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Biofortification, crop adoption and health information: Impact pathways in Mozambique and Uganda

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Abstract

Biofortification, breeding staple food crops to be dense sources of essential micronutrients, is fast emerging as a strategy to fight micronutrient malnutrition. Large scale biofortification investments are being made in several developing countries, but until recently little rigorous evidence about the impact of these investments has been available. In this paper, we report findings from randomized impact evaluations conducted in both Mozambique and Uganda to study the impact of large-scale pilot projects conducted between 2006 and 2009 to introduce provitamin-A-rich orange-fleshed sweet potato (OFSP) as a strategy to reduce vitamin A deficiency. In both countries, projects randomly assigned interventions of different cost and intensity to distribute OFSP vines, train households to grow OFSP, and disseminate the health benefits of vitamin A. We compare the impact of the interventions within and across the two countries on OFSP adoption, knowledge about vitamin A, and dietary intake of vitamin A by children, and use causal mediation analysis (Imai et al. 2011) to examine the impact pathways on vitamin A consumption. After two years of intervention, in both countries the project led to OFSP adoption rates of 61-68 percent among project households, improved household knowledge about vitamin A, and nearly doubled average dietary intake of vitamin A, with no difference between the more and less intense intervention models. Evidence suggests that vine access played the most important role in explaining the impact on vitamin A consumption in both countries. Consequently, future programs can be designed to have similar impacts at even lower costs.

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1 Motivation

Micronutrient malnutrition continues to be a major health problem affecting developing countries, and Sub-Saharan Africa in particular. It is responsible for a significant share of infant mortality (Bryce et al., 2003) and hinders human capital development (Alderman, Hoddinott, Kinsey, 2006). Vitamin A deficiency is one of the leading forms of micronutrient malnutrition, and is an important cause of morbidity, impaired night vision and, in more severe manifestations, of blindness and increased mortality in young children, affecting nearly 127 million pre-school aged children worldwide (Villamor and Fawzi 2000; Beaton, Martorell and Aronson 1993, Fawzi et al. 1993; West, 2002). Vitamin A deficiency accounts for 6 percent of all deaths of children under five years of age (Black et al., 2008). As such, it is a major health concern in many low-income populations with persistent high mortality rates (Ezzati et al., 2002). Aguayo and Baker (2005) argue that "...effective and sustained control of vitamin A deficiency has the potential to be among the most cost-effective and high-impact child-survival interventions in sub-Saharan Africa." In Mozambique and Uganda, the countries included in this study, 69 percent and 28 percent of preschool children are vitamin A deficient, respectively (Aguayo et al., 2005; UBOS and ORC Macro, 2001). Vitamin A deficiency disorders also affect adult women by increasing morbidity and mortality during pregnancy (Christian et al., 2000; West et al., 1999).

The leading strategies for alleviating vitamin A deficiency include supplementation and fortification. These approaches require annual campaigns to be effective, and coverage rates vary substantially across countries (UNICEF, 2007). An alternative and possibly complementary approach is biofortification, which seeks to reduce micronutrient deficiencies by breeding staple food crops to have improved micronutrient content and then supporting distribution strategies that allow poor consumers to substitute staples that are low in nutrients with nutrient-dense varieties of the same or similar crops (Bouis, 2002).

As a policy tool, biofortification has several advantages. First, staples are consumed daily and constitute a large proportion of diets of poor households, making biofortification pro-poor. Second, once the biofortified variety has been developed and widely adopted further costs are minimal. Third, with broad adoption and good access to seed or planting material, the crop can be grown and consumed for years to come. Fourth, it has the potential to reach vulnerable populations in remote areas that do not have access to commercially-marketed fortified foods. Finally, biofortified varieties are selected for yield properties to ensure they are high yieldin; in fact, for many crop-nutrient combinations, the adoption of biofortified varieties being introduced may even increase yields (Nestel et al, 2006).

In this paper, we examine outcomes of the first crop supported for distribution by HarvestPlus, a leading institution supporting the breeding and dissemination of biofortified crops. The crop is provitamin A-rich orange-fleshed sweet potato (OFSP), which was distributed in Mozambique and Uganda through the HarvestPlus Reaching End Users (REU) project.[1] The overall goal of the REU project was to reduce vitamin A deficiency among children under 5 years old and women of child-bearing age. To meet this goal, the REU conducted an integrated program to both improve knowledge of the benefits of vitamin A and encourage the adoption of and the consumption of OFSP by household members, particularly women and children. A unique feature of the REU is that it ran very similar programs in selected regions of Uganda and Mozambique, and the project included the same major components in both countries: (i) a seed systems component, which included vine distribution and agricultural extension; (ii) a demand creation component, which worked through nutrition trainings; and (iii) trainings in marketing and product development. The selected regions were areas where white- or yellow-fleshed sweet potato is either the primary staple crop (Uganda) or an important secondary staple (Mozambique).

A second important aspect of the REU is that it incorporated a rigorous, randomized impact evaluation, with baseline and endline surveys in both countries. The baseline and endline surveys were composed of two components: a socioeconomic survey and a nutrition and dietary intake survey, and the surveys were coordinated across countries to include measures of many of the same household characteristics and outcomes. As a basis for identifying impact through the evaluation, sampled farmer groups or church groups were randomly assigned into two treatment groups, one more intensive (Model 1) and the other less intensive (Model 2).[2] From the socioeconomic survey, we can identify gains in knowledge about biofortified crops and nutrition, and adoption of OFSP through the dietary intake survey, which included 24-hour dietary recall interviews, we can measure increases in intakes of vitamin A and other nutrients among young children in the sample. The impact evaluation is unique in that it measures com-

[1]The HarvestPlus-supported OFSP varieties in both countries are dense sources of betacarotene, bred locally, and have good agronomic properties.

[2]Hotz et al (2012a) and Hotz et al. (2012b) find that the REU both increased vitamin A intakes and reduced vitamin A deficiency among both mothers of child bearing age and children under 3 years old, Mozambique and Uganda, respectively.

parable outcomes from a similar intervention implemented simultaneously in two very different countries, therefore speaking towards external validity. The REU itself and the impact evaluations were both coordinated, such that the content and methodology of the surveys conducted in both countries overlapped significantly both at baseline and at the end of the project.

The objectives of this paper are threefold. First, we compare impacts on nutritional knowledge, crop adoption, and vitamin A intakes between the two countries. Second, we simultaneously compare the impacts of the two models on the same measures. Third, we study the contribution nutrition knowldege to crop adoption, and of both crop adoption and nutrition knowledge to the impacts on child diets. We rely on the randomized assignment to compare the impact of the interventions within and across the two countries on OFSP adoption, share of sweet potato area planted with OFSP, knowledge about vitamin A, and dietary intake of vitamin A by children. We then examine correlations between measures of vitamin A intakes among young children in both countries, and measures of adoption and learning from the demand creation component of the intervention, using causal mechanism analysis to measure the relative importance of the two components of the intervention (Imai et al., 2011).[3] For biofortification strategy, it is important to understand whether improvements in vitamin A consumption by children derived primarily from access to the new crop technology and successful adoption or whether information about the health benefits of the crop played a substantial role. These results are relevant to the growing literature on constraints to adoption of worthwhile agricultural technologies and the role of information in nutrition interventions. Finally, we use the results to discuss the cost effectiveness of the REU and the implications of the results for designing cost effective, scaled up interventions to disseminate OFSP.

The paper meets its objectives as follows. In the next section, we describe the REU in more detail, including the way that it builds upon previous interventions that disseminated OFSP. Next, we describe how we expect the intervention to work and provide a conceptual framework. Section 4 describes the experimental design in more detail. In section 5, we describe our estimation strategy. Section 6 provides the main impact results and draws out causal mechanisms. The seventh section describes implications of the results both in general and for cost effectiveness of projects that

[3]We do not consider the marketing component of the REU as a contributor to impacts on vitamin A intakes in this paper, as the project report indicated that it did not correlate strongly with vitamin A intakes (de Brauw et al., 2010).

disseminate OFSP specifically and biofortified products in general. The final section concludes.

2 Background

In this section, we first describe previous biofortification interventions that introduced OFSP. Next, we briefly describe the design and implementation of the REU project. The main features of the project were the same in both countries, but there were important differences in some of the details of implementation, also described below. The details differ as a result of agronomic characteristics, cropping patterns, diet, education, farmer group characteristics, and the overall implementation strategies.[4]

2.1 Literature Review

Sweet potato is a primary or secondary staple food crop in a number of countries in sub-Saharan Africa. OFSP that are rich in β-carotene are excellent sources of provitamin A. In an early efficacy study conducted in South Africa, van Jaarsveld et al. (2005) show that consumption of OFSP can improve vitamin A status, and therefore can play a significant role in food based strategies to overcome vitamin A deficiencies in developing countries.

If biofortified crops are to reduce micronutrient deficiency, they must be acceptable to both producers and consumers. Studies have shown that OFSP are broadly acceptable to cultivating farmers in both Uganda and Mozambique of biofortified OFSP varieties (Tumwegamire et al., 2007; Masumba et al., 2007). Willingness to pay studies demonstrate that that consumers like OFSP as much as the traditional white varieties, even when crop introduction is not accompanied with campaigns about nutritional benefits of OFSP (Naico and Lusk, 2010; Chowdhury et al., 2011). When consumers are informed about the nutritional value of consuming OFSP, they are willing to pay higher prices, with larger premiums for deeper orange OFSP.

Two previous efforts have introduced OFSP at the farm level prior to the REU. Hagenimana et al (2001) describe a project that occurred among 10 women's groups in two districts in Kenya between 1995 and 1997. The project was characterized by very high levels of extension supervision– 12 monthly visits over the year– and found

[4]For more detailed information on the REU Project design and implementation, see the HarvestPlus REU Donor Report (HarvestPlus, 2010).

that the frequency of consumption of vitamin A rich foods among children under 5 increased. A second two year quasi-experimental project, Towards Sustainable Nutrition Improvement (TSNI), worked to increase intakes of vitamin A and energy among young children through OFSP (Low et. al 2005). Low et al. (2007) show that adoption rates were quite high, with 90 percent of the treatment households producing OFSP in the second year, that OFSP was the major source of vitamin A among treated children and median vitamin A intakes were higher among this group compared to children in the control households (median 426 vs. 56 μg retinol activity equivalent, RAE). Along with substantial reductions in vitamin A deficiency, they find an increase in serum retinol concentration among treated children (by 0.075 $\frac{\mu mol}{L}$ on average). However, due to small farmer groups and intensive messaging, TSNI was quite expensive on a per beneficiary basis.

Therefore, there is some evidence that it is generally possible to alleviate vitamin A deficiency through biofortification. However, previous research on biofortification through OFSP lacks two important aspects. Both previous OFSP interventions were quite intensive, and scaling up either project would be difficult or impossible. Therefore, the first important question is whether or not a lighter intervention with lower levels of extension would be as effective in increasing vitamin A intakes among children. Second, the design of a scalable, cost effective intervention is therefore still in question. Meenakshi et al. (2007) conduct an *ex ante* assessment of cost effectiveness of biofortification in overcoming micronutrient malnutrition. In the case of vitamin A deficiency, they find that between 38 and 64 percent of the deficiency burden can be eliminated through effective dissemination of OFSP. There is, however, very little evidence on the *ex post* cost effectiveness of such strategies (Low et al. 2009). The REU was explicitly designed to use more cost effective strategies of dissemination. We return to the issue of cost effectiveness in the discussion of our results, in particular focusing attention on the relative importance of various REU project components.

2.2 The REU Project

The REU project was designed to integrate three components, focusing on the production, consumption, and exchange of OFSP. It was implemented in both countries using two models, which differ primarily in timing and intensity of activities. Therefore, Models 1 and 2 have different average and marginal costs per beneficiary. In the first year of the intervention, the two models (Model 1 and Model 2) are identical in agricultural extension and nutrition education activities, rather than testing the efficacy of dropping certain components of the intervention.[5] Differences between the two models occurred in the second year. In Model 1, the high intensity of extension visits and nutrition messages from year 1 were continued in year 2. In Model 2, the activities in agriculture and nutrition were scaled back substantially in the second year to provide cost savings. In year 1, the intensity of treatments was kept the same because the initial high level of activity was considered necessary for the crop to be adopted and accepted. In both countries, multiple OFSP varieties were distributed during vine dissemination and farmers were trained about the agronomic, taste and health characteristics of the different varieties. Farmers therefore had the opportunity to try the varieties and determine which ones they preferred to grow and consume.

Seed Systems (Production)

The seed systems and extension component had three primary tasks. Succinctly, the project grew large quantities of OFSP vines for dissemination, distributed vines to project farmers, and taught farmers growing techniques. In order to disseminate the vines in a cost effective manner, a hierarchical management structure was designed in which extensionists working for NGOs hired by the REU project would train selected volunteer extension promoters from among farmer group or community group members. These promoters then assisted in vine distribution and trained group members on how to grow OFSP and maintain the vines between seasons.

Demand Creation (Consumption)

The demand creation component used multiple strategies to train and inform people about the nutritional benefits of consuming OFSP and other sources of vitamin A. Information was conveyed through a variety of sources including group trainings with farmer group members, community theatre sessions related to the health benefits of OFSP, radio spots, billboards and other advertising. With regards to extension, the demand creation component had a similar structure to the seed systems component. Nutrition promoters were selected from among farmer group or community group members and were trained to deliver nutrition-related messages to their farmer group members. Communication tools were developed to assist nutrition promoters in

[5] For example, one option would have been to focus on production in a subset of project areas, dropping the demand creation component of the intervention. We return to this concept in the empirical work.

training farmer group members.

Differences Between the REU in Mozambique and Uganda

Though the REU intervention was structured in basically the same way in Mozambique and Uganda, there are two particularly relevant differences between the two countries. First, there is an important distinction between the vine distribution policies. Second, the extension model differed slightly between the two countries. We discuss these differences here.

Due to differences in programming and agroecological conditions, the vine distribution policies in Mozambique and Uganda differed in both timing and quantity. In Mozambique, the REU project team was concerned about dependency by beneficiaries and an over-reliance on donors and the government, so a policy of broad, free distribution of vines was rejected. Instead, in the first year farmers were given two kilograms of vines for free and were allowed to buy up to eight more kilograms of vines at a moderate price. Because of dry growing conditions and only one main agricultural season in Mozambique, it was difficult for farmers to maintain OFSP vines between seasons. As a result, the REU project conducted annual vine distributions to farmers participating in the project, with varying vine distribution policies. In contrast, in Uganda there are two distinct agricultural seasons for sweet potatoes and therefore farmers have less trouble maintaining planting material over time. As such, the vine distribution policy was to initially provide farmers participating in the project with 20 kilograms of vines for free in the first season of the project. In later seasons, very limited vine dissemination was done, primarily targeted to households or communities that had lost their vine material between seasons due to dry weather.

Second, there was an important difference between the structure of the extension work, which is potentially important in considering project impacts. In both countries, extensionists worked with promoters in farmer groups, who then spread project messages among households. In Mozambique, there were actually two extensionists: an agricultural and a nutrition extensionist, while both roles were taken by one extensionist in Uganda. In Mozambique, the nutrition extensionist worked with several nutritional promoters per village, as it was deemed important prior to the project to work on nutrition with small groups of women, approximately ten per group. As farmer groups were smaller in Uganda, one agricultural and one nutrition promoter was used in each group. We control for individuals who served either as promoters or as farmer group leaders in the empirical work.

3 Conceptual Framework

Although the primary goal of the REU is to reduce vitamin A deficiency through increased OFSP consumption, the mechanisms by which OFSP can affect the prevalence of vitamin A deficiency can be fairly complex. Farmers must first learn about and decide to grow the new OFSP varieties, initially through interaction with promoters linked to the agricultural extension program. Other members of the community may later gain access to OFSP, by purchasing vines or receiving them as gifts from other households, or by consuming OFSP obtained in the market or as gifts. Once the OFSP roots are available from fields or markets, households must decide how much OFSP to consume, who will consume it, and in what form. The nutrition promotion activities should affect these behaviors and increase demand for OFSP and other sources of vitamin A. The nutrition trainings also teach households how to store and prepare the crop to maintain high levels of β-carotene in consumption.

To better illustrate the way a biofortification project could affect consumption, we consider how consumption and production decisions would change within the context of the agricultural household model (e.g. Singh, Squire, and Strauss, 1986).[6] Consider a household's decision about the consumption of a specific good, i. Assuming that functions are well-behaved, according to the agricultural household model the consumption C of good i will be:

$$C_i = f\left(\mathbf{p_A}, \mathbf{p_B}, M + E\left(\sum_{j=1}^{N} \pi_j^*(\mathbf{p_A}, \mathbf{p_B}|\mathbf{Z}, \mathbf{X})\right)|\gamma, \mathbf{X}\right) \tag{1}$$

where $\mathbf{p_A}$ and $\mathbf{p_B}$ represent vectors of prices of goods in sets A and B, respectively; M represents exogenous household income outside of farming; Z represents household endowments; X represents the information set available to the household; and γ represents the households idiosyncratic preferences. Finally, j references the N crops that the household might grow, and π_j^* represents the expected profits of growing crop j given household endowments and information. The crops are a subset of all goods consumed by the household, so prices in these sets can also affect profits. If markets

[6] We use the unitary household model for the sake of simplicity; the results and therefore empirical strategy would be unchanged if we instead considered a cooperatively bargained household model (e.g. Chiappori et al., 1993).

are complete, then the production and consumption decisions are separable (e.g. Benjamin, 1992). In other words, one can assume that the household initially maximizes profits, and then decides upon consumption based on prices and income; household endowments do not affect the household's consumption decision.

Now, consider that the goods in set B lack markets. The resulting consumption level of good i is:

$$C_i' = f\left(\mathbf{p_A}, M + E\left(\sum_{j=1}^{N} \pi_j^*(\mathbf{p_A}|\mathbf{Z}, \mathbf{X})\right)|\gamma, \mathbf{X}\right) \tag{2}$$

Missing markets can occur for inputs, such as land, labor, credit, or outputs, such as specific crops. There are several implications of missing markets. First, decisions about what crops to grow may now be influenced by household consumer preferences. If the household prefers to consume a crop that is not marketed, then the household must produce that crop. Second, household endowments may now play a role in consumption decisions.

Within this framework, consider the introduction of a new crop such as OFSP. Whereas at least seasonal markets exist for sweet potatoes in both countries, prior to the project markets for OFSP were largely non-existent in both countries. Therefore the model considering missing markets in equation (2) is more appropriate than model of demand in equation (1) in which markets for all goods exist. The introduction of the new crop can largely be thought of as a change in the household information set, from X_0 to X_1.[7] The information set may continue to increase as well throughout the life of the project, as biofortified varieties are agronomically superior to white or yellow varieties, and farmers may learn about these traits as they experience higher yields with OFSP than they had with white or yellow sweet potatoes; alternatively, nutrition messages about the crop may also resonate further as the project continues.

An increase in available information related to OFSP may therefore influence adoption and consumption decisions. The information works through two channels. First, given that the information relates to growing OFSP and their health benefits, the information should unambiguously lead to more consumption of OFSP. However, if markets do not develop households must adopt OFSP as a crop to increase their consumption. If households already grow other types of sweet potato, then they must to switch part or all of the area under sweet potato cultivation to OFSP to meet desired consumption

[7]At least in the first year of the project, when planting material is distributed in project villages, the price of OFSP vines simultaneously falls from ∞ to 0.

of OFSP; they may also bring additional area under the cultivation of sweet potato by growing OFSP by acquiring new land or substituting for other crops. If households adopt OFSP, note that there could be positive or negative effects on full income; the decision to adopt may also be influenced by latent household preferences for OFSP over other foods. The consumption decision may, therefore, be enhanced or dampened by the income effect.

Augmented availability of OFSP within the household does not necessarily translate to enhanced consumption among children and women. The unitary household model does not differentiate between members, assuming that consumption is equitably split among household members. Given that the project targeted messages about OFSP to increasing consumption of OFSP among young children and women, the allocation of food within the household may also be affected by the project.

To illustrate the primary mechanisms by which the REU can affect consumption, recall that adoption is measured at the end of the project (Figure 1). The intervention may have affected information about the nutritional content of OFSP, or vitamin A in general, which could in turn affect adoption decisions. Second, the increased information on nutritional content might affect consumption of OFSP by young children directly, either hypothetically through market purchases or through targeting young children as consumers of OFSP within the household. An alternative mechanism for increased consumption of OFSP is through adoption; farmers simply adopt OFSP and then consume them. We may also measure a direct effect of the intervention on consumption, which could occur for one of two reasons. First, the project could affect production or consumption for reasons not explicitly modeled; second, it could be that the proxy variables we use in estimation do not fully reflect project effects. We return to this point in discussing results.

4 The REU Evaluation

The impact evaluation is designed as a randomized-controlled, prospective evaluation with three intervention arms, comparing two treatments and a control group. In both countries, farmer groups were first stratified by district and then randomly selected into one of two treatment groups (Model 1 or Model 2) or a control group. The baseline survey captures pre-program outcome measures and also control variables in case the contexts differ across intervention arms. The endline survey measures changes in outcomes over time and captures exogenous economic shocks the household has experienced since the baseline. Impact estimates have a causal interpretation in randomized field experiments because access to the program cannot be correlated with local conditions or household behavior in the way that is typical of targeted interventions and those in which household self-selection is a major determinant of participation.[8] Heckman and Smith (2005) and Heckman, Ichimura and Todd (1997) explain how randomly assigning access to an intervention eliminates selection bias and, in the absence of significant sampling error, makes it possible to identify causal impacts of the interventions. Households in the control farmer groups were not included in the major components of the interventions, such as agriculture and nutrition trainings from the promoters, for the entire study duration. In both countries, Control group households may have been exposed to the media messages, particularly by radio, but were not otherwise directly exposed to intervention model activities.[9]

4.1 Sample Design

In this section, we describe the sample design in both countries, the data that were collected, and the way that vitamin A intakes are measured. The sample design was based on separate power calculations for the two countries, which focused on different outcomes. In Mozambique, the sample size was based on expected outcomes from the dietary intake study, and in Uganda, on serum retinol collection for Model 1 and on expected outcomes from the dietary intake study for Model 2.[10]. In both countries, based on the calculated necessary sample sizes, the goal was to interview exactly the same set of households and reference children in the baseline and endline surveys.[11]

[8] In the analysis of impact, all households who are members of a farmer group that was randomly assigned to receive an intervention will be considered part of the treatment group even if they decided not to participate. This gives the estimated impacts an "intent-to-treat" interpretation and eliminates bias from the household decision about whether to participate.

[9] At the end of the study period, control farmer groups were given OFSP vines. The use of a control group is justified in this setting because the long-term net benefits and cost-effectiveness of introducing OFSP in this way are not known, so that it is not clear *ex ante* whether intervention households will derive a benefit from the interventions, particularly after accounting for their cost of participation.

[10] We also collected dietary intake data on a repeated cross-section of children under 36 months old in both countries, and on mothers of the reference children. See Hotz et al. (2012a) for those results in Mozambique and Hotz et al. (2012b) for results in Uganda

[11] In Mozambique, the study design passed the Internal Review Board for the Ministry of Health. In Uganda, XXXX

Mozambique

The Mozambique sample is composed of 36 community organizations, each in a separate village, from four districts of Zambézia province: 18 of the organizations are located in Milange, 9 in Gurué, and the remaining 9 organizations are split between Nicoadala (5 organizations) and Mopeia (4 organizations). These districts are illustrated on the map of Zambézia (Figure 2). Due to similar agroecological conditions and language spoken in both, the organizations in Nicoadala and Mopeia were selected from a single stratum (the"South"). Power calculations indicated that 12 households per community organization be included in the nutrition survey; given additional returns to collecting socioeconomic data and adoption data indicated by power calculations, we strove to conduct the socioeconomic survey in 20 households per community organization.

Communities initially selected had to meet four salient requirements: they had to have enough families with children between the ages of 6 and 35 months in them at baseline to be able to meet sample size requirements; they had to have reasonably high access to lowlands so that vines could be kept between growing seasons; third, we made sure that other agricultural interventions were not active in selected communities, and that selected communities had not been previously targeted for an OFSP project; and fourth, the selected communities could not be adjacent to one another, to ensure control communities would not immediately receive OFSP vines from neighbors, and to limit jealousy between communities.[12] The 36 villages included in the sample were then randomly selected into one of the two treatment arms or the control group, stratified by district.[13]

In the majority of villages the socioeconomic teams interviewed 20 households as planned at baseline (28 out of the 36 villages). In some villages, only seventeen to nineteen households were surveyed. These villages were short of households largely because the enumeration staff could not find enough households with children in the appropriate age range.[14] A total of 703 households were included in the socioeconomic

[12]To implement the REU in Mozambique, farmer groups had to be formed by project staff, often from church groups. Before the fieldwork occurred in all communities, staff informed the leaders of that village about the survey and compiled a list of households that were members of the primary community organization that would be used as the organization for the intervention. From that list of households, twenty-five households with children less than three years old were randomly selected from the list of community group, where five were meant as replacement households; in general the enumeration staff found that the community lists did not always accurately indicate households with children under three years old.

[13]Randomization took place at a project meeting in Mozambique by selecting papers with village names on them from an urn.

[14]In a few instances some listed households were excluded because they were simply too far away from the

survey baseline sample (Table 1).[15] In all 36 villages the teams did 24-hour recalls in 12 households as planned at baseline, the resulting sample was 441 children (column 2). In the endline survey, 628 households were resurveyed in the socioeconomic survey, whereas 409 of the reference children were found and interviewed in the dietary intake survey. We also analyze a convenience sample of younger siblings of the original reference children to analyze changes in diet among children under 36 months old. The endline sample includes 279 such children (column 3).[16]

Uganda

The Uganda sample includes 84 farmer groups from three districts: Kamuli, Bukedea, and Mukono (Figure 3). These districts were selected for the REU project because white- and yellow-fleshed sweetpotato is commonly grown and consumed there and these districts are relatively close to potential markets for OFSP. Farmer groups were sampled from a list of active farmer groups in each district obtained from the non-governmental organization (NGO) implementing partners based on consultation with local leaders. Within district strata, farmer groups were randomly assigned into one of two treatment arms (Models 1 and 2) or the control group, in proportions 12:4:12. The sample is unbalanced, with fewer farmer groups in Model 2, because it was determined that the large samples required for biochemical assessment were too costly to include in all three intervention arms. The resulting sample includes 36 farmer groups in Model 1, 12 in Model 2, and 36 in the Control group.

Within farmer groups, the sample size depended on power calculations that informed the analysis of dietary intakes. In contrast to Mozambique, in Uganda reference children were defined as children aged 3 to 5 years of age (36 to 71 months), so that nearly all of these children would age out of the Uganda government's vitamin A supplementation program a few months before the endline survey. As 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

rest of the village to interview.

[15]In Mozambique, an intermediate socioeconomic survey took place as well in 2008, which is not used for this paper.

[16]The endline survey also completed dietary intake surveys in additional households to specifically include oldest children; all additional households were also farmer group members. They are not included here because we lack baseline characteristics for those households. However, results related to impacts on vitamin A consumption from the full sample of 6 to 35 month olds do not differ qualitatively from those presented in this paper.

blood samples, the target sample size per cluster was 14 households. For the purposes of this paper, then, the baseline sample is 1176 households that were farmer group members at baseline.[17]

Dietary intakes were collected in households in all farmer groups but the sampling of reference children for the dietary intake interviews was unbalanced, in order to account for the smaller number of clusters in the Model 2 intervention arm. In Model 1 and Control clusters, eight reference children age 3-5 years were randomly selected from sample farmer group member households, while in Model 2 clusters 14 reference children were selected for the dietary intake interviews. This created a total of 576 reference children in the baseline. As in Mozambique, in Uganda dietary intake surveys were collected among both reference children and children aged 6 to 35 months. Children aged 6 to 35 months were primarily enumerated as a convenience sample as younger siblings of the primary reference children, so no additional household sampling was required.[18]

4.2 Survey Content

Socioeconomic Survey

In both countries, baseline socioeconomic surveys were conducted (in 2006 in Mozambique and in 2007 in Uganda) to elicit information about household demographics and human capital, primary employment, landholdings, agricultural production of grains and legumes, detailed production information on sweet potatoes and growing practices, details on OFSP adoption, the use of agricultural inputs, sources of information and social networks, food consumption and expenditures, food consumed away from home and consumption habits, non-food consumption and expenditures, assets and information about the house, livestock, and shocks. We further asked both the mother and the father of the reference child about their knowledge of child feeding practices, vitamin A and its sources, and the sources of news and information they use. The baseline questionnaires in each country were similar, but modified to be relevant to the local context.

The endline surveys conducted in 2009 in both countries largely followed the struc-

[17] The survey also included five households per farmer group that were neighbors, explicitly to learn about the diffusion of OFSP vines at endline.

[18] In a small number of farmer groups, one household was added to the sample to reach the target number of children aged 6 to 35 months.

ture of the baseline surveys, but there were some important differences. The surveys included redesigned modules related to sweet potato production and consumption to learn specific details about the experience households had in growing OFSP. We asked about production since the project began; due to issues with potential recall bias, we asked a more detailed set of questions about the previous 12 months and more limited questions about seasons prior to the previous 12 months. The demographic sections of both surveys were designed to learn about whether the same members of the household remained and whether new household members had moved into the household. Furthermore, the endline gathered information on household participation in the REU project, their experience with OFSP adoption and production, and an expanded social networks module. At endline, survey teams made several efforts to contact each household included in the baseline survey. Survey teams also went back to households where either the household head or spouse was not present during the first interview, to attempt to fill in the nutritional knowledge sections for both the father and the mother of the reference child, when both existed.

Nutrition Survey

The nutrition baseline surveys took place in 2006/2007 and the nutrition endline surveys took place in 2009. The baseline surveys took place simultaneously, whereas the endline nutrition survey took place in advance of the endline socioeconomic survey in both countries, so that OFSP would still be in the field and being consumed by households.[19] As with the socioeconomic survey, the endline survey strove to collect data among reference children in the panel households. The primary component of the nutrition survey, of course, was the dietary intake survey.[20]

In both countries, we added households to the nutrition survey to include a repeated cross-section of children under 36 months old.[21] Additional households were sampled from 2007 vine distribution lists and have a child under 3 years old, so that they would be comparable to households initially selected in the impact sample. We further

[19] See Arimond et al (2008) for a detailed description of field procedures followed during the dietary intake component of the study.

[20] Several other data collection components were also completed during the nutrition survey. Anthropometric measures of children and mothers in the dietary intake study and all other panel households when possible; modules on morbidity and young child feeding practices were collected among the households included in the dietary intake study plus four additional households included in the socioeconomic survey, and a food frequency questionnaire was also administered among children.

[21] We also conducted socioeconomic surveys among these additional households.

identified households with first born children in both countries for this sampling, due to the concern that the sample of 6 to 35 month old siblings is that by construction, unlike the baseline sample, it would have no first-born children. If first-born children have different patterns of dietary intakes than higher birth order children, this could create a bias in the dietary intake measures.[22]

The most intensive component of the nutrition survey was the dietary intake module, which was designed to capture detailed data on the quantity and composition of all food consumed in the 24-hour period ending on the morning of the interview for targeted individual household members. The dietary intake survey used a quantitative 24-hour recall methodology adapted from an interactive, multiple-pass method developed previously for use in Malawi (Gibson and Ferguson, 1999). Key features of the method include a group sensitization or training session for mothers two days prior to data collection in the home, and a multiple pass approach to gathering information on foods and recipes eaten. Previously compiled standard recipes were also used for common mixed dishes to minimize respondent burden in recalling details of recipe preparation. Standard recipe data were collected from women in communities following the methods of Gibson and Ferguson (2008).

We then used the dietary intake data to estimate each individual's consumption of food energy, vitamin A, protein, and other micronutrients in a 24-hour period using the following procedure. A table of conversion factors was compiled from local sources where possible to convert food volumes or sizes to weights representative of the food state as consumed. Weights were then converted into energy and nutrient intakes using a food composition table compiled for this project, specific to each country.[23] One complication is that different varieties of OFSP have different β-carotene content, and in both countries the composition of varieties differed. To measure the average β-carotene content of OFSP being grown in specific districts in each country, we had samples of each OFSP variety analyzed for β-carotene content. We then used project data to estimate the proportion of each variety being grown by district and the yield per plant (in kgs) to weight the variety-specific β-carotene and estimate average vitamin

[22]In Uganda, a sampling frame was also developed to oversample older children, as the age distribution of siblings would miss a number of children roughly 20 to 35 months old at the time of the endline. Due to differential timing in Mozambique, this point was not a concern there.

[23]Where not possible from local sources, weights were derived from the USDA Nutrient Database (USDA, 2006). The USDA Nutrient Database was the primary source for conversion factors due to completeness and high quality analytic and sampling standards. Where nutrient content of raw foods was converted to cooked forms, appropriate water content changes and nutrient retention factors were applied (USDA, 2003).

A content.

From this procedure, we compute two measures of vitamin A dietary intakes. The first is the measure of dietary intakes of vitamin A computed directly from the 24-hour recall survey. This measure has a very high variance because of individual variability in consumption patterns across days. The second measure adjusts dietary intakes for within person variability. On a subset of participants in the study, a second day of dietary recall was completed, and we use the Iowa State University method to estimate usual vitamin A intake distributions (Nusser et al., 1996). The resulting distribution of vitamin A intakes, known as the Best Linear Unbiased Predictors (BLUPs), reflect only the between person variance in intakes. We largely focus on the first measure for this study, as the adjustments use group membership in the computation of the BLUPs, inflating, for example, the vitamin A consumption among children who are in non-participants in the treatment groups. For both age groups of children in the sample, it is necessary to adjust estimated impacts of the program for breastfeeding status because breastfed children receive fewer nutrients through complementary foods consumed and it is not possible to account for the nutrients they receive from the breastmilk in a recall survey.

5 Estimation Strategy

We measure the basic impacts of the REU in the following estimation framework. We want to explain an outcome, Y_{i1}, measured at the end line (period 1). To estimate the impacts of Models 1 and 2 on the outcome Y:

$$Y_{i1} = \alpha + \beta_1 T_{1i} + \beta_2 T_{2i} + \gamma X_i + \psi Y_{i0} + \varepsilon_i \tag{3}$$

where T_1 represents an indicator variable for households in Model 1 farmer groups, T_2 is an indicator variable for households in Model 2 farmer groups, i indexes households, X_i is a vector of baseline household characteristics, Y_{i0} is the baseline outcome, which is available for nutrition knowledge and vitamin A consumption outcomes, and ε_i is a mean zero error term. Equation (3) is a more flexible functional form than the difference-in-differences estimator and is identical to the difference-in-differences estimator if γ is restricted to 1. Since X_i and Y_{i0} are both theoretically orthogonal to the treatment variable, it should be possible to omit them from models with no consequences for the point estimate of β. However, these variables may also explain some of the variation in the endline outcome Y_{i1}, hence reducing the overall variance of the estimator. As a result, this form of the treatment model has more power than the difference-in-differences estimator when autocorrelation in the outcome variable exists (McKenzie, 2011).

The coefficients β_1 and β_2 represent the average intent-to-treat effect on Model 1 and Model 2 households or individuals, respectively. In addition to testing whether the intent-to-treat effect is larger than zero for each group, we can use equation (3) to test the null hypothesis that $\beta_1 = \beta_2$, which implies that the impacts of Models 1 and 2 were no different. If impacts are no different, we can instead estimate a simplified model:

$$Y_{i1} = \alpha + \beta T_i + \gamma X_i + \psi Y_{i0} + \varepsilon_i \tag{4}$$

where T now indicates a treatment indicator variable. In estimation, we find very few significant differences between impacts among Model 1 and Model 2 farmers, so we conduct the causal mediation analysis using equation (4) as the primary regression.

5.1 Measuring Outcomes

Given the parallel nature of the surveys in both countries, we can construct a set of comparable outcomes that trace impacts on nutritional knowledge, OFSP adoption, and vitamin A intakes among children. As we are focused on understanding how the project worked in terms of the conceptual model in Figure 1, we first choose variables that measure the impacts of nutritional extension (N_i) that logically might lead to adoption (A_i) or consumption (C_i). We therefore measure the impacts of nutritional extension using two variables: the number of vitamin A messages promoted by the REU that mothers could recite, and conditional on knowing about vitamin A, whether mothers named OFSP as avitamin A source when asked an open ended question regarding vitamin A food sources.

We primarily measure adoption as an indicator variable, defined as whether or not farmers kept vines for the following season (Mozambique) or if farmers were growing OFSP at the time of the final survey (Uganda).[24] An indicator variable does not

[24]Given that the project distributed vines to farmers in the last year of the REU in Mozambique, we deemed that whether or not farmers kept vines as a better indicator of adoption. Follow-up fieldwork conducted by the International Potato Center (CIP) in 2010 indicated that this variable reliably estimated adoption at the community level.

measure the extent of adoption, so we also measure the intensity of adoption, we also use the share of OFSP in the total sweet potato area farmed by the household. The drawback to this variable is that it is undefined for households that do not grow sweet potatoes; yet for those that do grow sweet potatoes, it measures the commitment to OFSP quite well.[25] Finally, we measure consumption using the unadjusted vitamin A intakes (C_i) directly, calculated from the dietary intake studies (Hotz et al., 2012a; Hotz et al., 2012b). We will measure impacts of the REU on daily vitamin A intakes both among the reference children and among the repeated cross-section of children aged 6 to 35 months. For the latter group, ΔC_i is not available by definition. Therefore, we estimate a modified version of equation (3):

$$\Delta Y_{it} = \alpha + \eta_1 T_{1it} + \eta_2 T_{2it} + \psi E_i + \beta_1 E_{it} \cdot T_{1it} + \beta_2 E_{it} \cdot T_{2i} + \gamma X_{i0} + \varepsilon_{it} \tag{5}$$

where E is an indicator variable for the endline survey; and X is now referenced by a zero denoting that it is measured at baseline. The impacts of Models 1 and 2 are still measured by β_1 and β_2, respectively, and if we accept the null hypothesis that $\beta_1 = \beta_2$ we can simplify equation (5) to measure a single treatment effect.

5.2 Causal Mediation Analysis

We are interested in understanding the contribution of additional nutritional knowledge to adoption, and the contribution of additional nutritional knowledge and adoption to increased vitamin A consumption among children (Figure 1). As the treatment assignment was randomized, we can identify the average treatment effect, but we are also interested in the average causal mediation effect, or the average effect of the treatment that occurs through a mediating variable. Consider that the outcome of interest Y_i for individual i is a function of both the treatment and some mediating variable $M_i(T_i)$, which is itself affected by the treatment. Following Imai et al (2011), we can write the casual mediating effect as quantity as:

$$\delta_i(t) \equiv Y_i(t, M_i(1)) - Y_i(t, M_i(0)) \tag{6}$$

for each treatment status $t = 0, 1$. The quantity $\delta_i(t)$ represents the change in the outcome Y that corresponds to the change in the mediator variable from the control to

[25]Both of the adoption variables are measured at endline only, so $A_{i0} = 0 \; \forall \; i$.

the treatment condition while holding the effect of the treatment otherwise constant. Clearly, for observations receiving the treatment $M_i(0)$ cannot be observed, so this quantity must be estimated.

The direct effect $\zeta_i(t)$ of the treatment is what remains after the indirect effect is estimated, and can be written as:

$$\zeta_i(t) \equiv Y_i(1, M_i(t)) - Y_i(0, M_i(t)) \tag{7}$$

for each treatment status $t = 0, 1$. Averaging over all individuals i, the average causal mediation effect (ACME) is $\overline{\delta}(t)$ and the average direct effect (ADE) is $\overline{\zeta}(t)$. The average treatment effect $\overline{\beta}$ is equal to the sum of the ACME and the ADE, $\overline{\beta} = \overline{\delta}(t) + \overline{\zeta}(t)$.

To estimate the ACME and the ADE, we must make a further assumption, that Imai et al. (2010) call the sequential ignorability assumption. First, we assume that given the baseline characteristics, assignment to the treatment is independent of outcomes and mediator variables:

$$\{Y_i(t, m), M_i(t)\} \perp T_i | X_i = x \tag{8}$$

Equation (8) should hold due to the randomization of the treatment. Second, the sequential ignorability assumption states that:

$$Y_i(t, m) \perp M_i(t) | T_i = t, X_i = x \tag{9}$$

Equation (9) implies that once we control for actual treatment status and observed baseline characteristics, there are no unobservables that confound the relationship between the outcome and the mediator variable. The assumption is clearly quite strong. If some unobservable affects both the mediating variable and the outcome, then estimates of the ACME are likely to be biased. However, making the assumption allows us to estimate both the ACME and the ADE, without any parametric assumptions; that is, Imai et al. (2010) demonstrate that no further distributional or functional form assumptions must be made to identify the ACME and ADE if the assumption in equation (9) holds. Therefore, in exchange for making a strong assumption about the relationship between the outcome and the mediator, we can estimate the ACME and the ADE with few additional assumptions. Further, after computing the ACME and the ADE, we test the robustness of our estimates to unobservables that might be correlated with both the mediator and the outcome.

After making the sequential ignorability assumption, an initial way of estimating the ACME is to assume a linear relationship and estimate:

$$\Delta Y_i = \alpha + \kappa T_i + \xi M_i + \gamma X_i + u_i \tag{10}$$

The ACME can be calculated using M_i as the dependent variable in equation (4); it is $\hat{\beta}\hat{\xi}$, where β is the effect of the treatment on the mediator and ξ is the effect of the mediator on the outcome. Sequential ignorability implies zero correlation between the error terms ε_i and u_i; however, a finding of no correlation does not necessarily imply that sequential ignorability holds.

Imai et al. (2011) propose a non-parametric estimator for equations (6) and (7), which relaxes the linearity assumption in equation (10). They estimate the ACME by estimating regression models as above, then predicting the treatment effect using the value of the mediator variable predicted in the treatment condition, then the control condition, and averaging over those for all values. In estimating regression models predicting the mediator and the outcome of interest, the linearity assumption above can be relaxed; for example, a logit or a probit model can be used to estimate a binary outcome.[26]

Imai et al. (2010) further propose a method of testing the sensitivity of the ACME estimate to the sequential ignorability assumption. Define $\rho = \varepsilon_i u_i$, or the correlation between the two error terms. If $\rho \neq 0$, it implies that a confounding variable (or a set of confounding variables) exists that biases the ACME estimate. Larger values of ρ, in absolute value terms, imply larger bias in the estimate of the ACME. Imai et al. (2010) note that it is possible to demonstrate how much a potentially omitted variable might affect the relationship between the outcome and the mediator through the goodness of fit (R^2). If an unobserved variable, such as the predisposition to participate in programs, was unobserved and was quite important, it would change the goodness of fit in both models. On the other hand, if it does not matter much, it would slightly change the R^2 in both models. Therefore, the relative change in R^2 between the two models can be used as a sensitivity check, simulating over many possible changes in the goodness of fit. We incorporate sensitivity checks into our analysis, in case there is a confounding variable that violates the sequential ignorability assumption and might

[26] We note that if a logit or probit model is used in estimating the ACME and ADE, alternative assumptions are made about the structure of the error terms. However, such models may be more appropriate.

affect our estimates of the contributions of nutritional knowledge variables to OFSP adoption, or of nutritional knowledge or adoption to vitamin A consumption among children.

6 Results

In this section, we first present estimates of the impact of the REU on nutritional knowledge indicators, adoption behavior, and vitamin A consumption among children. We then present estimates for adoption behavior using causal mediation analysis to ascertain how much of the adoption behavior can be explained through the knowledge of messages regarding health of vitamin A, including sensitivity analysis. We finally present estimates for vitamin A intakes using causal mediation analysis to understand how much of those results can be explained through either nutritional knowledge or adoption behavior.

6.1 Main Impact Estimates

Before we estimate impacts, it is important to consider whether there are large differences in descriptive statistics at baseline between Model 1, Model 2, and control households (Table 2). Although there are some discrepancies between averages for some statistics between groups, in most cases they are not statistically significant.[27] Where they are significiant, controlling for these observable characteristics in regressions may slightly affect impact estimates.

We next present average values for the nutritional knowledge indicators at baseline and endline, adoption at endline, the share of OFSP in total sweet potato area at baseline and endline, and vitamin A intakes among both reference children and the repeated cross-section at baseline and endline (Table 3). At least descriptively, we find substantial evidence of impacts in both countries. In Mozambique, we find that approximately two thirds of mothers in the two treatment groups name OFSP as a source of vitamin A at endline, whereas only one third of mothers in the control group do so. Less than 20 percent of mothers did the same prior to the baseline. The pattern of learning was similar in Uganda. We find similar improvements in the number of vitamin A messages that women can recite.

[27]These slight differences are studied in more detail in project baseline reports (Arimond et al., 2007; Gilligan et al., 2008).

Examining adoption across the two countries, we also find that the REU appears to have had impacts. In Mozambique, 75 and 79 percent of farmers in Models 1 and 2 were growing OFSP at endline, whereas only 9 percent of farmers in the Control group were doing so. Among farmers growing OFSP, the share of OFSP in total area devoted to sweet potatoes increased as well, from between 11 and 20 percent at baseline to between 70 and 73 percent at endline, whereas it actually declined among the control group. It is worth noting that only about 50 percent of baseline farmers were growing any sweet potatoes, so many farmers are dropped altogether from the reported proportions at baseline.

Average dietary intakes of vitamin A by reference children also increased substantially in Model 1 and Model 2 households in both countries (Table 3, Panel C). Reference children, aged 6 to 35 months in Mozambique, consumed slightly more than 200 μg RAE of vitamin A at baseline, regardless of group membership. In Uganda, the reference children were older and so it is not surprising that their baseline consumption of vitamin A is higher, at between 430 and 550 μg RAE in unadjusted terms; once the averages are adjusted, they are all quite similar. In 2009, reference children in both countries assigned to Models 1 and 2 consume more vitamin A than children in the control groups. In Mozambique, where children are aged 3-5 years at endline, according to unadjusted intakes children in Models 1 and 2 consume over 600 μg RAE on average, whereas in the control group they consume only 350 μg RAE. In Uganda, children consume between 860 and 1105 μg RAE in the Model 1 and 2 groups, whereas the control group consumes 575 μg RAE on average. The BLUPs tell a similar story, though standard deviations are substantially reduced. As with adoption and nutritional knowledge, these statistics suggest that Models 1 and 2 both had positive impacts on vitamin A intakes, but there was little difference in impacts between the two models.

Impacts on Nutritional Knowledge Indicators

We initially estimate equation (3) using the two nutrition knowledge indicators as the dependent variable (Table 4). For Mozambique, we find that the REU had a significant impact on the proportion of mothers who named OFSP as a source of vitamin A, whether or not we control for household baseline characteristics (columns 1 and 2). We also find that the REU had a significant impact on the number of vitamin A messages known (columns 3 and 4). In Uganda, point estimates for both dependent variables are somewhat higher than in Mozambique, with or without controls for baseline characteristics. Mothers naming OFSP as a source of vitamin A increased by more than 40 percentage points in both Models (columns 5 and 6), whereas the number of messages known also increased by approximately half a message on average (columns 7 and 8).

While the coefficient estimates differ somewhat by Model for both Mozambique and Uganda, in neither country do we find larger point estimates for Model 1 than Model 2. Moreover, there are no statistically significant differences between models. Had we found a pattern of larger point estimates for Model 1 than Model 2, we might have begun to believe that Model 1 was more effective, but perhaps we might have believed that the sample simply lacked power to measure the difference between Models 1 and 2. However, we find larger point estimates among Model 2 mothers for the number of vitamin A messages known in both countries, so it does not seem likely that Model 1 had larger impacts overall than Model 2. We report the average treatment effect across Model 1 and Model 2 using the same specifications at the bottom of Table 4 with one variable to indicate households that were assigned to either treatment group. We find that the estimated impacts of the REU on nutritional knowledge were somewhat higher in Uganda than in Mozambique. In Mozambique, mothers naming OFSP as a source of vitamin A increased by 24.4 percentage points (column 2), while the same measure increased by 44.6 percentage points in Uganda. Mothers knew 0.35 more vitamin A messages as a result of the program in Mozambique, while they knew an additional 0.53 messages in Uganda. Therefore, there are some clear, if modest, gains in nutritional knowledge that occurred among mothers during the REU in both countries. There are two important implications. First, for causal mediation analysis it should not matter that we average impacts among Models 1 and 2. Second, Model 2 was explicitly designed to be less costly than Model 1. As such, these estimates suggest that Model 2 was more cost effective than Model 1.

Impacts on OFSP Adoption Indicators

Esimating equation (4) with an indicator for adoption as the dependent variable demonstrates that both Models 1 and 2 had an impact on adopting OFSP in both countries (Table 5). In Mozambique, when additional household characteristics are not included, we find that households in Model 1 were 65.7 percentage points more likely to adopt than the control group, and households in Model 2 were 69.2 percentage points more likely to adopt. When we control for additional household characteristics, coefficient estimates on the Model indicators decrease somewhat, to 62.5 and 65 percentage points for Models 1 and 2, respectively. In Mozambique, two explanatory variables are clearly correlated with adoption. Households headed by a female at baseline are less likely to adopt, whereas households that include a leader or promoter are significantly more likely to adopt.

In Uganda, we find remarkably similar results (Table 5, columns 5 and 6). Households in Models 1 and 2 are 63.5 and 57.3 percentage points more likely to adopt OFSP than the control, when we do not control for additional household characteristics. When we do so, the coefficients on the treatment indicators only decrease slightly, to 61.2 and 57.0 percentage points, respectively. As in Mozambique, leader or promoter status is positively correlated with adoption. Therefore, we can generally conclude that in both countries the REU was successful in leading to OFSP adoption among farmers. Furthermore, as point estimates for adoption were similar in both countries, it is clear that combining the two treatment groups is appropriate for causal mediation analysis. The combined estimates represent the impact we seek to explain through causal mediation analysis; in Mozambique, the impact estimate is 63.8 percentage points, whereas it is 60.2 percentage points in Uganda (Table 5, columns 2 and 6, respectively).

Next, we estimate the impact of Models 1 and 2 on the share of sweet potato area devoted to OFSP, to measure the intensity of the intervention (Table 5, columns 3, 4, 7 and 8). Recall that these regressions are conditional on growing any sweet potato, as observations drop when no area is devoted to sweet potatoes. We find that farmers in Mozambique devote 61.5 and 59 percentage points more of their sweet potato area to OFSP when participating in Models 1 and 2, respectively. Only about half of the sample in Mozambique grew OFSP prior to the baseline, and so it is not surprising that the coefficient is relatively large. Many farmers actually adopted OFSP as their only sweet potato variety between the baseline and endline. In Uganda, farmers were more likely to grow sweet potatoes prior to the baseline, so it is not surprising that the share of sweet potato area devoted to OFSP only rises by between 43.3 and 43.7 percentage points among the Model 1 and 2 farmers relative to the control group. In both countries, there was substantial substitution in production of orange-fleshed sweet potato for conventional white and yellow varieties. However, in Uganda in particular, households demonstrated a preference for variety, keeping more than half of their sweet potato fields devoted to conventional varieties. There are no significant differences in impacts on planted area between Models 1 and 2 in both countries, so, as with the discrete adoption indicator, we can combine the two estimates to one treatment indicator without much loss of generality (Table 5, columns 3,4, 7 and 8).

In summary, we find that the REU had a significant impact on OFSP adoption, when we use both discrete and continuous variables to measure adoption. In Mozambique, the proportion of farmers growing OFSP increased by 63.8 percentage points relative to the control group, and farmers in the treatment groups who grew sweet potatoes devoted 60.8 percentage points more of their land to OFSP than sweet potato farmers in the control group, demonstrating that adoption was substantial. In Uganda, we also find substantial discrete adoption– relative to the control group, farmers adopting OFSP increased by 60.2 percentage points in the treatment groups. The share of sweet potato area devoted to OFSP increased somewhat less than in Mozambique, by 43.6 percentage points, in part because farmers in Uganda were more likely to grow both white and orange sweet potatoes by the final survey.

Impacts on Vitamin A Intakes: Reference Children

The REU project led to substantial increases in average dietary intakes of vitamin A for reference children in both countries (Table 6).[28] Average vitamin A intakes of reference children in Mozambique increased by between 188 and 208 μg RAE, as measured by the BLUPs, with an average impact of 191.5 μg RAE as a result of the program. This impact is substantial, given that the recommended daily intake for children aged 6-35 months is 210 μg RAE. There is no difference in impact between Model 1 and Model 2, suggesting that the more intensive trainings in Model 1 did not contribute to additional improvements in vitamin A intakes. In Uganda, the impact on dietary intakes of vitamin A for reference children was somewhat larger, ranging from 210.8 to 327.1 μg RAE in the BLUPS for Model 1 and Model 2, respectively, with an average treatment effect of 254.1 μg RAE. The larger effect in Uganda than in Mozambique may in part reflect the fact that reference children were 6-35 months of age at baseline in Mozambique but 36-83 months of age at baseline in Uganda. The period between baseline and endline was nearly 36 months in Mozambique and was only 24 months in Uganda, however, the somewhat older children in Uganda should have had higher intakes of food energy and many nutrients by virtue of their age. As in Mozambique, this effect size in Uganda is very large, given that the cutoff for adequate dietary intakes of vitamin A in children age 3-5 years is 26 μg RAE. Impacts on dietary

[28]See Hotz et al., 2012a and Hotz et al., 2012b for additional analysis of the nutritional impacts of the REU project in Mozambique and Uganda, respectively.

intakes in Uganda as measured by the BLUPs are statistically significantly larger for Model 2 than Model 1, again indicating no gain to the additional trainings provided under Model 1.

6.2 Causal Mediation Analysis: Estimates

Next, we want to understand the contributions of additional nutritional knowledge to the adoption decision and the contributions of nutritional knowledge and adoption to the intakes of vitamin A among children. As discussed in section 5.2, to estimate causal mediation effcets we make the sequential ignorability assumption embedded in equations (8) and (9). After estimating equations (6) and (10), we provide conditional correlations between the error terms of equation (10) and a version of equation (4) which uses the mediating variable as the dependent variable, to understand whether bias might exist in our estimates of the ACME, and if so, in which direction the bias might be.

OFSP Adoption and Nutritional Knowledge

Our first goal is to understand the mediating effect of increased nutritional knowledge on our measures of adoption. We measure adoption and nutritional knowledge in both countries in two different ways, so there are eight different mediation effects that we measure in this subsection. Where possible, we estimate equation (6); however, in practice it is only possible to estimate the ACME this way when at least the mediating variable is specified as a continuous variable. The continuous measure is the increase in knowledge of vitamin A messages, so the non-parametric estimates use that variable as the mediator. In non-parametric estimation, we measure the ACME both directly and by interacting the mediating variable with the treatment variable, to try to isolate the impacts of the mediating variable for treated households. For all combinations, we also make a linearity assumption and estimate equation (4). We then describe the impacts that correlation between residuals would potentially have on our estimates for the continuous measure of adoption, and provide estimates of correlations from the linear versions of all of our estimates.

We first estimate causal mediation effects making the linearity assumption (Table 7). Whether we use the OFSP as a source of vitamin A variable or the number of vitamin A messages known as the mediating variable, in either case we find a very limited amount of adoption occurs through nutritional knowledge. When we use OFSP as a source of vitamin A as the mediating variable, we find a positive but insignificant coefficient (0.058) on the mediating variable in Mozambique (Table 7, column 2), and a statistically significant coefficient in Uganda of 0.082 (Table 7, column 6). In Mozambique, controlling for baseline characteristics the point estimate for the effect of the number of vitamin A messages known at endline on the probability of OFSP adoption is 0.049 (column 4); in Uganda, it is 0.027 (column 8). In Panel A of Table 9, we calculate the ACME and the ADE for each of the two mediating variables and countries, whether or not we condition on baseline characteristics, we find that the mediating effect of the nutrition variables never exceeds 5 percent in Mozambique (in column 3) and 11 percent in Uganda (in column 5). Therefore both mediating variables suggest that the effect that increased knowledge had some limited importance for the adoption of OFSP in both countries.

We next use the share of sweet potato area planted in OFSP as the adoption measure, continiuing the linearity assumption, and we find similar results (Table 8). The results are quite similar to those found in Table 7. In Mozambique, we find small, positive coefficient estimates for both mediating variables (columns 1-4); all but one are significantly different from zero. In Uganda, for both mediating variables we estimate coefficients on the mediating variables that are small and not significantly different from zero (columns 5-8). Therefore there appears to be only a small amount of mediation through nutritional knowledge on the intensity of participation. Not surprinsingly, when we compute the ACME in both countries, we find that it is very small relative to the ADE (Table 9, Panel B). In fact the ACME is only significant at better than the 5 percent level when we use the OFSP as a source of vitamin A variable as a mediator in Mozambique, and the point estimates suggest an ACME of 5 percent or less. The ACME is not significantly different from zero in Uganda.

We finally relax the linearity assumption, using the share of sweet potato area planted in OFSP as the impact variable and the number of vitamin A messages as the mediator, and graph the ACME relative to the ADE and the total impact. We initially examine results without an interaction between the mediator and the treatment variable (Figure 4). We find a very small ACME in Mozambique, and the ACME in Uganda is not significantly different from zero. We then repeat the figure interacting the mediator and the treatment (Figure 5); the rationale for the interaction is to better isolate the way the mediation variable works for treated households than non-treatment households. Not surprisingly, the positive ACME is found among the treatment group in Mozambique, but neither ACME (through the treatment or control) are significantly different from zero in Uganda. Therefore, it is not even clear that the share of sweet potato area planted with OFSP is mediated by knowledge of vitamin A messages in Uganda (Panel A). In sum, to this point the non-parametric estimates are quite consistent with the estimates made with the linearity assumption. the mediation effect appears to be quite small.

Before we make any conclusions based on our estimates of mediation effects on adoption through nutritional knowledge, we need to consider how the sequential ignorability assumptions may affect our estimates. We initially graph the ACME under the assumption that the conditional correlation between error terms is not correct, when using the increase in the number of vitamin A messages known as the mediating variable and the share of sweet potato area devoted to OFSP as the dependent variable (Figure 6).[29] In both countries, the graphs suggest that if there is a negative correlation between error terms, then we are underestimating the ACME. Even if the correlation between error terms was substantial and negative in Mozambique (e.g. -0.5), little adoption would be explained by the mediating variable. More adoption would be explained by the mediating variable in Uganda if there was substantial negative correlation between error terms. In both cases, if the conditional correlation is positive, then the ACME is actually overestimated.

Therefore, it is worth considering the most plausible direction of correlation between the error terms. Recall that the REU provided households both with OFSP vines and nutritional knowledge. The residuals in explaining nutritional knowledge, then, are the amount of increased nutritional knowledge that we cannot explain after controlling for the treatment effect and baseline household characteristics, and the residuals in explaining adoption is the amount of adoption we cannot explain after controlling for the same variables and the mediating variable. It seems likely that if anything, the residuals would be positively correlated, since a negative correlation would imply that households with additional unexplained nutritional knowledge are actually less likely to have unexplained adoption behavior. We would therefore expect positive correlations between residuals, if any correlation exists.

In fact, we estimated correlations between residuals between the regressions explaining mediating variable and the equations estimated in Tables 7 and 8 including baseline characteristics, and find small positive correlations in Uganda, and no correlations at

[29] Panel A shows the relationship without the interaction between the treatment and mediating variable, and Panel B shows the relationship with the interaction. Since results are quite similar qualitatively, we discuss them together.

all in Mozambique (Table 9, Panels A and B). These conditional correlations suggest that if anything, we overestimate the ACME in Uganda, but not in Mozambique. In Uganda, the correlations are slightly higher for the variable measuring knowledge that OFSP is a source of vitamin A, suggesting that the conclusion that as much as 11 percent of adoption in Uganda can be explained through this increase in knowledge is an upper bound.

In summary, using the available measures we find that the demand creation component of the intervention had little impact on adoption of OFSP. One could conclude that the demand creation component was therefore ineffective, in that it did not contribute much to adoption. Alternatively, either the initial price of vines (zero), the vines' other traits such as resistence to pests, characteristics or consumer acceptance of OFSP were enough to catalyze adoption, and enhancing nutritional knowledge was not necessary for project success. However, it could be that the variables representing project messages available to us are not broad enough; the general message that OFSP are healthy might have been an important part of adoption. That message, however, is not simple to measure quantitatively given the available data. We return to this concept as we discuss the cost effectiveness implications of our results.

Nutritional Knowledge, OFSP Adoption, and Vitamin A Intakes

Our next goal is to understand the role in both adoption and nutritional knowledge in explaining vitamin A intakes in the target population. We limit ourselves to examining the mediation effects of OFSP adoption and nutritional knowledge among the reference children; that is, children who were aged 6 to 35 months at baseline in Mozambique and children who were aged 3 to 5 years in Uganda. We initially estimate a version of equation (10) with two potential mediating variables, one measuring adoption and one measuring nutritional knowledge.[30] We build up estimates in both countries by first estimating models with each mediating variable alone, then testing each possible nutritional knowledge indicator. We focus on the binary measure of adoption and test both possible measures of nutritional knowledge; given that we are primarily using binary mediating variables, we continue to make the linearity assumption in these estimates as well as the strong sequential ignorability assumption. All results on causal mechanisms are, of course, conditional on those assumptions.

[30] Given that in the previous subsection we found that nutritional knowledge only has a small impact, if any, on adoption, we ignore the possibility that the effect of adoption on intakes flows through incresaed nutritional knowledge.

Before presenting estimates, we finally note that we use the unadjusted vitamin A intakes rather than the BLUPs also presented in Table 6. The BLUPs are particularly useful in predicting the vitamin A deficiency within a group, but they are likely to produce biased mediation effects. The variance adjustment done using the second day recall is done within each strata for each treatment group, and so at the individual level it adjusts one day estimates of vitamin A intakes upwards among non-adopters and downwards among adopters. The unadjusted vitamin A intakes are noisier, but should provide us with estimates of the mediation effects that are only affected by any bias generated from the independence assumptions.

In Mozambique, when we add the adoption variable as a mediator in a regression explaining vitamin A intakes, we find that it usurps nearly the whole treatment effect (Table 10, column 1). Whereas the confidence intervals are wider, we find that there is no evidence of a direct effect when we graph the average causal mediation effect (Figure 7, Panel A).[31] However, it appears that the level of participation in growing OFSP does not matter as much (Figure 8, Panel A). When we use the share of OFSP in SP area as the mediator, we find no mediation effect. So the act of growing OFSP appears to induce vitamin A intakes; the amount grown appears not to matter.

When we instead use one of the two nutrition knowledge indicators as a mediating variable (Table 10, columns 2 and 3), we find that the coefficient estimates on the mediating variables are relatively small and imprecisely estimated, both with t ratios below 1. Graphically, the direct effect looks quite similar to the total treatment effect (Figure 9, Panel A). As with adoption, the sensitivity analysis demonstrates that there would have to be a very strong, negative correlation between error terms to generate a large mediation effect through nutritional knowledge. Therefore, it seems like the demand creation component had little to do with adoption behavior in Mozambique.

To confirm this hypothesis, we use the discrete adoption variable and the two nutrition knowledge variables sequentially as multiple mediation variables (Table 10, columns 4 and 5). We find that the coefficient estimate on the adoption variable is nearly the same in both specifications as it had been when it appeared alone. The estimated coefficients on the nutrition knowledge variables remain relatively small and are not statistically different from zero. These results appear quite consistent with the results from the previous subsection, which suggested that nutritional knowledge only had a small impact on adoption, if any. These results combine to suggest nutritional

[31] For this subsection, we use graphs without the interaction between the treatment and mediator, for simplicity of exposition. The graphs do not differ much qualitatively from those presented.

knowledge did not have much of an effect on vitamin A intakes among the reference children, at least in Mozambique.

We next explore the mediation effects among reference children in Uganda (Table 10, columns 6 through 10). As in Mozambique, we find a large, statistically significant coefficient estimate on the adoption variable (column 6). However, we also note that the point estimate on the treatment effect remains reasonably large, suggesting unexplained variation in vitamin A intakes; this estimate shows up as a relatively large average direct effect (Figure 7, Panel B). As in Mozambique, we find that using a continuous measure of adoption, the share of OFSP in sweet potato area, yields almost no average causal mediation effect (Figure 8, Panel B). As such, we conclude that the amount of OFSP grown does not appear to affect dietary intakes among children seperately from the act of growing OFSP.

We then use the nutritional knowledge variables as the mediators (Table 10, columns 7 and 8). The point estimate for the coefficient on the variable measuring whether the mother names OFSP as a food source of vitamin A is actually negative; the coefficient on the variable measuring the number of vitamin A messages is positive, but not significantly different from zero. Graphing the average causal mediation effect and the average direct effect, not surprisingly we find that the number of vitamin A messages does not appear to be a mediator (Figure 9, Panel B). Similar to Mozambique, the error terms would have to have a substantial negative correlation before the mediation effect through nutritional knowledge would explain a substantial amount of the average treatment effect for dietary intakes of vitamin A.

When we estimate models with two mediating variables in Uganda (Table 10, columns 9 and 10), coefficient estimates on the mediating variables do not change much from the regressions in which they entered alone. Because we estimate a negative mediating effect on the OFSP as a source of vitamin A indicator variable, we focus interpretation on the number of vitamin A messages as a mediating variable. An interesting aspect of this regression is that the residual effect of the treatment, contained in the direct effect, drops somewhat in magnitude with both mediating variables used, relative to just using the adoption variable. Compared with the results for Mozambique, there still appears to be a reasonable amount of the treatment effect that remains unexplained by the two mediating variables.

We use the coefficient estimates above to estimate each ACME and the remaining ADE of the treatment on vitamin A intakes among the reference children (Table 11). Specifically, we use the results in column 1 of Table 10 in Mozambique and column 6 in Uganda to estimate the ACME through adoption without the nutritional knowledge variables, and columns 5 and 10 for Mozambique and Uganda, respectively, when we add the number of vitamin A messages known as a mediating variable.

In Mozambique, we find that the increase in vitamin A intakes among the treatment group can fully be explained through the adoption of OFSP, regardless of whether we control for nutritional knowledge indicators (columns 1 and 2). The estimated ACME for adoption, 190 μg RAE, is almost identical to the average treatment effect on the treated estimated in Table 6 (188 μg RAE), and it does not change when we also control for the number of vitamin A messages known. Meanwhile, when we estimate the ACME for the number of vitamin A messages known, we estimate a small effect (14.1 μg RAE) that is not precisely estimated. The point estimate represents 7.5 percent of the average treatment effect. At least among reference children in Mozambique, these results suggest the impact pathway runs almost directly through adoption. If households adopt OFSP, they find their way into the diet of younger children.

The findings in Uganda are substantially different (Table 11, columns 3 and 4). The ACME for adoption is 201.1 μg RAE, explaining less than half of the average treatment effect of 420 μg RAE on its own (column 3). It drops slightly when the number of vitamin A messages are added to the regression, which explain about 14 percent of the average treatment effect; the coefficient estimate is 58.6 μg RAE and it is significant at the 10 percent level. Whereas the ACME for adoption continues to explain the largest share of the average treatment effect, just over 40 percent of it is left unexplained by the mediating variables. Since the direct pathway from the program directly to consumption is unlikely, these results suggest that some variable is missing that might help explain adoption and intakes by reference children.[32]

As we have discussed throughout the paper, the nutritional knowledge variables are inherently narrow; they are measuring whether mothers grasp specific knowledge that was disseminated as part of the project. It seems plausible that the general health message of the project– that is, that OFSP are healthy for younger children to consume– may help explain some of the remaining increase in intakes by younger children.[33] Conditional on the assumptions we made to generate estimates of the mediation effects, at least in Uganda the nutritional knowledge component of the project may have had

[32]The estimated ADE could in part reflect unmodeled correlations between the residuals in error terms between the two mediating variables and the outcome variable.

[33]This message comes across both in the overall project report (HarvestPlus, 2010) and in qualitative research that was done as part of the project.

an important role in increasing vitamin A intakes, though its role appears small based on the narrow measures of nutritional knowledge. Given that the correlation between error terms in the mediation regressions is likely to be positive, if anything, these estimated impacts are likely upper bounds.

7 Cost Effectiveness Implications

We next want to consider the implications of our results for the cost effectiveness of future, similar interventions to the REU. In this section, we first discuss the cost per beneficiary of the REU program, and then we discuss the implications of our findings for the components of the REU that could be dropped without materially affecting the overall impacts of the project. We conclude the section by describing a hypothetical scaled-up intervention and its cost per beneficiary in both countries.

Before beginning, it is worth discussing a few points. First, we will focus on the average costs per beneficiary, since the marginal costs are a difficult concept to define in this case (see de Brauw et al., 2010, for an extended discussion). Second, we will begin our consideration of costs from the perspective of Model 2, since Models 1 and 2 clearly had similar impacts, and Model 2 was relatively less expensive, as it reached more beneficiaries in both countries. Third, we recognize that there are several types of beneficiaries to the intervention, and we must limit the way we measure beneficiaries.

We measure beneficiaries in four ways. First, we choose to define direct beneficiaries as the number of households who received vines from the project at some point in time. In both countries, organization or farmer group membership was fluid, so estimating the actual number of REU beneficiaries is not trivial. We use aggregates from initial vine distribution lists to construct estimates of the number of direct beneficiaries by this definition across the two models. Second, other households also benefited from the project through vines given to them by direct beneficiaries.[34] In both countries, we measured such beneficiaries in the endline survey, and we call them indirect beneficiaries. Diffusion rates were 0.32 in Mozambique and 1.0 in Uganda among Model 2 households (Table 12).

[34]We base our estimates of indirect beneficiaries on the vine diffusion modules that were included in both endline surveys. Therefore we may underestimate diffusion somewhat if there was a great deal of consumption of OFSP by households purchasing OFSP in markets or receiving OFSP from direct beneficiary households. However, given that most households in the intervention in both countries grew OFSP for home consumption, the magnitude of our underestimate is likely to be quite minimal.

The third and fourth definitions of beneficiaries are at the individual level, embedding a further concept: that the target beneficiaries of the REU are mothers and children, for whom increased vitamin A consumption is most important. The project focused on improving the vitamin A status of mothers and children aged 6-59 months of age, so based on that we estimate the number of mothers and children aged 6-59 months that live in each intervention household (Table 13). Ugandan households are somewhat larger than Zambézian households; in Uganda there are 1.73 children under 5 per household, whereas in Mozambique there are 1.25 children. Based on the average of 0.97 mothers per household in Mozambique and 0.99 in Uganda, we assume there are approximately 2.22 beneficiaries per household in Mozambique and 2.69 beneficiaries per household in Uganda. Finally, it is important to note that not all beneficiaries actually adopt OFSP, so we also estimate the benefits per adopting household, based on our difference-in-difference estimates of adoption impacts.

We initially estimate the average costs of replicating the REU on a per direct beneficiary household and per direct beneficiary to Model 2 in both countries (Table 14). On a per household or per beneficiary basis, Model 2 was slightly more expensive in Mozambique than in Uganda ($146 versus $132 per household). Once we make both adjustments, to the per individual beneficiary basis and account for diffusion, we find that the costs per individual beneficiary were $52 in Mozambique and $26 in Uganda. Note that the intervention appears less expensive, in relative terms, in Uganda as the number of direct beneficiaries per household were higher, as was diffusion. Clearly, increasing diffusion can help make the costs per beneficiary lower, as the intervention is effective at reaching more people. Once we account for the fact that not all households that benefit from the project actually adopt vines, the cost per individual beneficiary increases to $67 in Mozambique and $36 in Uganda. About 70 percent of the disparity between countries is due to the difference in diffusion rates.

That said, the larger impact evaluation and the results here suggest some improvements to the implementation design that would not materially affect overall adoption or dietary intakes. According to the findings in de Brauw et al. (2010), the marketing component of the REU did not influence household adoption or dietary intakes, so it could hypothetically be dropped from a future intervention focused on distribution, adoption, and increasing intakes. We show the budget proportions of each component in Figure 11; dropping marketing would save 11 percent of the budget in Mozambique and 21 percent in Uganda, where more effort was applied by extensionists on marketing. The results in section 6.2 suggest that the bulk of the demand creation messages did not have a large effect on the adoption of OFSP by REU participitants, nor dietary intakes. However, as we have discussed our measures are somewhat narrow and focus on detailed messages; it could be that the broader message that OFSP are healthier than white or yellow sweet potatoes is the important one leading to adoption. If so, then the project messages and therefore expenditures on demand creation can be scaled back substantially, though not totally. We consider the implications of cutting the demand creation budget by 25, 50, and 75 percent in both countries, on top of removing the marketing component.[35]

We find that average costs per adopting household drop to between \$127 and \$170 in Mozambique and \$120 and \$157 in Uganda, depending upon the reduction in the demand creation budget. A 50 percent reduction is probably the largest feasible reduction if any contact with households related to demand creation messages is to be maintained, so we believe that costs per adopting household could be reasonably reduced to \$141 in Mozambique and \$132 in Uganda. In both countries, an increased emphasis on promoting diffusion would help decrease average cost estimates even further.

8 Conclusion

In this paper, we have produced impact estimates of a biofortification program from a randomized control trial conducted in both Mozambique and Uganda using similar integrated delivery models. The program was delivered using two models, which differed in intensity. In general, we find that in these settings, biofortification works, and further we found that the less intense program worked just as well as the more intense program in both countries. Each program had strong and similar impacts on adoption. The average treatment effect on increases in vitamin A consumption were larger in Uganda than Mozambique; this difference is related to the age difference among reference children at baseline, as they were older (3 to 5) in Uganda than Mozambique (6 to 35 months) and therefore consume more food in general at endline. Nonetheless, these results suggest an increase in consumption on average of the United States recommended daily allowance of vitamin A in both countries or better, which suggests

[35] The latter two reductions are based on the notion of heavily cutting back the nutrition extension messages in both countries, but retaining some basic messages, or alternatively just using mass marketing, such as radio and billboards, to promote the nutrition messages of the project. In the longer term, if adoption was successful and an organic market for OFSP did not appear, one might consider a follow-up marketing intervention.

that the integrated program had a strong impact on the nutritional content of diet among children in treated households.

We then used causal mediation analysis to try to understand the mechanisms by which the program worked. We initially find that in both countries, knowledge of the project's nutritional messages had little direct effect on the adoption of OFSP. Adoption is therefore likely due to a combination of factors; OFSP are not that agronomically different than white sweet potatoes, and people liked to consume them, so it was not difficult to convince producers to produce them for own consumption in most cases. Since some work is necessary to maintain the vines over time, one lingering question is whether farmers will be able to sustain them over longer periods of time. Further work is being conducted to study how well farmers were able to maintain vines in the medium term.

We next used causal mediation analysis to understand the role that adoption and increased nutritional knowledge play in explaining increased vitamin A intakes among the reference children in the project. Here, the results vary significantly across the two countries. In Mozambique, the increase in consumption among reference children can be explained exclusively through the adoption of OFSP, as defined by households planning to keep vines for the next growing season (in 2010). Nutritional knowledge appears to have played a limited role in promoting vitamin A intakes by younger children in Mozambique. In Uganda, whereas adoption was the largest factor in explaining adoption, increased nutritional knowledge also played a role in increasing intakes, and a relatively large amount was not explained by either mediation variable. The most plausible explanation is that broader project messages, related to the fact that OFSP are healthy to consume, played an important role in catalyzing consumption by younger children.

Finally, we discussed the implications of our results for the cost effectiveness of future programs to promote OFSP. We find that Model 2 was more cost effective than Model 1 and we make suggestions about how future projects might reduce the cost structure, by focusing the messages in demand creation and eliminating the marketing component of the intervention. Costs could be further reduced, at least in the short term, if farmers could be more actively induced to share OFSP planting material with non-project members, since the project would then have more beneficiaries. Future research will focus on designing effective mechanisms to induce farmers to share OFSP planting material with others.

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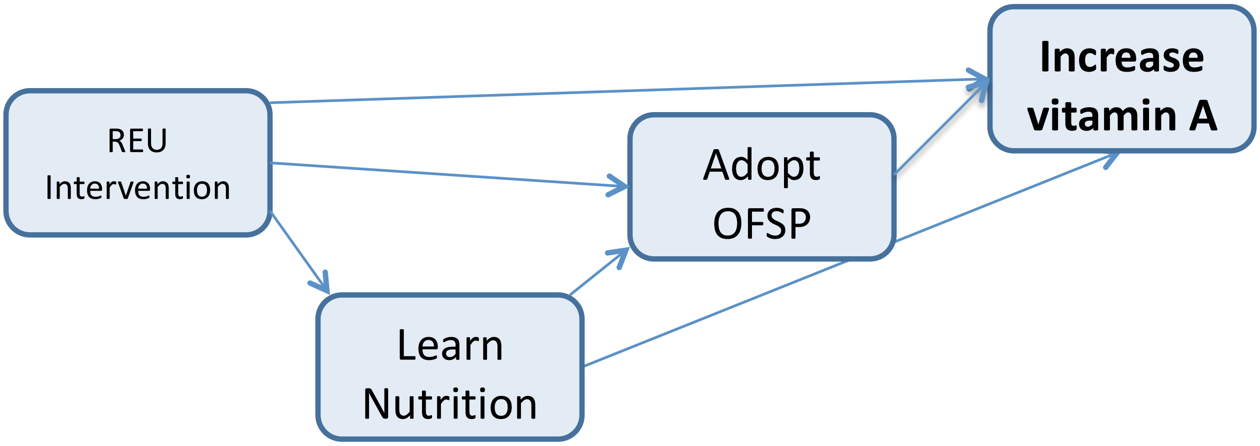


Figure 1. Schematic Representation of Potential Mechanisms to Improve Vitamin A Consumption among Targeted Children in REU Intervention, Mozambique and Uganda

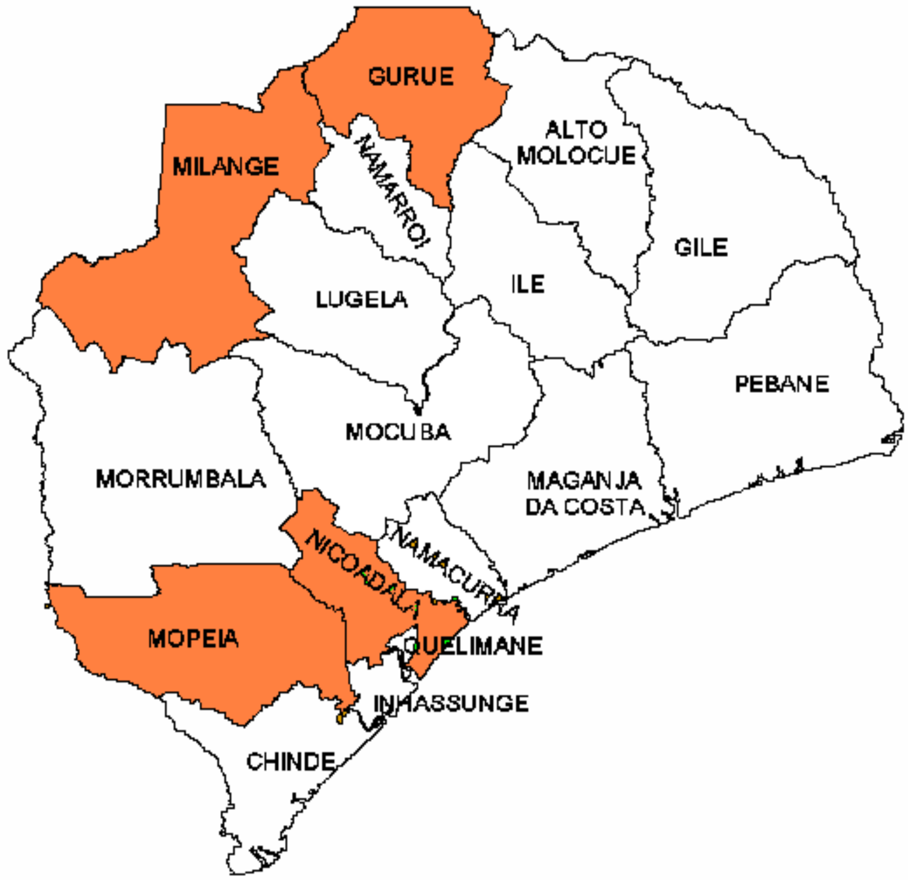


Figure 2. Location of REU Project Sites in Zambezia, Mozambique

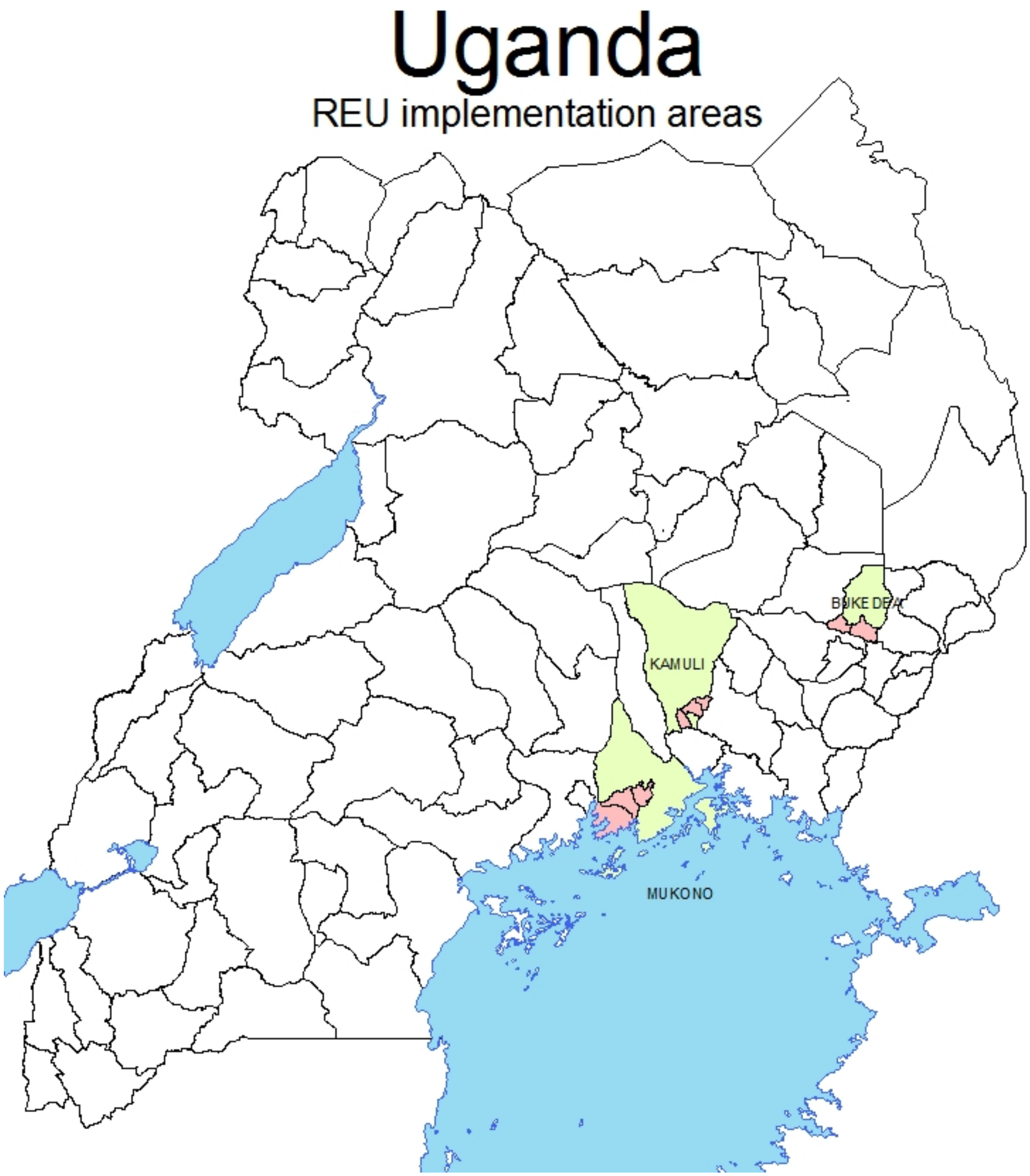
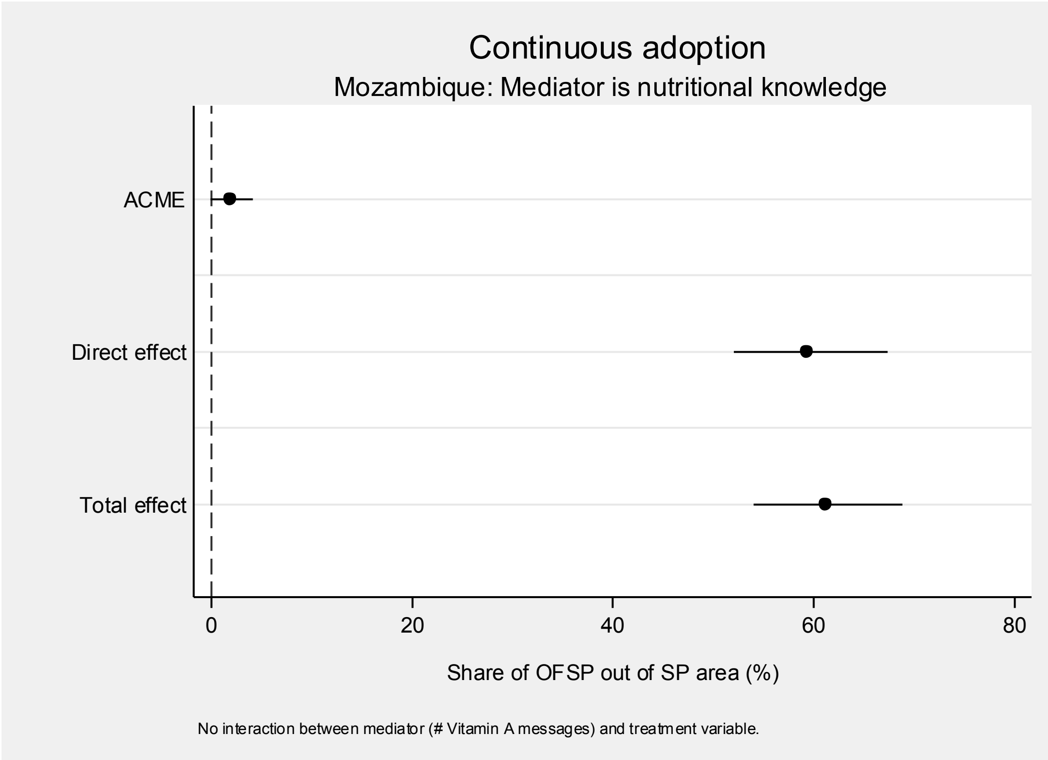


Figure 3. Location of REU Project Sites in Uganda

Panel A: Mozambique



Panel B: Uganda

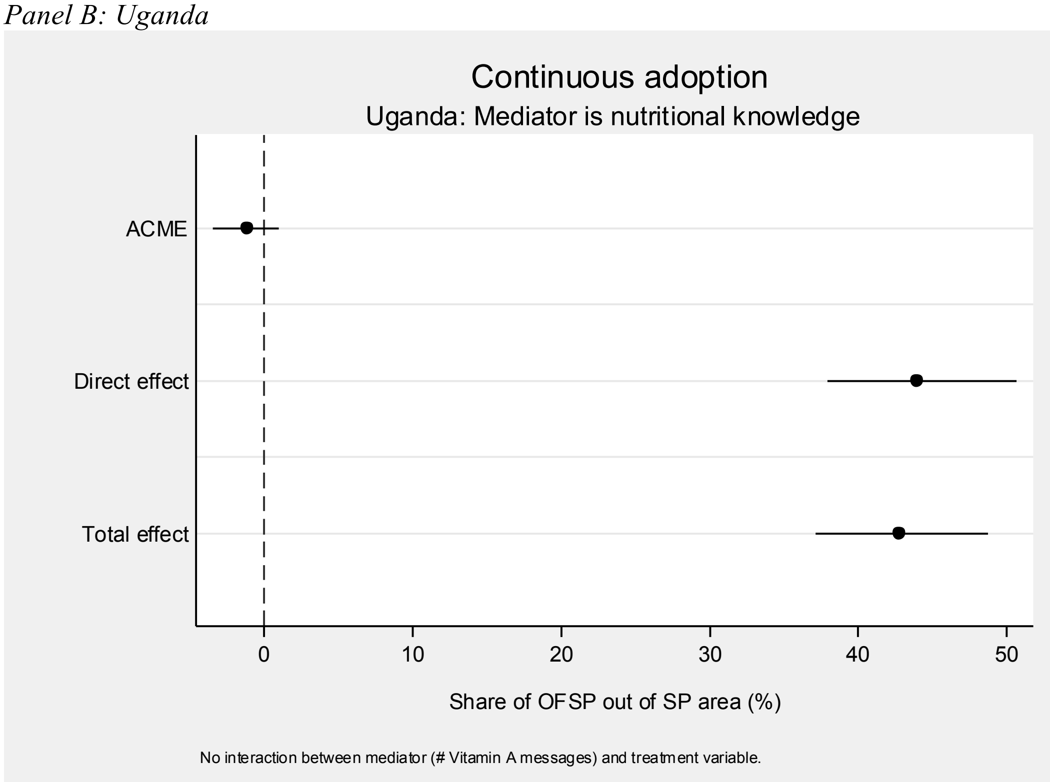
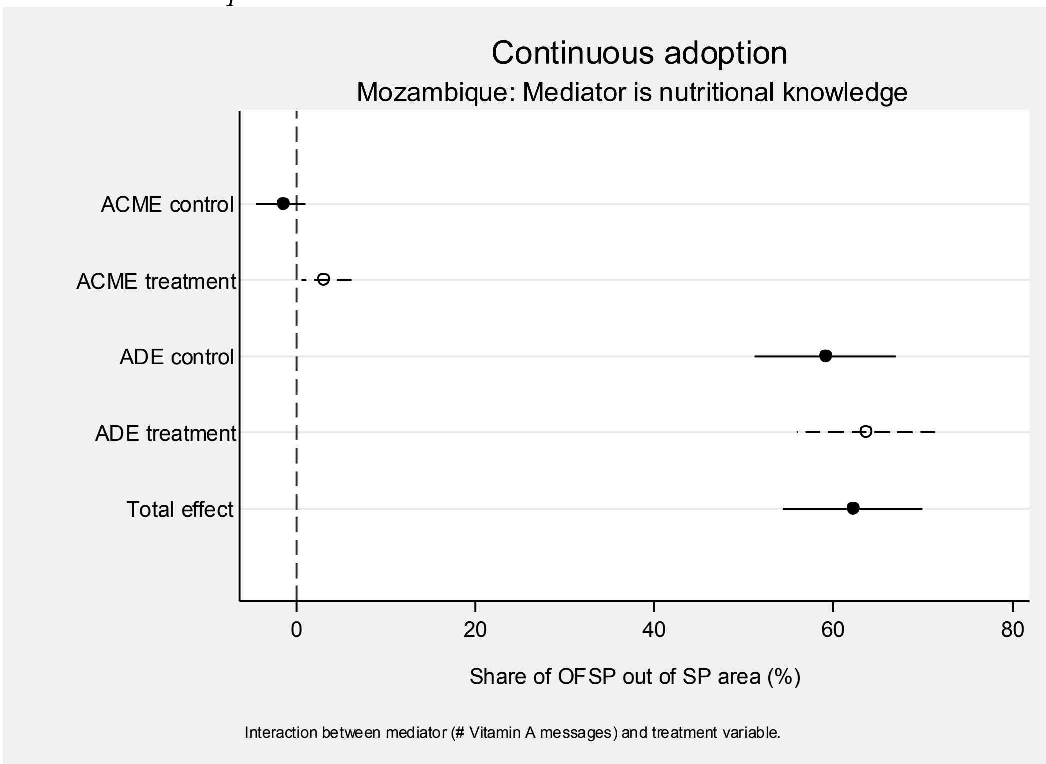


Figure 4. Average Causal Mediation Effects, using number of vitamin A messages as mediator variable and share of OFSP in SP area as the impact variable, Mozambique and Uganda

Panel A: Mozambique



Panel B: Uganda

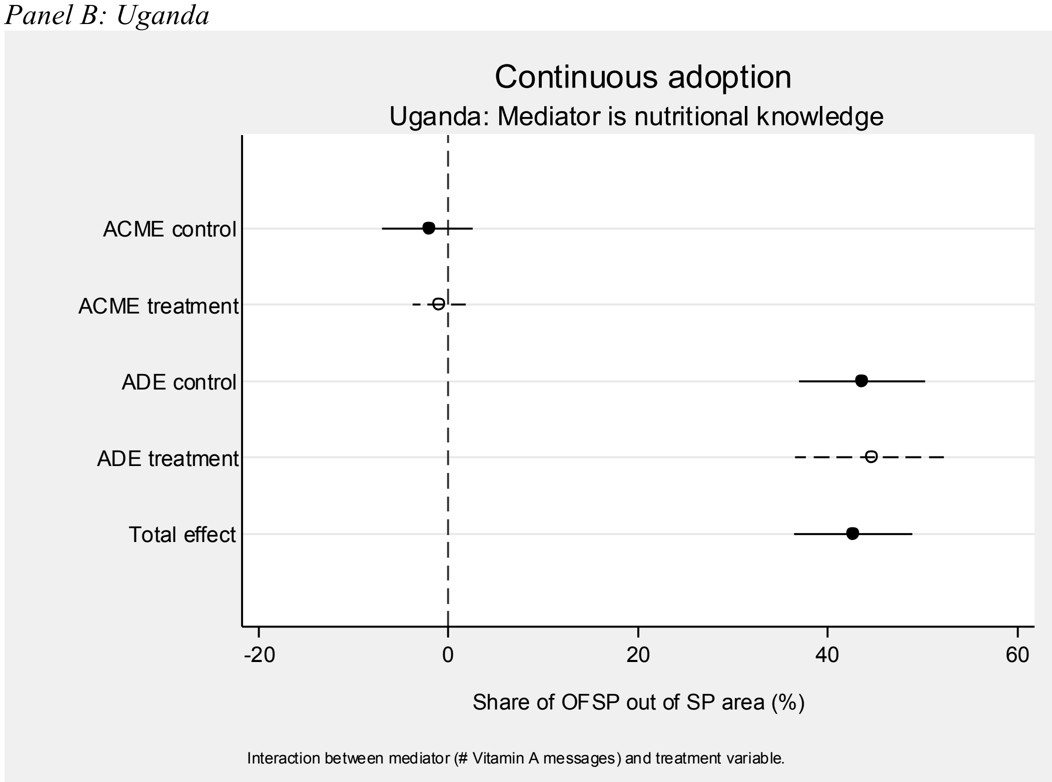
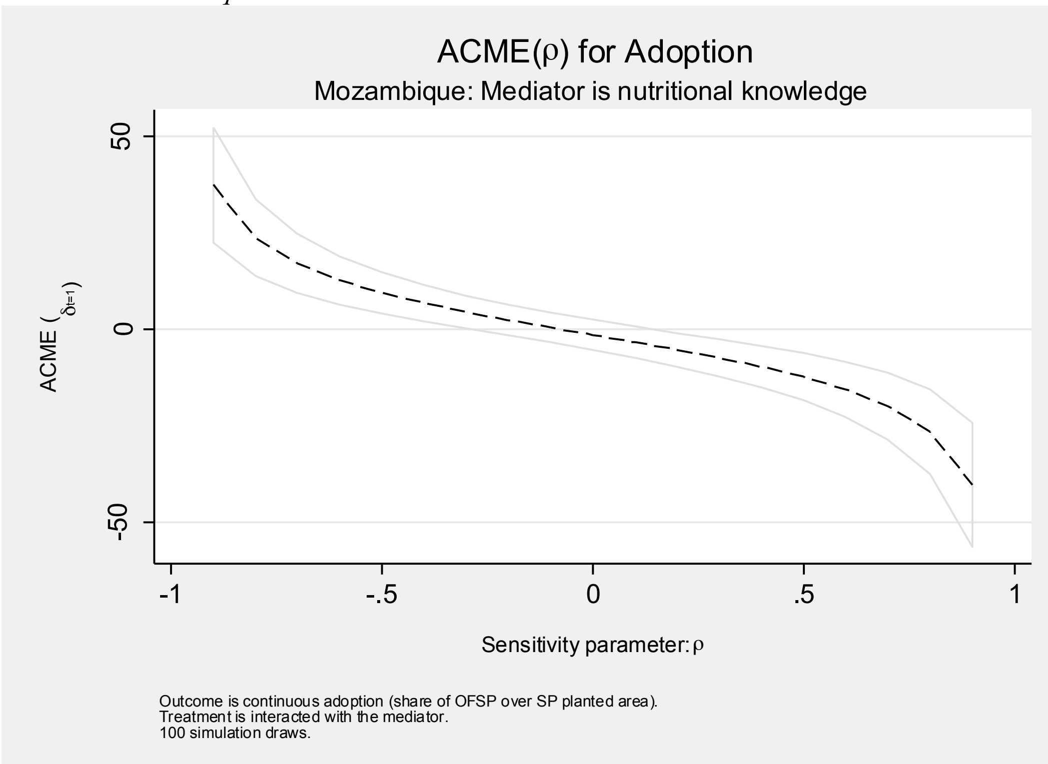


Figure 5. Average Causal Mediation Effects, using number of vitamin A messages as mediator variable and share of OFSP in SP area as the impact variable, including interaction term, Mozambique and Uganda

Panel A. Mozambique



Panel B. Uganda

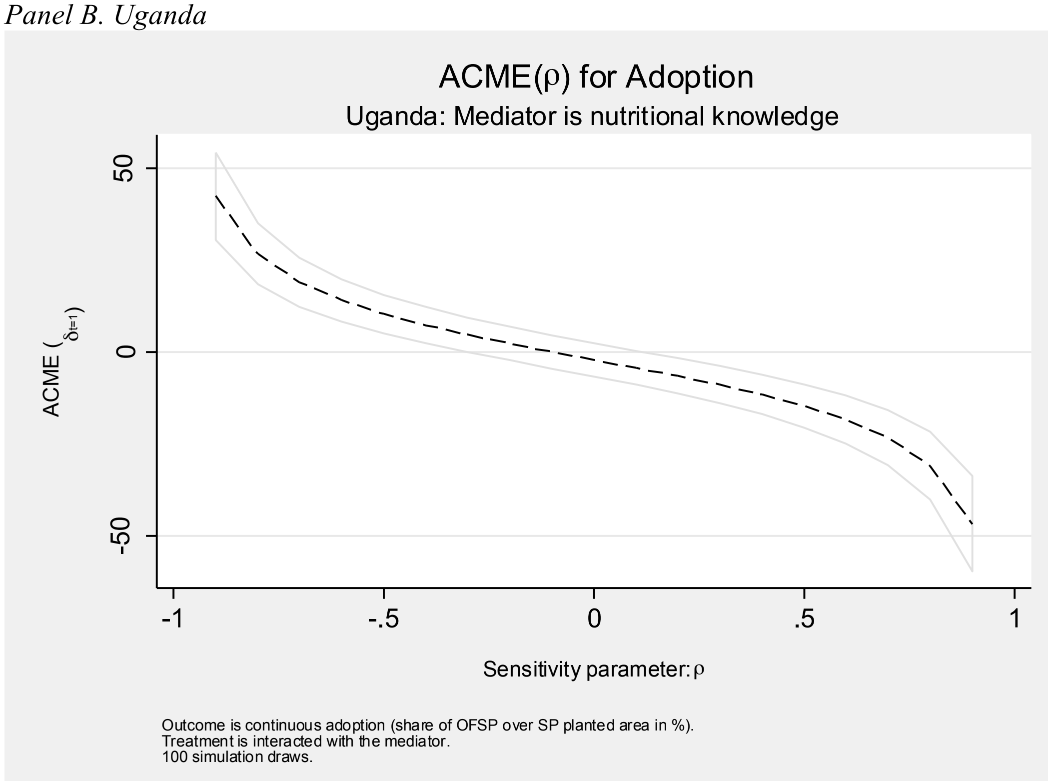
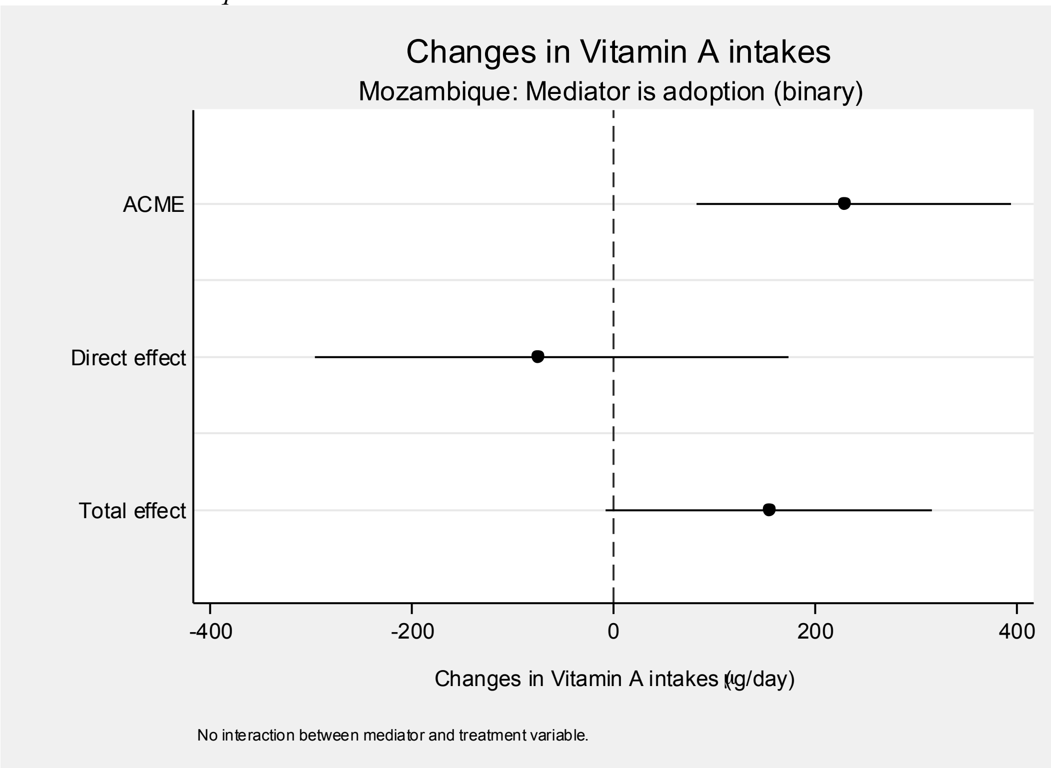


Figure 6. Sensitivity Analysis, using number of vitamin A messages as mediator variable, for and share of OFSP in SP area as the impact variable, including interaction terms, Mozambique and Uganda

Panel A. Mozambique



Panel B. Uganda

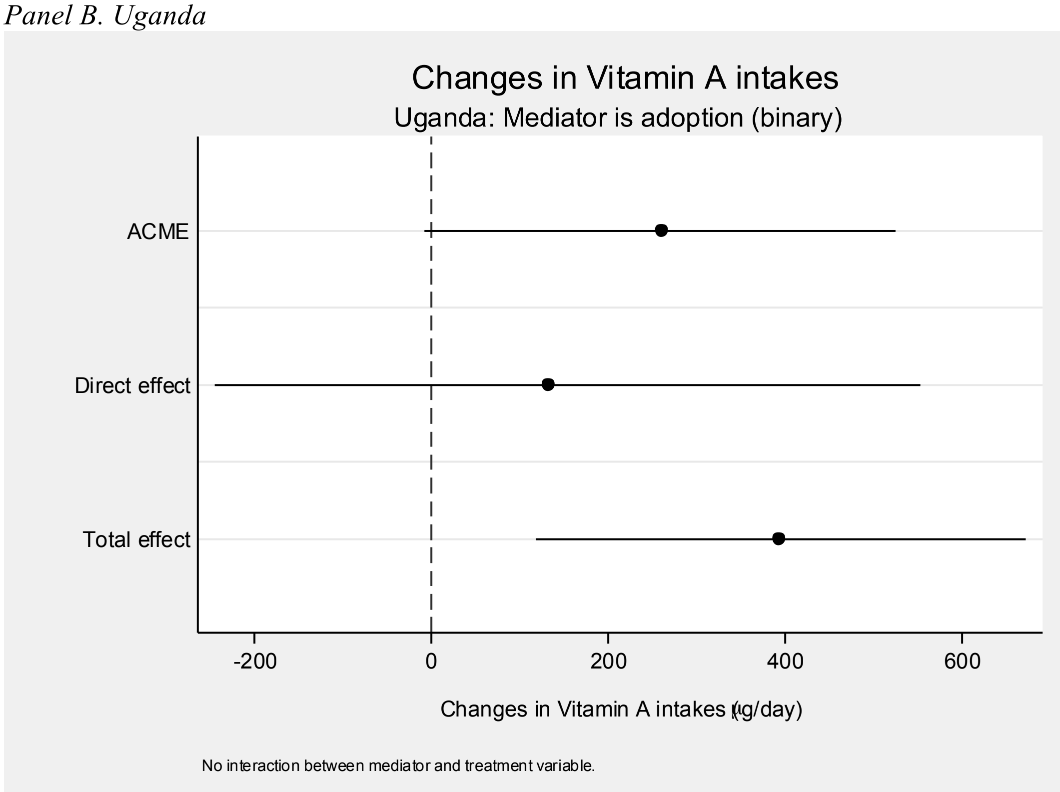
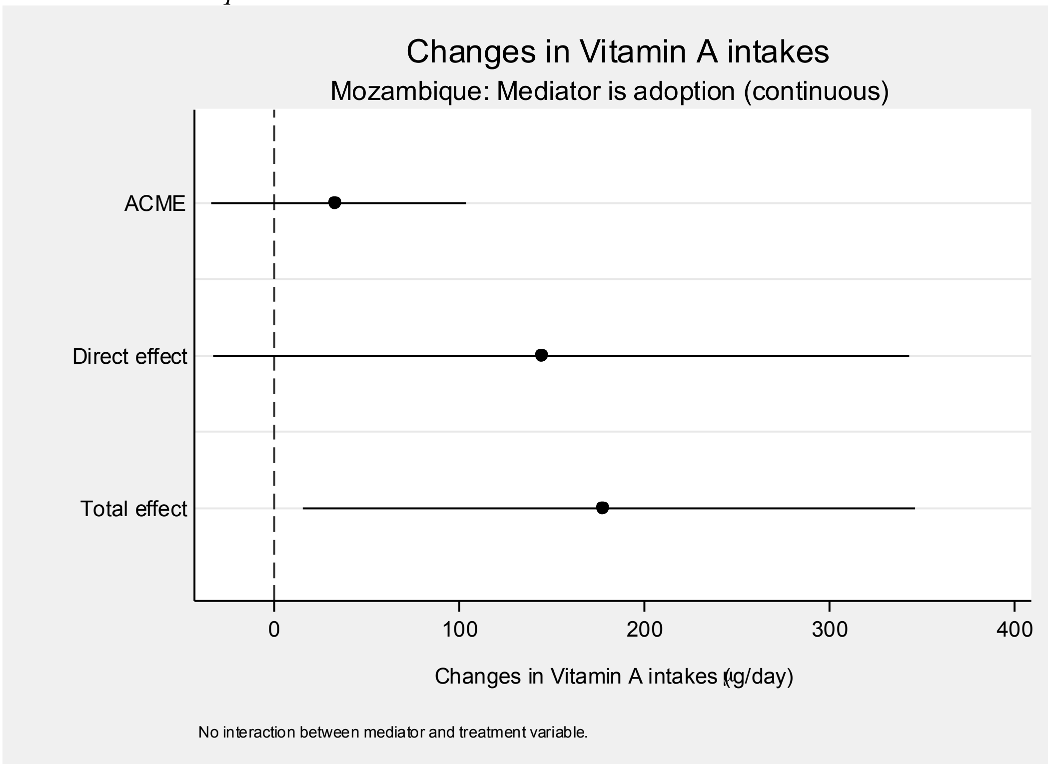


Figure 7. Average Causal Mediation Effects, using discrete adoption as mediator variable and change in vitamin A intakes among reference children as the impact variable, Mozambique and Uganda

Panel A. Mozambique



Panel B. Uganda

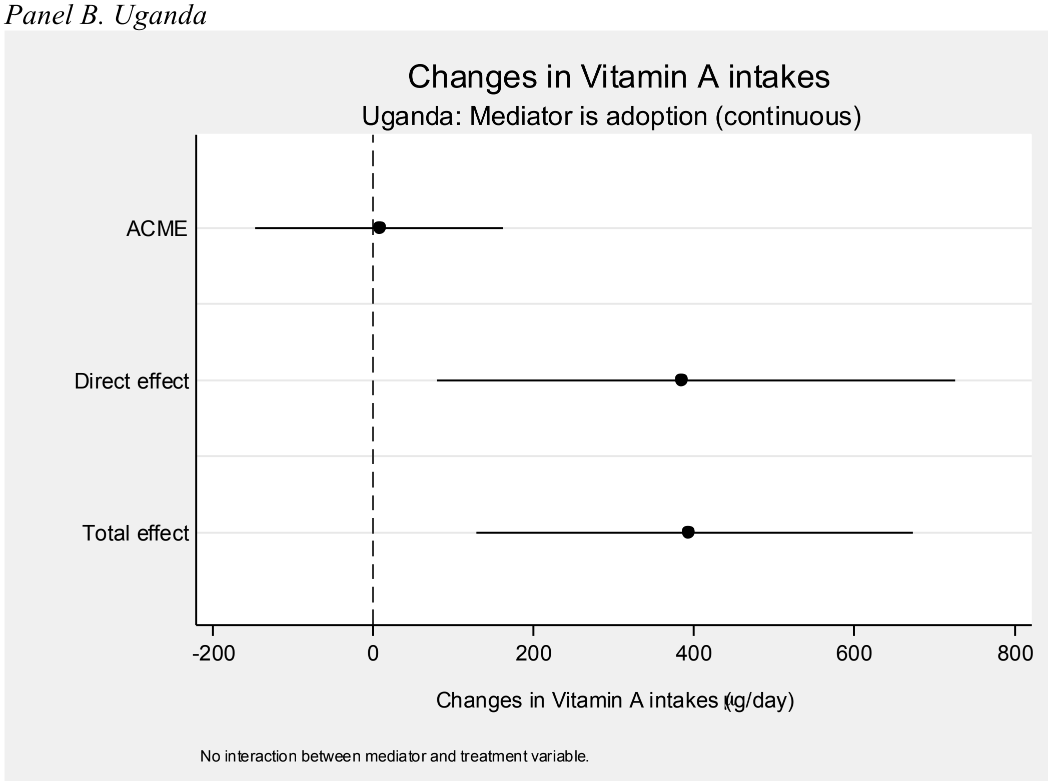
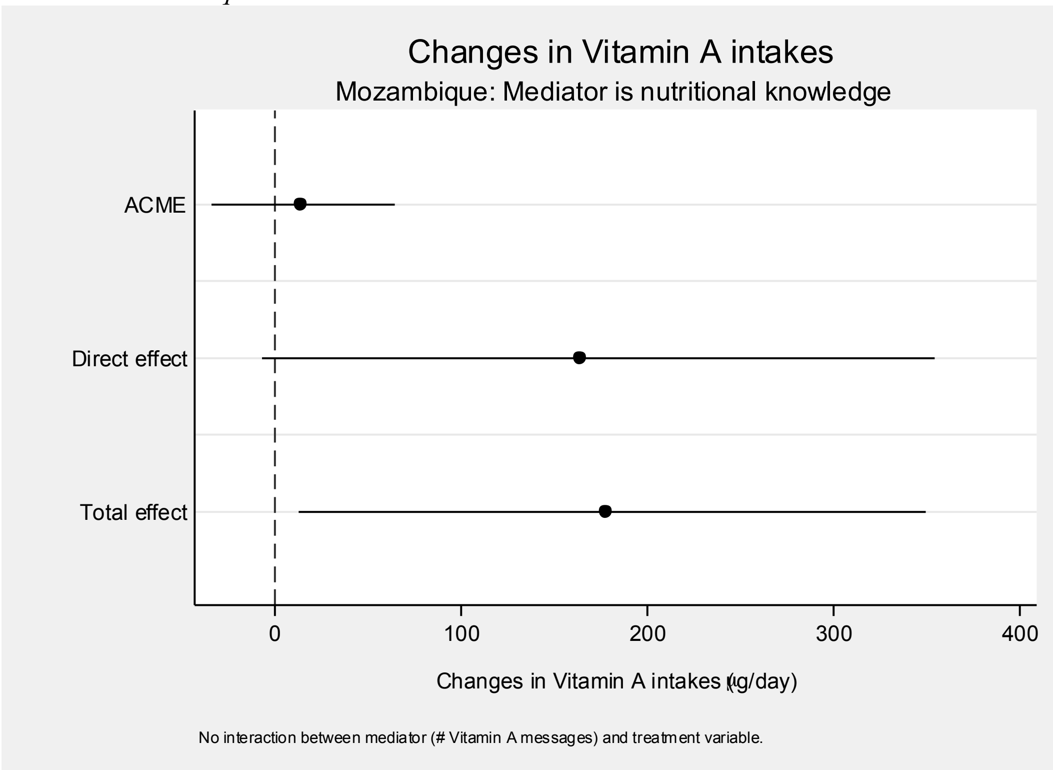


Figure 8. Average Causal Mediation Effects, using share of OFSP in sweet potato area as mediator variable and change in vitamin A intakes among reference children as the impact variable, Mozambique and Uganda

Panel A. Mozambique



Panel B. Uganda

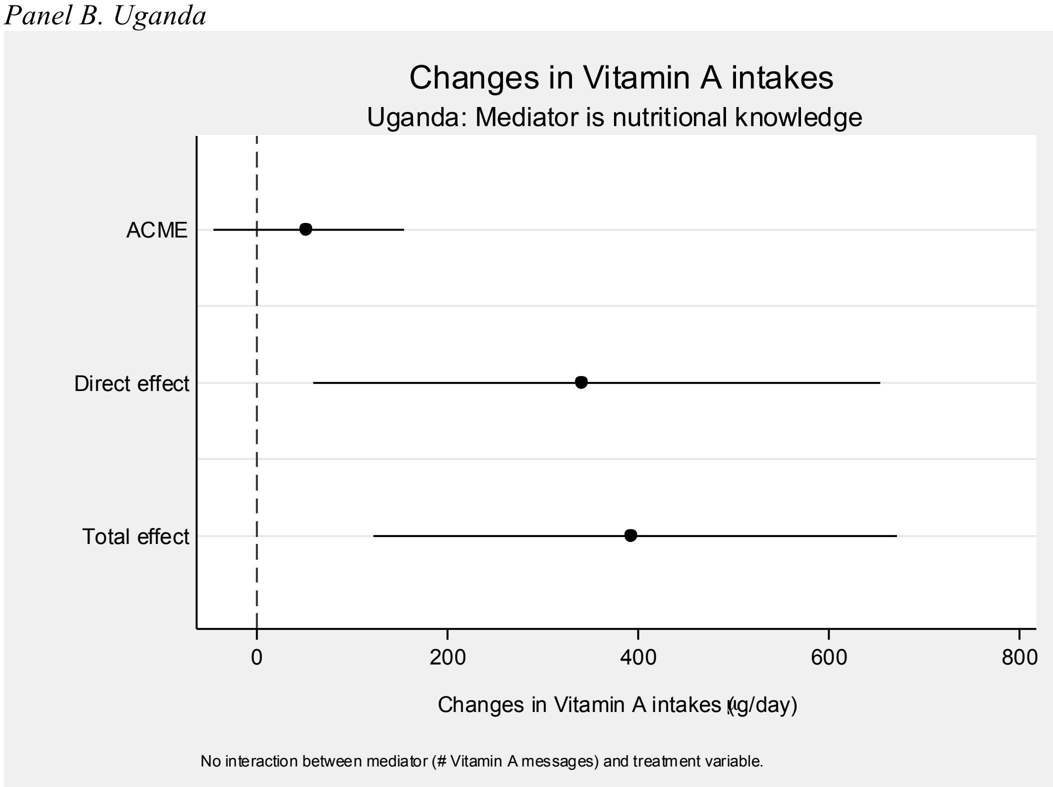
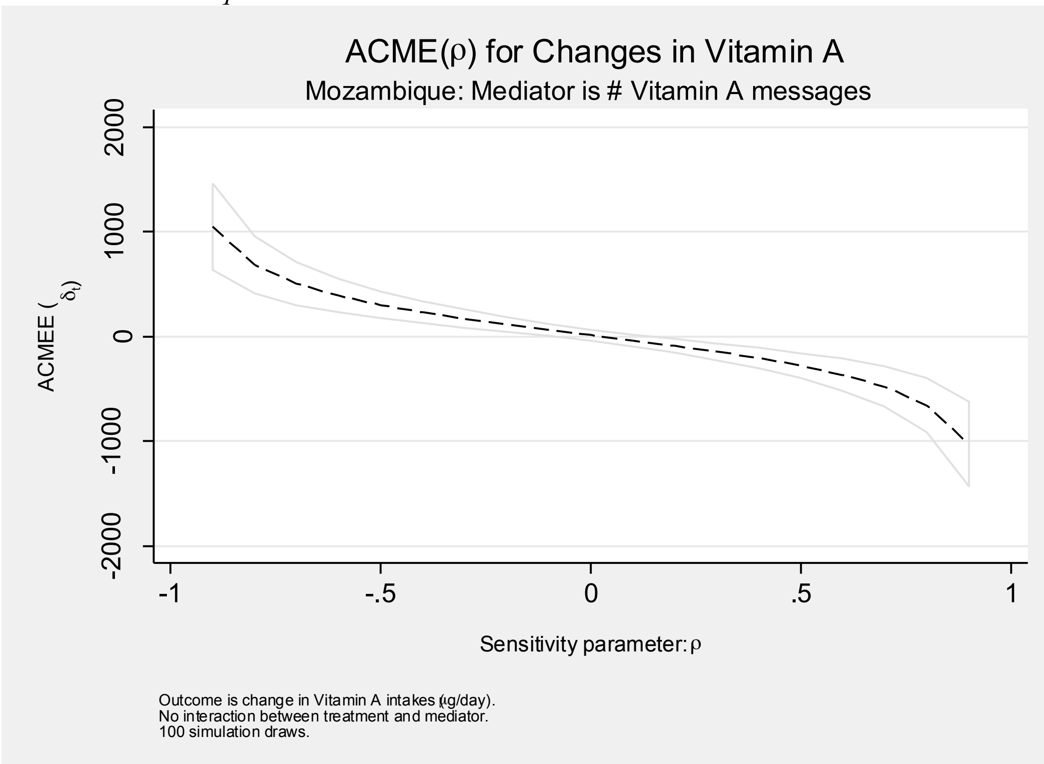


Figure 9. Average Causal Mediation Effects, using vitamin A messages known as mediator variable and change in vitamin A intakes among reference children as the impact variable, Mozambique and Uganda

Panel A. Mozambique



Panel B. Uganda

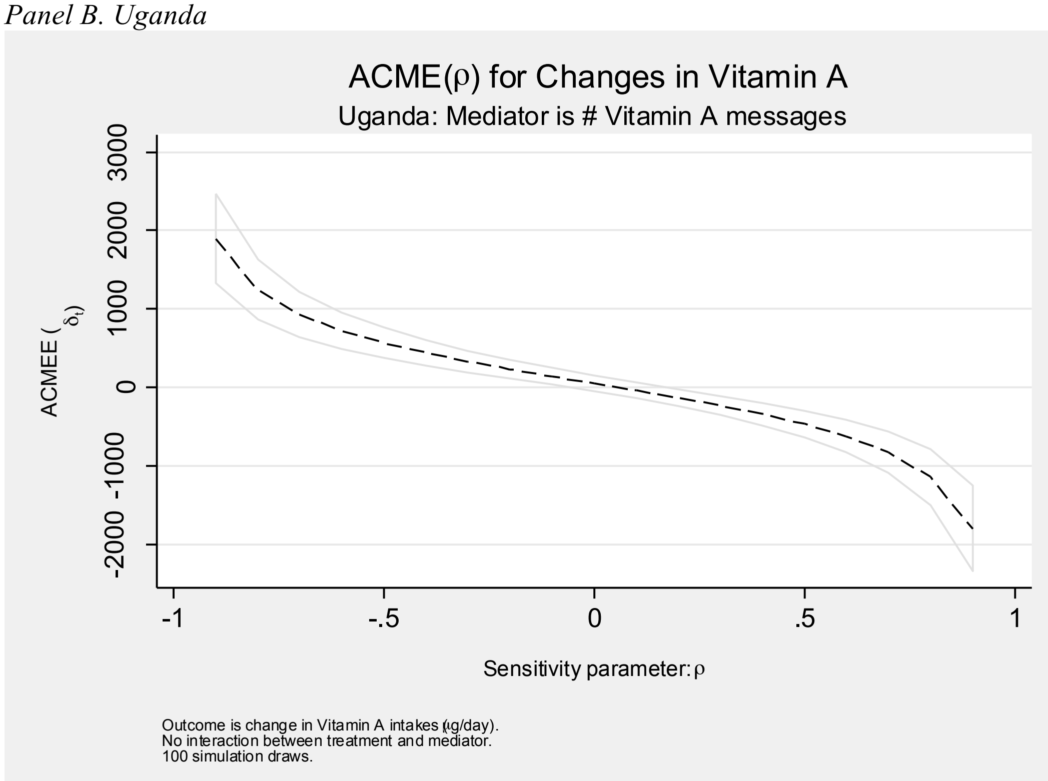
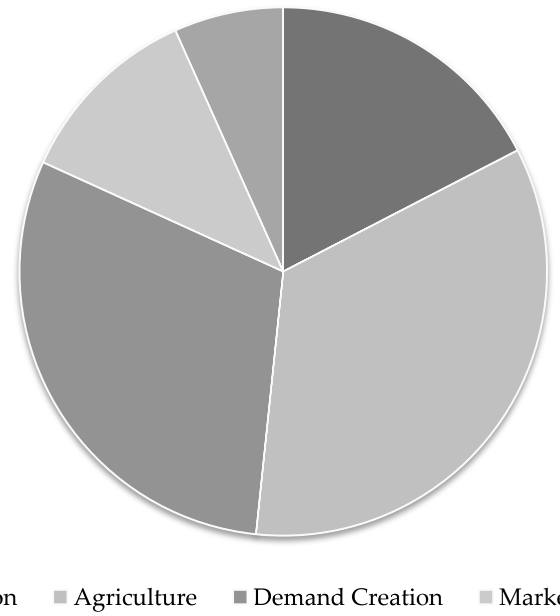


Figure 10. Sensitivity Analysis, using number of vitamin A messages as mediator variable, for vitamin A intakes among reference children as the impact variable, including interaction terms, Mozambique and Uganda

Panel A. Mozambique



Panel B. Uganda

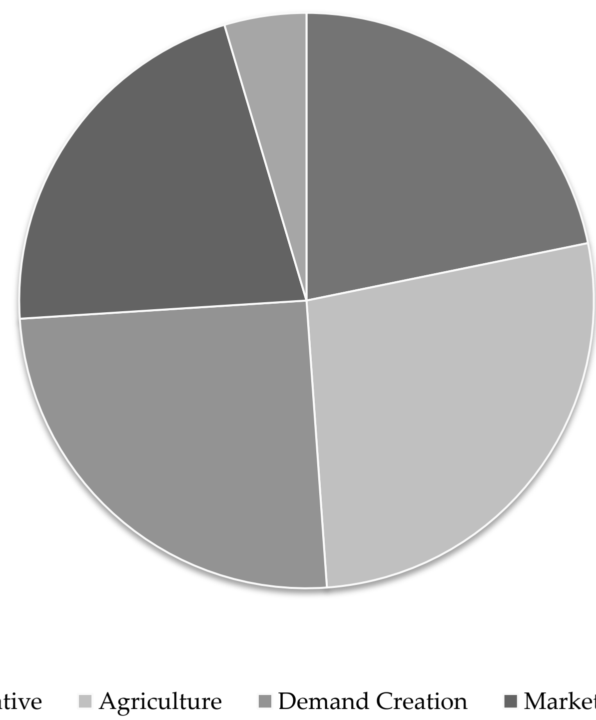


Figure 11. Budget Shares of REU Project Components, Mozambique and Uganda

Table 1. Sample Sizes, REU, Mozambique and Uganda, by Baseline/Endline, Group, and Type of Survey

	Household Socioeconomic Survey	Reference Children	Children Aged 6-35 Months
Mozambique			
Baseline	703	441	376
Endline	628	409	173
Uganda			
Baseline	1,176	545	266
Endline	1,116	481	273

Table 2. Baseline Characteristics, by Model, Mozambique and Uganda

Characteristic	Mozambique			Uganda		
	Model 1	Model 2	Control	Model 1	Model 2	Control
Female head	0.05	0.07	0.07	0.10	0.18	0.11
Household size	5.82	5.81	5.85	7.55	7.42	7.68
	(1.94)	(1.81)	(1.82)	(2.79)	(2.68)	(3.00)
Years of schooling, head	2.74	3.77	2.88	6.65	6.92	7.07
	(2.49)	(2.62)	(2.39)	(3.41)	(3.76)	(3.74)
Log, monthly per capita expenditures	0.88	1.05	0.98	9.99	10.04	9.99
	(0.71)	(0.70)	(0.79)	(0.74)	(0.74)	(0.71)
Access to lowlands	0.62	0.65	0.66	0.45	0.35	0.43
Grew OFSP prior to baseline	0.11	0.09	0.06	0.07	0.04	0.06
Grew sweet potato in year prior to baseline	0.47	0.55	0.51	0.83	0.79	0.85
Leader or promoter	0.21	0.24	N/A	0.17	0.17	0.20

Notes: Standard deviations in parentheses for continuous variables.

Source: Baseline and endline surveys, Mozambique and Uganda

Table 3. Average Baseline and Endline Outcomes, by Treatment Group, Mozambique and Uganda

Outcome	Mozambique			Uganda		
	Model 1	Model 2	Control	Model 1	Model 2	Control
Nutritional Knowledge Indicators						
Knows OFSP has vitamin A						
Baseline	0.12	0.20	0.17	0.08	0.11	0.06
Endline	0.68	0.63	0.35	0.67	0.67	0.24
Number of Vitamin A Messages						
Baseline	0.71	0.74	0.73	0.89	0.85	0.89
	(0.63)	(0.60)	(0.62)	(0.70)	(0.75)	(0.70)
Endline	1.28	1.47	0.91	1.28	1.39	0.88
	(0.68)	(0.76)	(0.66)	(0.84)	(0.80)	(0.70)
Adoption Indicators						
Growing OFSP						
Endline	0.75	0.79	0.09	0.66	0.62	0.06
Share of OFSP in sweet potato area						
Baseline	0.20	0.11	0.12	0.00	0.00	0.01
Endline	0.73	0.70	0.07	0.47	0.44	0.02
Vitamin A Intakes, Reference Children						
Mean intakes						
Baseline	209.9	204.7	187.8	540.2	431.3	549.1
	(192.4)	(222.9)	(187.9)	(913.6)	(445.6)	(1076.8)
Endline	646.7	624.6	350.2	863.2	1104.7	575.5
	(825.6)	(726.6)	(609.6)	(1110.5)	(1562.9)	(794.6)
BLUPs						
Baseline	228.6	209.5	209.6	481.0	486.4	472.0
	(120.9)	(79.2)	(58.0)	(240.3)	(124.5)	(311.3)
Endline	558.9	552.8	323.5	778.5	948.0	560.8
	(374.4)	(231.1)	(59.0)	(345.2)	(540.9)	(155.1)

Notes: For continuous outcomes, standard deviations in parentheses. Reference children were aged 6-35 months at baseline in Mozambique and 3-5 years at baseline in Uganda.

Source: REU Baseline and Endline Survey Data, Mozambique and Uganda

Table 4. Impacts of REU Models 1 and 2 on Nutritional Knowledge Indicators at Endline, Mozambique and Uganda

	Mozambique				Uganda			
	Knows OFSP a source of vitamin A, 2009		Number of Messages Known, 2009		Knows OFSP a source of vitamin A, 2009		Number of Messages Known, 2009	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model 1	0.325***	0.283***	0.368***	0.256***	0.459***	0.447***	0.507***	0.515***
	(0.083)	(0.050)	(0.110)	(0.087)	(0.040)	(0.032)	(0.066)	(0.065)
Model 2	0.268***	0.206***	0.556***	0.438***	0.449***	0.440***	0.606***	0.603***
	(0.090)	(0.055)	(0.108)	(0.087)	(0.059)	(0.042)	(0.107)	(0.107)
Female head		0.001		-0.124		0.096*		0.169*
		(0.064)		(0.079)		(0.057)		(0.090)
Household size		-0.011		0.023*		0.005		0.003
		(0.009)		(0.014)		(0.005)		(0.010)
Years of schooling, Head		0.015*		-0.015		0.001		0.009
		(0.008)		(0.011)		(0.004)		(0.008)
Log, per capita expenditures		-0.029		0.058		-0.004		0.016
		(0.029)		(0.039)		(0.020)		(0.044)
Land area, highest tercile		0.034		-0.145**		0.043		0.005
		(0.052)		(0.061)		(0.039)		(0.070)
Land area, middle tercile		0.050		-0.008		-0.003		-0.021
		(0.047)		(0.069)		(0.030)		(0.068)
Access to lowlands		0.010		0.134*		0.071**		-0.019
		(0.030)		(0.079)		(0.032)		(0.050)
Grew OFSP prior to baseline		0.095		-0.087		0.133**		0.172
		(0.072)		(0.114)		(0.056)		(0.114)
Grew sweet potatoes in 12 months prior to baseline		-0.037		0.049		-0.089		0.027
		(0.033)		(0.053)		(0.057)		(0.074)
Leader or promoter		0.182***		0.604***		0.017		0.114*
		(0.054)		(0.071)		(0.043)		(0.068)
Knows OFSP has vitamin A, baseline		0.090				0.108*		
		(0.061)				(0.056)		
Number of messages known, baseline				0.127**				0.044
				(0.050)				(0.035)
Logarithm of farmer group size						-0.044		0.073
						(0.072)		(0.148)
Number of obs.	610	610	610	609	1063	892	1112	976
R^2	0.079	0.194	0.030	0.137	0.205	0.264	0.103	0.124
Test H_0: Model 1 = Model 2 (p-value)	0.425	0.180	0.028	0.013	0.875	0.850	0.406	0.442
Average treatment effect of both interventions								
Treated	0.295***	0.244***	0.467***	0.348***	0.456***	0.446***	0.528***	0.529***
	(0.079)	(0.045)	(0.103)	(0.082)	(0.035)	(0.030)	(0.060)	(0.060)

Notes: Tests of equality of impact of Model 1 and Model2 are adjusted Wald tests. Average treatment effects reported at the bottom of the table are average impacts over Model 1 and Model 2, using the same specification for that column. Standard errors clustered at the village level in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level. *Source:* Mozambique and Uganda baseline and endline surveys, REU project.

Table 5. Impacts of REU Models 1 and 2 on Measures of Adoption at Endline, Mozambique and Uganda

	Mozambique				Uganda			
	Adopted OFSP		Share of OFSP in SP Area		Adopted OFSP		Share of OFSP in SP Area	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model 1	0.657***	0.625***	0.653***	0.615***	0.635***	0.612***	0.445***	0.437***
	(0.050)	(0.047)	(0.043)	(0.041)	(0.029)	(0.030)	(0.021)	(0.022)
Model 2	0.692***	0.650***	0.622***	0.590***	0.573***	0.570***	0.402***	0.433***
	(0.035)	(0.039)	(0.042)	(0.033)	(0.041)	(0.046)	(0.039)	(0.041)
Female head		-0.152**		-0.109*		-0.010		0.007
		(0.063)		(0.056)		(0.041)		(0.032)
Household size		0.013		0.002		0.007*		-0.001
		(0.008)		(0.007)		(0.003)		(0.003)
Years of schooling, Head		0.003		-0.004		-0.001		-0.002
		(0.006)		(0.005)		(0.004)		(0.002)
Log, per capita expenditures		0.002		0.001		-0.002		-0.013
		(0.023)		(0.021)		(0.018)		(0.012)
Land area, highest tercile		0.002		0.021		-0.017		-0.017
		(0.038)		(0.030)		(0.035)		(0.026)
Land area, middle tercile		0.034		0.007		-0.006		-0.000
		(0.044)		(0.037)		(0.031)		(0.020)
Access to lowlands		-0.019		0.028		0.019		0.025
		(0.029)		(0.030)		(0.023)		(0.022)
Grew OFSP prior to baseline		-0.041		-0.004		0.094**		0.067**
		(0.048)		(0.042)		(0.046)		(0.030)
Grew sweet potatoes in 12 months prior to baseline		0.060*		-0.022		0.040		-0.063*
		(0.035)		(0.035)		(0.029)		(0.034)
Leader or promoter		0.161***		0.115***		0.142***		0.133***
		(0.045)		(0.030)		(0.051)		(0.036)
Recruited						-0.004		-0.066***
						(0.030)		(0.021)
Logarithm of farmer group size						-0.110		-0.039
						(0.069)		(0.046)
Number of Obs.	628	628	551	551	1110	988	854	752
R^2	0.411	0.443	0.481	0.514	0.461	0.467	0.437	0.465
Test H_0: Model 1 = Model 2 (p-value)	0.441	0.573	0.533	0.565	0.875	0.698	0.406	0.445
Average treatment effect of both interventions								
Treated	0.675***	0.638***	0.637***	0.602***	0.617***	0.602***	0.434***	0.436***
	(0.037)	(0.037)	(0.035)	(0.030)	(0.033)	(0.026)	(0.019)	(0.020)

Notes: Tests of equality of impact of Model 1 and Model2 are adjusted Wald tests. Average treatment effects reported at the bottom of the table are average impacts over Model 1 and Model 2, using the same specification for that column. Standard errors clustered at the village level in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level. *Source:* Mozambique and Uganda baseline and endline surveys, REU project.

Table 6. Impacts of REU Interventions on Change in Vitamin A Consumption, Reference Children, Mozambique and Uganda

	Mozambique				Uganda			
	Intakes of Vitamin A, RAE		Adjusted Intakes (BLUPS)		Intakes of Vitamin A, RAE		Adjusted Intakes (BLUPS)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model 1	243.0***	193.6***	203.8***	195.6***	308.3**	338.8**	210.9***	210.8***
	(85.8)	(91.2)	(35.0)	(34.4)	(148.4)	(147.7)	(38.3)	(41.2)
Model 2	211.8**	182.9**	208.4**	188.1**	677.1***	558.2***	377.5***	327.1***
	(96.3)	(89.0)	(26.3)	(22.0)	(222.0)	(164.5)	(78.0)	(59.1)
Age in months		-6.00		-3.14		5.2		4.5**
		(5.49)		(2.88)		(6.4)		(1.9)
Male		-646.5		-178.6		-1.7		2.0
		(407.3)		(89.9)		(130.0)		(35.3)
Still breastfed at baseline		136.3		96.6**		-898.3***		--
		(108.6)		(40.6)		(255.9)		(0.0)
Female head		-239.2		-58.2		79.1		-58.1
		(157.6)		(80.5)		(163.4)		(46.9)
Household size		-17.6		-6.9		-9.0		-7.8
		(20.4)		(8.0)		(19.3)		(6.1)
Years of schooling, Head		-6.2		0.8		2.4		-5.6
		(17.0)		(8.5)		(14.6)		(5.2)
Log, per capita expenditures		-56.9		-33.3		43.6		-0.9
		(64.7)		(25.4)		(54.5)		(17.9)
Land area, highest tercile		136.9		50.3		148.9		161.3***
		(120.4)		(55.2)		(194.5)		(50.3)
Land area, middle tercile		108.5		81.2		79.7		66.8
		(103.1)		(43.1)		(134.4)		(50.0)
Access to lowlands		-135.9		-21.5		88.1		-53.5
		(87.2)		(35.6)		(152.8)		(38.7)
Grew OFSP prior to baseline		24.6		-34.1		46.0		6.3
		(156.8)		(70.8)		(178.4)		(55.8)
Grew sweet potatoes in year prior to baseline		-38.6		1.9		145.3		70.6
		(82.4)		(36.6)		(285.2)		(46.9)
Farmer group leader		379.7**		163.0**		135.8		42.0
or nutrition promoter		(167.5)		(72.1)		(134.4)		(41.0)
Number of Obs.	379	376	318	318	478	425	473	421
R^2	0.013	0.088	0.064	0.164	0.032	0.057	0.123	0.161
Test H_0: Model 1 = Model 2 (p-value)	0.710	0.870	0.913	0.823	0.107	0.144	0.044	0.041
Average treatment effect of both interventions								
Treated	226.0***	187.9***	206.4***	191.5***	449.7***	420.5***	274.7***	254.1***
	(81.6)	(84.0)	(22.5)	(22.8)	(145.7)	(136.7)	(42.9)	(41.3)

Notes: Tests of equality of impact of Model 1 and Model2 are adjusted Wald tests. Average treatment effects reported at the bottom of the table are average impacts over Model 1 and Model 2, using the same specification for that column. Standard errors clustered at the village level in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level. *Source:* Mozambique and Uganda baseline and endline surveys, REU project.

Table 7. Average Impacts of REU on Discrete Measure of OFSP Adoption at Endline, Including Nutrition Knowledge Mediating Variables, Mozambique and Uganda

	Mozambique				Uganda			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treated	0.650***	0.625***	0.637***	0.622***	0.544***	0.573***	0.601***	0.599***
	(0.040)	(0.041)	(0.040)	(0.040)	(0.039)	(0.031)	(0.034)	(0.028)
Knows OFSP is source of vitamin A, endline	0.086**	0.058			0.156***	0.082**		
	(0.041)	(0.041)			(0.031)	(0.031)		
Number of vitamin A messages known, endline			0.081***	0.049**			0.037***	0.027*
			(0.022)	(0.022)			(0.014)	(0.014)
Female head		-0.150**		-0.145**		-0.034		-0.025
		(0.068)		(0.068)		(0.039)		(0.038)
Household size		0.016*		0.013*		0.005		0.006
		(0.009)		(0.008)		(0.004)		(0.004)
Years of schooling, Head		0.004		0.005		-0.002		-0.001
		(0.006)		(0.007)		(0.004)		(0.004)
Log, per capita expenditures		0.009		0.003		0.002		-0.001
		(0.024)		(0.022)		(0.018)		(0.017)
Land area, highest tercile		0.001		0.004		-0.033		-0.020
		(0.040)		(0.040)		(0.035)		(0.034)
Land area, middle tercile		0.028		0.030		-0.025		-0.010
		(0.044)		(0.045)		(0.032)		(0.030)
Access to lowlands		-0.018		-0.029		0.009		0.016
		(0.030)		(0.029)		(0.023)		(0.022)
Grew OFSP prior to baseline		-0.061		-0.056		0.073		0.081*
		(0.047)		(0.047)		(0.049)		(0.046)
Grew sweet potatoes in year prior to baseline		0.061*		0.059		0.054		0.055
		(0.035)		(0.036)		(0.042)		(0.043)
Farmer group leader or nutrition promoter		0.146***		0.126***		0.080***		0.077***
		(0.046)		(0.046)		(0.028)		(0.028)
Recruited						-0.001		-0.005
						(0.029)		(0.029)
Log, FG size						-0.119*		-0.119*
						(0.069)		(0.069)
Number of Obs.	610	610	610	609	1063	905	1110	988
R^2	0.418	0.448	0.425	0.450	0.468	0.468	0.462	0.468

Notes: Standard errors clustered at the village level in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level. *Source:* Mozambique and Uganda baseline and endline surveys, REU project.

Table 8. Average Impacts of REU on Share of OFSP in Sweet Potato Area at Endline, including Nutrition Knowledge Mediating Variables, Mozambique and Uganda, at Endline

	Mozambique				Uganda			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treated	0.609***	0.591***	0.609***	0.593***	0.446***	0.429***	0.438***	0.431***
	(0.036)	(0.032)	(0.040)	(0.035)	(0.030)	(0.024)	(0.024)	(0.021)
Knows OFSP is source of vitamin A, endline	0.092***	0.056*			-0.014	0.009		
	(0.031)	(0.033)			(0.027)	(0.024)		
Number of vitamin A messages known, endline			0.051**	0.025			0.006	0.010
			(0.022)	(0.022)			(0.012)	(0.010)
Female Head		-0.114**		-0.108**		0.005		0.004
		(0.058)		(0.054)		(0.032)		(0.031)
Household Size		0.005		0.002		-0.001		-0.000
		(0.008)		(0.007)		(0.003)		(0.003)
Years of Schooling, Head		-0.005		-0.004		-0.002		-0.002
		(0.005)		(0.005)		(0.003)		(0.002)
Log, per Capita Expenditures		0.006		-0.001		-0.015		-0.013
		(0.023)		(0.022)		(0.013)		(0.012)
Land Area, Highest Tercile		0.017		0.025		-0.010		-0.012
		(0.031)		(0.030)		(0.026)		(0.025)
Land Area, Middle Tercile		0.006		0.007		-0.006		-0.001
		(0.037)		(0.037)		(0.020)		(0.020)
Access to Lowlands		0.023		0.021		0.014		0.020
		(0.033)		(0.032)		(0.023)		(0.022)
Grew OFSP prior to baseline		0.006		0.007		0.077**		0.065**
		(0.043)		(0.042)		(0.035)		(0.031)
Sweet potato grower		-0.027		-0.030		-0.148**		-0.136***
		(0.036)		(0.037)		(0.059)		(0.052)
Farmer group leader		0.099***		0.096***		0.061***		0.053***
or nutrition promoter		(0.033)		(0.027)		(0.021)		(0.019)
Knows OFSP is source of vitamin A, baseline		-0.031				-0.050		
		(0.055)				(0.032)		
Number of vitamin A messages known, baseline				-0.002				-0.004
				(0.026)				(0.011)
Recruited						-0.065***		-0.065***
						(0.021)		(0.021)
Log, FG size						-0.050		-0.047
						(0.048)		(0.046)
Number of Obs.	534	534	534	533	811	684	853	747
R^2	0.488	0.514	0.485	0.511	0.406	0.467	0.403	0.464

Notes: Standard errors clustered at the village level in parentheses. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level. *Source:* Mozambique and Uganda baseline and endline surveys, REU project.

Table 9. Estimates of ACME and ADE for the Role of Nutrition Knowledge in OFSP Adoption and Share of OFSP in Sweet Potato Area at Endline, including Nutrition Knowledge Mediating Variables, Mozambique and Uganda

	Mozambique				Uganda			
	Knows OFSP a source of vitamin A, 2009		Number of Messages Known, 2009		Knows OFSP a source of vitamin A, 2009		Number of Messages Known, 2009	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: OFSP Adoption								
Conditioning variables	no	yes	no	yes	no	yes	no	yes
Treatment effect on knowledge	0.295	0.244	0.467	0.348	0.456	0.446	0.528	0.529
Knowledge effect on adoption	0.086	0.058	0.081	0.049	0.156	0.082	0.037	0.027
ACME	0.025**	0.014	0.035**	0.017*	0.071***	0.036**	0.020***	0.014*
	(0.012)	(0.009)	(0.013)	(0.009)	(0.015)	(0.015)	(0.007)	(0.008)
ADE	0.650***	0.623***	0.639***	0.620**	0.546	0.560***	0.598***	0.603***
	(0.041)	(0.040)	(0.041)	(0.040)	(0.038)	(0.035)	(0.034)	(0.034)
Correlation, residuals	<0.0001	<0.0001	<0.0001	<0.0001	0.037	0.005	0.025	-0.0015
Panel B: Share of OFSP in SP area								
Conditioning variables	no	yes	no	yes	no	yes	no	yes
Treatment effect on knowledge	0.295	0.244	0.467	0.348	0.456	0.446	0.528	0.531
Knowledge effect on adoption	0.092	0.056	0.051	0.025	-0.014	0.009	0.006	0.010
ACME	0.027***	0.014**	0.022*	0.009	-0.006	0.004	0.003	0.005
	(0.009)	(0.007)	(0.012)	(0.008)	(0.012)	(0.011)	(0.006)	(0.005)
ADE	0.610***	0.589***	0.614***	0.594***	0.443***	0.433***	0.434***	0.432
	(0.035)	(0.032)	(0.038)	(0.034)	(0.028)	(0.024)	(0.024)	(0.022)
Correlation, residuals	<0.0001	<0.0001	<0.0001	<0.0001	0.073	0.0002	0.048	0.0005

Notes: Standard errors on ACME and ADE generated using seemingly unrelated regressions. The ACME is generated by multiplying the treatment effect on knowledge by the knowledge effect on adoption.

Table 10. Causal Mediation Analysis, Change in Vitamin A Consumption, Reference Children, Mozambique and Uganda

	Mozambique					Uganda				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treated	1.1	178.7*	176.6*	-4.8	1.3	216.0	511.1**	364.1**	315.2	174.6
	(108.7)	(92.5)	(89.6)	(111.7)	(110.2)	(189.4)	(199.5)	(143.0)	(238.6)	(189.8)
Plans to conserve vines or planted OFSP this season	279.3***			284.0***	279.8***	337.5**			330.0*	322.5*
	(96.0)			(95.9)	(96.5)	(166.8)			(174.1)	(162.6)
Knows OFSP is source of vitamin A, endline		76.5		56.8			-208.3		-217.1	
		(80.7)		(78.8)			(210.7)		(211.4)	
Number of vitamin A messages known, endline			62.9		32.0			121.3**		110.3*
			(65.8)		(68.4)			(59.9)		(59.9)
Child's age in months	-6.26	-6.23	-5.96	-6.34	-6.09	5.3	5.6	5.5	5.3	5.5
	(5.40)	(5.57)	(5.35)	(5.52)	(5.37)	(6.5)	(6.6)	(6.4)	(6.5)	(6.4)
Gender (1=male)	-599.0	-648.4	-636.1	-601.0	-593.6	-7.4	28.9	6.1	18.0	-6.5
	(384.4)	(399.7)	(397.6)	(379.3)	(378.5)	(126.9)	(133.1)	(131.3)	(129.4)	(127.7)
Still breastfed in 2006	127.4	151.1	147.8	144.0	142.3	-831.2***	-710.0***	-943.3***	-789.1***	-1,005.0***
	(112.2)	(108.0)	(105.9)	(111.4)	(110.7)	(214.0)	(230.2)	(232.0)	(218.8)	(225.8)
Female head	-213.9	-242.2	-244.3	-214.2	-216.3	86.0	91.3	70.7	92.5	67.9
	(152.7)	(154.5)	(153.2)	(151.2)	(151.1)	(163.5)	(174.1)	(165.6)	(174.7)	(165.9)
Household size	-23.2	-12.9	-15.1	-18.7	-20.1	-13.3	-11.1	-8.7	-13.8	-12.0
	(19.3)	(20.3)	(20.5)	(19.0)	(19.3)	(18.8)	(20.4)	(19.0)	(20.0)	(18.5)
Years of schooling, head	-11.0	-10.7	-9.5	-15.2	-14.3	6.3	2.6	2.7	5.1	4.9
	(18.5)	(17.9)	(18.4)	(18.1)	(18.5)	(14.0)	(15.2)	(14.4)	(15.0)	(14.3)
Log per capita consumption	-60.8	-60.3	-58.7	-62.9	-61.4	30.7	33.4	47.2	26.9	41.6
	(62.1)	(64.6)	(65.3)	(62.1)	(62.9)	(58.5)	(60.2)	(55.8)	(62.9)	(58.2)
Land area, top tercile	123.8	142.3	152.3	131.4	136.8	149.6	181.9	134.6	180.8	132.2
	(118.5)	(111.9)	(115.7)	(112.2)	(116.8)	(191.3)	(191.4)	(193.8)	(188.5)	(191.0)
Land area, middle tercile	81.3	113.7	115.8	87.4	88.6	84.5	58.9	70.0	63.5	72.1
	(99.7)	(101.5)	(102.4)	(101.5)	(101.7)	(133.8)	(147.7)	(137.0)	(145.6)	(135.9)
Access to lowlands	-126.8	-127.5	-130.8	-117.9	-120.0	89.1	97.7	89.3	95.7	89.5
	(91.8)	(89.5)	(89.2)	(94.6)	(94.4)	(155.0)	(164.8)	(154.5)	(166.5)	(156.3)
Grew OFSP prior to baseline	42.1	7.6	21.3	24.4	32.6	14.2	37.2	17.0	35.3	15.0
	(150.9)	(158.5)	(155.9)	(152.8)	(151.6)	(173.9)	(192.2)	(183.5)	(190.1)	(183.5)
Grew sweet potatoes in year prior to baseline	-66.4	-36.6	-44.9	-63.4	-67.1	151.4	115.5	143.0	125.4	154.9
	(78.6)	(82.6)	(80.7)	(79.0)	(77.6)	(283.6)	(296.4)	(289.7)	(292.1)	(286.2)
Farmer group leader or nutrition promoter	340.1**	356.0**	332.2**	317.3**	309.1**	95.5	154.7	124.7	117.3	88.4
	(170.0)	(172.1)	(179.4)	(175.0)	(182.4)	(139.9)	(140.5)	(131.9)	(145.6)	(137.1)
Number of observations	376	372	372	372	372	376	372	372	372	372
R2	0.108	0.091	0.092	0.111	0.110	0.093	0.077	0.077	0.096	0.095

Notes: Models in both countries include district (strata) dummy variables. Standard errors are clustered at the village level in Mozambique and the farmer group level in Uganda. *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

Table 11. Estimates of ACME and ADE, Change in Vitamin A Consumption Based on Linearity Assumptions

	Mozambique		Uganda	
	(1)	(2)	(3)	(4)
ACME, Adoption	190.3***	189.7***	201.1**	192.1*
	(61.1)	(62.3)	(99.6)	(97.0)
ACME, Number of Vitamin A Messages Known		14.1		58.6*
		(26.2)		(34.2)
ADE	-2.16	-15.7	219.4	169.7
	(107.8)	(108.7)	(188.3)	(189.6)*
Share of Treatment Effect, Adoption (%)	101.2	101.3	47.8	45.7
Share of Treatment Effect, Vitamin A Messages (%)		7.5		13.9

Notes: Standard errors on ACME and ADE generated using seemingly unrelated regressions. Regressions underlying the mediation effects include all explanatory variables included in Table 10. The ACME for adoption is generated by multiplying the treatment effect on adoption by the adoption effect on vitamin A intakes, and the ACME for the number of vitamin A messages is generated by multiplying the treatment effect on knowledge by the knowledge effect on vitamin A intakes.

Table 12. Average Number of Additional Households Receiving Vines from Direct Beneficiaries, REU, Model 2, Mozambique and Uganda

Country	Diffusion Rate
Mozambique	0.32
Uganda	1.00

Table 13. Primary Beneficiaries per Household, Mozambique and Uganda

Beneficiaries per Household	**Mozambique**	**Uganda**
Mothers	0.97	0.99
Children aged 6-59 months	1.25	1.73
Total	2.22	2.72

Table 14. Average Costs per Beneficiary Household and Individual, REU, Model 2, Mozambique and Uganda

Average Costs per	Mozambique	Uganda
Direct Household Beneficiary	$146	$132
Direct Individual Beneficiary	$65	$49
Direct+Indirect Household Beneficiary	$117	$66
Direct+Indirect Individual Beneficiary	$52	$26
Considering Adopting Households Only		
Direct Household Beneficiary	$191	$199
Direct Individual Beneficiary	$85	$74
Direct+Indirect Household Beneficiary	$153	$100
Direct+Indirect Individual Beneficiary	$68	$36

Table 15. Average Costs per Adopting Household in Reduced REU Program, Mozambique and Uganda

Average Costs per Adopting…	Mozambique	Uganda
Direct Household Beneficiary	$191	$199
Direct Household Beneficiary, dropping marketing component	$170	$157
Direct Household Beneficiary, dropping 25 percent of demand creation and marketing	$156	$145
Direct Household Beneficiary, dropping 50 percent of demand creation and marketing	$141	$132
Direct Household Beneficiary, dropping 75 percent of demand creation and marketing	$127	$120