098)
Parcel control: joint, female first	0.091**
	(0.046)
No. other parcels: female only	-0.088***
	(0.022)
No. other parcels: male only	-0.035
	(0.024)
No. other parcels: joint, female first	-0.133***
	(0.016)
No. other parcels: joint, male first	-0.116***
	(0.012)
Observations	5032

Notes: Dependent variable is 1 if OSP grown on this parcel in this season, 0 otherwise. Model is analogous to columns (2) of Table 4. Other control variables not reported. Omitted category for parcel control is joint, male listed first. Standard errors adjusted for stratification by district and clustering at the farmer group level. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 6: OSP adoption by female ownership of nonland assets

Dep Var: Grow OSP on this parcel	Low share of female ownership of nonland assets (1)	High share of female ownership of nonland assets (2)
Parcel control: female only	0.032	-0.036
	(0.049)	(0.035)
Parcel control: male only	-0.085	-0.198
	(0.065)	(0.082)**
Parcel control: joint, female 1st	0.097	0.021
	(0.029)***	(0.032)
Observations	2377	2655

Notes: Low share of female ownership of nonland assets is below 3 percent of nonland assets (the sample median). High share is greater than or equal to 3 percent. Other control variables not reported (see column 2 in Table 4). Estimates are marginal effects at the mean of the data from logit models. Sample is farmer group member households in treated farmer groups. Omitted category for parcel control is joint, male listed first. Standard errors adjusted for stratification by district and clustering at the farmer group level. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 7: OSP adoption by size of landholdings

Dep Var: Grow OSP on this parcel	Land area < 3.25 acres (1)	Land area ≥ 3.25 acres (2)
Parcel control: female only	-0.011	0.021
	(0.034)	(0.037)
Parcel control: male only	-0.269	-0.007
	(0.078)***	(0.052)
Parcel control: joint, female first	0.057	0.047
	(0.030)*	(0.032)
Observations	2405	2627

Notes: Other control variables not reported (see column 2 in Table 4). Estimates are marginal effects at the mean of the data from logit models. Sample is farmer group member households in treated farmer groups. Omitted category for parcel control is joint, male listed first. Standard errors adjusted for stratification by district and clustering at the farmer group level. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.

Table 8: Gender-based differences in diffusion of OSP, 2007-2009

Dep Var: Shared OSP vines with other households	All	Kamuli	Bukedea	Mukono
Household has at least one female farmer group member	-0.032	0.221	-0.163**	0.099
	(0.066)	(0.198)	(0.078)	(0.150)
Fraction of the value of nonland assets exclusively owned by female household members, 2007	0.165	0.775**	-0.124	0.191
	(0.125)	(0.339)	(0.187)	(0.199)
Female-headed household, 2007	-0.247	-1.372**	0.278	-0.162
	(0.153)	(0.564)	(0.279)	(0.202)
Household size, 2007	-0.005	-0.024	-0.007	0.018
	(0.011)	(0.030)	(0.019)	(0.017)
Household head education	0.008	-0.009	0.008	0.021*
	(0.006)	(0.017)	(0.008)	(0.011)
Quintile 2: Total expenditure per adult eq.	-0.101	-0.193	-0.067	0
	(0.074)	(0.152)	(0.106)	(0.135)
Quintile 3: Total expenditure per adult eq.	-0.065	-0.14	-0.071	0.063
	(0.082)	(0.145)	(0.155)	(0.113)
Quintile 4: Total expenditure per adult eq.	-0.052	-0.276*	0.131	0.011
	(0.085)	(0.167)	(0.153)	(0.103)
Quintile 5: Total expenditure per adult eq.	0.014	0.067	-0.02	0.093
	(0.090)	(0.161)	(0.160)	(0.114)
Total land area, 2007	-0.01	-0.012	-0.013	-0.005
	(0.008)	(0.016)	(0.018)	(0.012)
Female share of land area, 2007	0.078	0.186	0.04	-0.019
	(0.071)	(0.142)	(0.259)	(0.068)
Share of 'good' soils, 2007	-0.117**	-0.217*	-0.135	-0.058
	(0.059)	(0.119)	(0.126)	(0.081)
Ever changed farming practices as a result of advice received	0.016	0.018	0.08	-0.036
	(0.058)	(0.158)	(0.088)	(0.085)
Mother knows what vitamin A is, 2007	0.395**	--	0.186	--
	(0.192)		(0.293)	
Farmer group leader	0.146**	0.111	0.071	0.336**
	(0.070)	(0.187)	(0.124)	(0.149)
Ever give advice on farming, 2007	0.085	0.159	0.063	0.071
	(0.065)	(0.124)	(0.099)	(0.095)
Bukedea	0.145*			
	(0.087)			
Mukono	0.17**			
	(0.071)			
Observations	446	109	175	158

Notes: Models are logit models estimated. Estimates are marginal effects at the mean of the data. Sample is farmer group member households in treated farmer groups. *significant at the 10% level; . **significant at the 5% level; ***significant at the 1% level.

Table 9: Gender differences in control over assets and child consumption of vitamin A

Dep Var: Change in dietary intake of vitamin A (μg RAE), 2007-2009	
Panel A	
Average impact of OSP project	445.5***
	(146.0)
Share of nonland assets exclusively controlled by women	509.3**
	(237.8)
Panel B	
Average impact of OSP project	269.0*
	(140.1)
Interaction of treatment effect with share of nonland assets	356.2
exclusively controlled by women greater than 5 percent	(279.1)

Notes: Units are μg of retinol activity equivalents, a measure of vitamin A in the diet. Sample includes children age 3-5 years in each round. * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.