Cost-Effectiveness through Bundled Distribution: Impacts of a package of goods on livelihoods in Rural Tanzania

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Abstract

There are a wide variety of development interventions that have been shown to improve welfare of poor, rural households. However, these are frequently delivered piecemeal. Using a randomized controlled trial, we test a new model of aid delivery called the Human Development Fund (HDF) in which a bundle of promising income-generating goods (such as fertilizer and hybrid chickens) and preventative health products (such as insecticide-treated bednets and corn-soy nutritional powder) are given to rural households in Tanzania using a low-cost one-time distribution system. We find large and positive effects of the HDF program on income and household consumption. Net income derived from maize, chickens, and energy increases by 144 USD, resulting in a tripling of total net income in these categories, and a 35% return on the cost of the income-generating assets of HDF. Household consumption also increases by 6.1% in the year following the HDF bundle distribution. However, the vast majority of the income increase is driven by maize profits, with the other income-generating goods (hybrid chickens and solar lamps) yielding disappointing results.

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1. Introduction

There is extensive and growing literature showing the efficacy of various interventions in improving welfare among poor, rural populations. For instance, insecticide-treated nets (ITN, (Cohen and Dupas 2010; Pryce, Richardson, and Lengeler 2018), providing agricultural inputs such as seeds and fertilizer (Deutschmann et al. 2019; Carter, Laajaj, and Yang 2019; Duflo, Kremer, and Robinson 2008; Beaman et al. 2013), and solar lamps (Chen et al. 2017; Rom, Günther, and Harrison 2017) have been shown to be impactful through in many contexts. However, these interventions are typically delivered by separate organizations specializing in each intervention. If delivered together, impactful interventions could be delivered at lower cost, and also may have complementarities that make them more effective if delivered all at once.

This paper studies the impact of the Human Development Fund (HDF) program, which provides a free one-time transfer of a bundle of income-generating and preventative health goods to poor, rural households. HDF is designed to be low-cost and simple to operationalize, with the idea that this design could achieve a unique combination of cost-effectiveness and scale. The HDF bundle was designed through a long inception phase, integrating insights from literature, ex-ante cost-effectiveness models, farmer feedback, and product field tests. The final bundle included hybrid maize seed, maize fertilizer, one solar light, three ITNs, corn-soy blend (CSB) nutritional powder for infants, 10 hybrid chicks, 30 tree seedlings and three sealed harvest bags. Recipients also received a simple one-time training on optimal product use and complementary farming practices.

We report results from a pre-registered cluster-randomized controlled trial in rural Tanzania with 1,920 rural households in 192 villages. Our data set is unique in that it consists of a year-long monthly panel survey of households, allowing us to track changes in our outcomes over time. The primary outcomes are income from sources directly impacted by the distributed products (Direct Income Gains, or DIG), as well as non-durable household consumption. We also studied secondary outcomes such as asset ownership, product utilization, and nutrition behavior.

We find that the HDF bundle dramatically improved household income, with mean treatment household DIG (over the 12 months following distribution) increasing by \$144[2] relative to a mean household DIG in the control of \$72 (an increase of 100%). This gain in income compares favorably to the total \$81 cost of the income-generating products in the bundle.

Treatment household consumption is also found to be higher than control. Monthly non-durable treatment consumption is 11% higher than control (\$99 vs \$89) 9-12 months after bundle distribution. Over the course of 12 months after the bundle distribution, treatment households experienced an average of 6.1% higher monthly non-durable household consumption compared

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[2] All currency amounts are denominated in U.S. dollars unless otherwise specified.

to control. This results in a total of $90 of increased consumption over the year. We find no statistically significant effect on total asset values.

We find a mixed effect of the HDF bundle on health behavior. Overall, the proportion of household members sleeping under an ITN is 10 percentage points higher in treatment households than in control, with 80% of treatment household members sleeping under an ITN 9-11 months after bundle distribution. However, this effect is mostly concentrated amongst household members aged over 5 years old, as we did not find any effect on children (under the age of 5) sleeping under an ITN (who are most susceptible to complications from malaria). We find significant increases in consumption of CSB by children in treatment households, as consumption of CSB is rare among our control households. Receiving the bundle also leads to an increase in the percentage of children per household that achieve minimum dietary diversity[3].

Although the financial impacts of the HDF intervention are quite large, they are almost entirely driven by maize inputs. Increases in household maize profits account for 84% of the total difference in treatment and control DIG, with increases in energy profits (from solar lamp use) and chicken profits accounting for just 11% and 5% of total DIG impact respectively. This calls into question the value of the bundle approach that is core to the HDF strategy. It seems likely that a program that simply distributed maize inputs would have been more cost-effective, at least in terms of short-term income gains, and given the context of where the intervention took place.

The idea of bundling a group of complementary interventions together is not new, and is a common feature of rural development programs. Perhaps the most well-known example is the Millenium Villages Project, which offered simultaneous interventions in many sectors including agriculture, health, and education. Although child mortality fell in project villages (Pronyk et al. 2012), the intervention was expensive and there is considerable controversy over its effectiveness (Bump et al. 2012; Masset, García-Hombrados, and Acharya 2020; Carr 2008)

More recently, a number of organizations have implemented “graduation” programs, which typically provide a combination of productive assets (such as livestock), training, savings accounts, cash and health information or services, and are targeted toward the very poorest households in rural communities (BRAC Centre 2017). Graduation programs have been extensively evaluated and shown to have large economic impacts that sustain over several years (Banerjee et al. 2015; Emran, Robano, and Smith 2014; Sedlmayr, Shah, and Sulaiman 2020; Balboni et al. 2020). However, graduation and other comprehensive livelihood programs can be very expensive to implement: the six programs profiled in Banerjee et al (2015) averaged a cost of 1,468 USD per household. These high costs are due to the high value of assets transferred (385 USD) as well as high implementation costs.

Graduation programs are effective but costly, so their success is inspiring innovation to try to find more cost-effective ways to deliver similar benefits. A lower-cost, lower-complexity bundle

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[3] This effect is only significantly at the 10% level, whereas other significant impacts we report in this paper are significant at the 5% level.

program may prove simpler to execute and able to reach more households. Banerjee et al. (2018) studies one such approach in which households were given about $40 in productive assets and finds no impact on household welfare (Banerjee et al. 2018). While this effort to develop more cost-effective bundled approaches failed, the HDF program is a further innovation in the space, as it uses a systematic approach to bundling together the most cost-effective interventions identified through literature review, ex-ante cost-effectiveness models, farmer feedback, and field tests.

Our results suggest that a low-cost bundle of productive assets, like that provided in the HDF program, can be cost-effective at generating economic impact. Both Banerjee at al (2015) and Sedlmayr, Shah, and Sulaiman (2019) estimate that the income benefits of graduation programs exceed their costs after about 3 to 4 years. Our finding is that income gains after one year are greater than the cost of the entire bundle (including non-income-generating products), which suggests a favorable return on investment versus graduation programs, albeit with lower impact in absolute terms. We similarly find favorable cost-effectiveness on the basis of a benefit-cost ratio using one-year consumption. In a review of dozens of evaluations, Sulaiman et al. (2016) find this benefit-cost ratio to be 0.3 for cash transfer programs, 0.2 for livelihood development programs, and 0.11 for graduation programs on average. A conservative benefit-cost ratio for HDF is 0.56.

This paper proceeds as follows. Section 2 outlines the context and the intervention approach, including how the components of the HDF bundle were selected. Section 3 describes the data and empirical methods. Section 4 reports the results. Section 5 provides a discussion of the results, and section 6 concludes.

2. Context and Intervention

The HDF program was implemented by One Acre Fund (1AF), a non-governmental organization (NGO). 1AF’s Core Program delivers a large package of agricultural inputs - as well as farming trainings and market facilitation services - on credit to over one million farming households across East Africa each year. A randomized evaluation (Deutschmann et at 2019) found the program to significantly increase farmer income. However, the core program requires an intense field presence to operate and not all farmers are comfortable with taking loans. The HDF program was designed as a service that could reach more farmers, lower income farmers, and be scaled faster than 1AF’s core program.

The HDF program was implemented in the Singida region of Tanzania. According to Tanzania government data, Singida is the second poorest of Tanzania’s 25 administrative regions, with 49% of households living in poverty, compared to 36% across all of Tanzania (Research and Analysis Working Group 2009). The region is highly dependent on agriculture, with 95% of household heads reporting crop cultivation as their main source of income. The most commonly grown crop in the region is maize, grown by 70% of households and covering 48% of all crop land (Ministry of Agriculture, Food Security, and Cooperatives 2012).

Singida was selected for the trial through a detailed selection process, taking into account the following factors: potential for maize input provision having a large impact (using a cost-effectiveness model), local government cooperation, and avoiding areas where 1AF's core program operates. Using data from public sources as well as a scouting survey in 6 regions in Tanzania, we established Singida as the region that scored highest on the above criteria. We conducted an additional validation exercise on the suitability of the HDF program in the region through a survey of 400 households conducted between January and February 2019. Although Singida scored most highly among the scouted regions, many of the regions where 1AF's core program operates would have potentially made better sites for the pilot had 1AF not already been present there.

Intervention and Implementation

The HDF program consisted of a one-time delivery of a bundle of goods, selected for maximum impact through a long process of literature review, an ex-ante comparative cost-effectiveness model, farmer consultation, and field trials. 1AF originally intended to distribute the bundle all at once in order to minimize distribution costs. However, in practice hybrid chicks needed to be delivered separately from the rest of the bundle for logistical feasibility.

Table 1 shows the final bundle delivered to treatment households and, where relevant, which households were eligible. The bunde included maize inputs, hybrid chicks, a solar light, post-harvest storage bags, corn-soy blend, insecticide-treated nets, and tree seedlings. Eligibility was determined by 1AF field team surveys (which were separate from the baseline used as part of this impact evaluation.) Individual product costs as well as costs associated with implementation during this study are given on a per-household basis. Management and delivery costs per household were high during the study since it was the first time HDF had been implemented, and relatively few households were included. Costs per household would be much lower at scale; we explore this further in the discussion section.

The treatment intervention took place between September and November 2019. Following the baseline survey, treatment households were visited by 1AF's field team to inform them that they had been selected to receive the free bundle of goods and training. Only two of the 640 treatment households declined to participate. Each cluster of 10 households (sampling explained below) was invited to vote on one household leader to be their Group Leader, following suggested criteria of familiarity with maize agriculture, public speaking experience and personal connections to the other households. This Group Leader was then invited to a two-day training in a nearby town, given to groups of about 15 Group Leaders at once. This was a training-of-trainers approach, in which Group Leaders learned how to train their group members on good agricultural practices for maize, tree seedling planting, correct dosage of corn-soy blend, chicken upkeep and other key practices to ensure productive and safe use of bundle products. Group Leaders were then expected to pass this training on to their group members before product distribution. Group leaders were compensated for travel costs and provided food but were otherwise not paid for their role. Each treatment household was also provided with a large poster, which summarised key training points with simple diagrams.

Once all Group Leaders had been trained, product distribution started with distribution of hybrid chicks. These were distributed about one month before all other products due the operational complexity of distributing live chicks and concerns about contamination of the corn soy blend from the chicks if delivered together. Chick distribution had been carefully tested during product tests and great care was taken to ensure chick wellbeing, resulting in distribution survival rates of over 99%. Mosquito nets were hung directly in treatment household homes by program staff to promote use.

Product and site selection

The selection of specific bundle products was a 15-month process, designed to be farmer-centred, iterative and data-driven. The process began with a high-level literature review to identify products with proven impact in similar contexts, as summarized above. Output from this literature review was fed into an optimization model to estimate the impacts of different products in Tanzania, Rwanda, Uganda, Ethiopia, and Malawi. This resulted in a longlist of 17 potential products: solar lamps, hybrid chickens, oral rehydration salts, deworming pills, hybrid maize seed, maize fertilizer vitamin A supplements, CSB, unconditional cash transfers, eggs during pregnancy, micronutrient powder, ITNs, weather forecasts by SMS, tree seedlings, fuel-efficient cookstoves, a poster about nutrition and sealed harvest bags. Through the optimization model, Tanzania was selected as the country with the highest impact potential on income, adjusted for purchasing power parity.

The longlist of potential products was then taken to intensive one-on-one and group discussions with 20 randomly selected smallholder farmers in a village in Morogoro region. This region was chosen for its proximity to 1AF's headquarters, before a pilot region had been selected. Farmers were introduced to each of the products in detail and then asked to rank them using a prioritization matrix, based on one-to-one comparisons such as "If you could have 3 hybrid chickens or 3 mosquito bed nets, which would you choose?". This resulted in clear preference for some products over others, in particular a strong interest in hybrid chickens and very low interest in vitamins or deworming pills, producing a shortlist of products for further testing. Participants were given some of these products after the interviews were completed, resulting in initial program design insights.

Publicly available datasets were used to create a shortlist of 6 potential regions, based on malaria prevalence, maize cultivation and where 1AF had no plans to scale its Core Program. A scouting survey with approximately 1,000 households across those 6 regions identified Singida as the region with the highest potential for program impact. Product-specific tests were conducted with a total of approximately 300 smallholder farmers in Singida region, covering maize inputs, chickens, corn soy blend, tree seedlings and mosquito nets. Small quantitative and qualitative studies tested key impact assumptions behind the products, verified farmer demand and allowed testing of delivery logistics.

Direct provision of agricultural inputs to smallholder farmers has been demonstrated to increase agricultural productivity and rural incomes. Deutchmann et al (2019) conducted a randomized controlled trial (RCT) of 1AF's Core Program, which provides agricultural inputs on loan to smallholder farmers across East Africa, including in Tanzania. Deutchmann et al found that treatment farmer maize yields increased 24% and maize profits increased 16% (Deutschmann et al. 2019). Carter et al 2019 conducted an RCT of an input subsidies program from the government of Mozambique, finding positive impacts on maize yields and household consumption (Carter, Laajaj, and Yang 2019). The HDF regional scouting survey found that the large majority of households in rural Singida cultivate at least 1 acre of maize each year but that few had access to quality inputs. Qualitative product tests with 30 farmers in Singida found strong interest in receiving maize inputs in the bundle and high adherence to a set of simple trainings on input use. The exact composition of the bundled maize inputs, including ideal seed variety and fertilizer dosage, was determined following consultation with the Singida Regional Agricultural Office and 1AF's Agricultural Research Team. The maize bundle distributed to treatment farmers included 30kg of DAP, 60kg of urea, 10kg of hybrid maize seed, a scoop for fertilizer micro-dosing and a string marked at 30cm intervals to support row planting.

Solar lights have been proposed as poverty-reducing tools, freeing up household income by reducing expenditure on other energy sources, such as kerosene or batteries for torches. Although less studied than agricultural inputs, a randomized evaluation in Kenya found solar lights reduced energy expenditure by half, and a quasi-experimental study in Uganda found energy expenditure reductions of over 70% (Rom, Günther, and Harrison 2017; Chen et al. 2017). The HDF scouting survey indicated that rural households in Singida spend about $10 per year on lighting and phone charging expenses. This figure was higher for households that did not already own solar lamps, resulting in the decision to target solar lamps only at the roughly 50% of households that did not already own them. Qualitative discussions with rural households suggested strong interest in receiving solar lamps in the bundle, however no actual product trials were conducted with solar lamps.

Improved chicken breeds have potential to generate multiple benefits for rural households. Eggs and fully-grown birds can be sold, generating income, or consumed, reducing expenditure (IDinsight 2018). Egg and meat consumption can also provide important protein sources for young children (Passarelli et al. 2020). HDF regional scouting data indicated that over 90% of rural Singida households keep chickens. mall-sample product tests indicated that participants were able to build a simple chicken hutch and had access to markets for chickens and eggs.

In addition to higher levels of poverty, rural households are also exposed to substantially higher risk of malaria. In a 2017 study in Tanzania, 7% of a random sample of rural children tested positive for malaria, versus just 2% of urban children (Ministry of Health, Community Development, Gender and Children and Ministry of Health Zanzibar 2018). Insecticide-treated nets (ITN) have been consistently shown to be highly effective at reducing malaria transmission through systematic reviews (Pryce, Richardson, and Lengeler 2018). Focus group discussions with Singida households revealed malaria to be a significant reported challenge. While most households reported owning ITN, often distributed for free by the government, they reported that the ITN were often quite old and worn. Small sample trials of ITNs in Singida indicated high adherence to sleeping under the ITN at night.

Malnutrition is a significant challenge in Tanzania. The World Bank estimates that 34% of under 5's are stunted (The World Bank 2018). The challenge of poor nutrition is particularly acute in the Singida region, with the Tanzanian government estimating that 5% of children in Singida suffer from Global Acute Malnutrition, the highest level of any region in the country (Tanzania Food and Nutrition Centre 2019). Corn-soy blend (CSB) is a fortified food blend, commonly provided by the World Food Program to treat moderate acute malnutrition (World Food Program 2018). Focus group discussions indicated that Singida households were not aware of malnutrition as a specific challenge but that interviewees responded positively to the idea of supplements designed to help children develop healthily. Small sample product tests with Singida households with CSB found high adherence to use of the product, with most of the supplement going directly to the young children intended as recipients.

Trees may represent an opportunity for farmers to build steady income, from fruit sales, and long-term assets, for eventual timber sales. A World Bank survey of 5 African countries, including Tanzania, found that trees account for 6% of annual income across all rural households, or 17% for those growing trees (Miller, Muñoz-Mora, and Christiaensen 2017). Tree planting by smallholder farmers is especially common in Tanzania, with 55% of rural households planting trees (Miller 2016). There are, however, few rigorous evaluations of the income potential of a tree distribution program. Given the very low cost of tree seedlings (about $0.10 each) and farmer interest expressed through product tests, a mixed bundle of tree seedlings was included in the HDF program. The bundle included 10 fruit trees (5 papaya and 5 cashew seedlings), 10 timber trees (5 acacias and 5 grevillea seedlings), and 10 agroforestry trees (5 gliricidia and 5 acrocarpus seedlings).

As part of this pilot process, 40 households were given the cash-equivalent of the bundle products. When told that they were being given cash to compare their outcomes to farmers receiving products, these cash households consistently reported that they would prefer products of equivalent value, saying that they had little of quality to buy in their villages. Although we had considered adding cash as part of the HDF bundle, this experience informed our decision to not include cash.

After product testing, and larger-scale piloting, the final product bundle included the following products: 10kg of hybrid maize seed, 60kg of maize fertilizer, one solar light, three ITNs, corn-soy blend (CSB) nutritional powder for infants, 10 hybrid chicks, 30 tree seedlings and three sealed harvest bags.

3. Methods and Data

Design

This study is a cluster-randomized control trial randomized at the village level.

Our sample included 192 villages located in the Singida region of Tanzania. The chosen villages were a random subset of 300 officially recognized villages in the region. We excluded villages where survey piloting, product testing, or distribution piloting had taken place, as well as all villages in one district where little maize was grown. Before baseline, we randomly assigned the chosen villages to either treatment or control arms. We stratified the randomization by district, the largest administrative area beneath the region. We chose villages as the level of randomization both to avoid the spillover effects to neighboring households.

During baseline data collection, field staff worked with village administrators to establish a list of village "Balozis". Balozis are ambassadors who represent a village sub-part made of 10 to 30 households, amongst which the Balozi lives. Once field staff established a list of Balozis, we randomly selected one Balozi per village. The Balozi's household as well as the nine households closest to the Balozi's house were invited to become study participants, collectively called a *kikundi* (small group).[4] We excluded from the sample households that were unavailable during the week of baseline surveying, or those that declined to participate. These households were replaced by the next closest household to the Balozi's house. Field staff followed the same procedure when a household declined to participate in the study. Given 192 villages and 10 households per village, our target sample size was 1,920 households.

Given the high expense of implementing the HDF program in treatment households, we assigned 64 villages (kikundi) to treatment and 128 villages (kikundi) to control. Ex-ante, we estimated that this design had a minimal detectable effect size of .18 standard deviations.[5] The study's actual sample size differs somewhat from the design, as described in the Data section below and Table 8. Baseline data collection was conducted between August and October 2019. It was rolled out geographically with a proportionate number of treatment and control group villages surveyed each week. The distribution of the HDF bundle (the treatment) occurred between September and November 2019, two to three months after randomization and before the maize planting season. 1AF began enrolling households in the HDF program while the baseline survey was still ongoing, but a given household was only enrolled after all sampled villages in that household had received the baseline survey. Furthermore, households were not

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[4] This procedure changed after September 17, 2019, when government officials requested that the Balozis themselves no longer participate in the study. From then on, we invited the 10 households closest to the Balozi's house to participate in the study.

[5] This estimate is based on assumptions of power of .8, size of .05, intra-cluster correlation of .1, and a correlation between baseline and endline outcomes of .3. We use the harmonic mean of the uneven cluster sizes in C and T (85), as suggested in Spybrook et al (2011). Stata command: calculationclustersampsi, detectabledifference rho(.1) k(85) m(10) base_correl(.3)

actually treated (e.g., they did not receive the HDF bundle or any training) until after the baseline survey was complete.

Our study was registered along with a pre-analysis plan in the American Economics Association's trial registry (AEARCTR-0005027), and received ethical approval from the National Institute for Medical Research (NIRM) as well as approval from the Tanzania's Commission for Science and Technology (COSTECH)

Data

Data collection procedures

One Acre Fund and IDinsight jointly carried out data collection between August 2019 and November 2020. The villages were randomly allocated into three equal cohorts, and one cohort was surveyed each month. This process resulted in each household being surveyed at baseline (August-October), and then four additional times over the course of 12 months. Households were surveyed once every three months.

Each follow-up survey gathered data on income (revenue and expenses for maize, chickens, and energy) as well as household consumption. Certain rounds contained additional variables used in the analysis, such as bednet usage and tree survival.

We collected data using tablet computers by field staff hired by OAF. All surveyed were conducted in person. We used the electronic data collection software CommCare to administer the surveys and store data. We utilized a standard suite of data quality procedures designed and overseen by IDinsight) including automated daily checks and resurveys in the case of poor data quality.

Outcomes of interest

Primary outcomes

As described in our pre-analysis plan, our two primary outcomes were net direct income gained (DIG) from the products included in the HDF bundle and one-month non-durable household consumption measured 9-11 months after the transfer (which corresponds to 1-3 months after the primary maize harvest). Direct income gains is a measure of the first-order income (or savings) effects from the three primary income-generating components of the HDF bundle. We calculated DIG as the sum of profits from cultivating maize during the primary maize season, profits from raising chickens, and profits from producing energy to light one's home and charging mobile phones.

We measured profits from maize as the difference between the value of the maize harvest and farmers' expenditure on agricultural inputs (such as labor[6] and chemical inputs). Chicken profits consist of the value of eggs produced plus the value of chickens consumed or sold minus any expenses that went toward maintaining chickens, such as feed, transport costs (for sale), and veterinary treatment. We also measure the current sales value of the current flock of chickens, and use this as a proxy for the future income stream from chickens. Energy profits were the sum of the revenue from charging cell phones using home solar systems, less the energy costs to pay others to charge cell phones, and lighting costs (such as kerosene, batteries, and repairs). We also include in energy profits the value of HDF-distributed lamps, calculated as the estimated discounted flow of future profits from the lamps. We extrapolated the one-year impact of lamps to five years, discounting for the saving rate in Tanzania[7] plus the rate at which lamps were expected to stop working (The World Bank 2019a; 2019b).

We chose DIG as a primary outcome as it gives an easy to understand, first-order measure of the impact of HDF on income. It is akin to measuring maize profits for a maize intervention or chicken profits for a chicken intervention, and provides a number that is easily comparable to 1AF's pilot implementation costs, thus allowing for calculation of Social Returns on Investment (SROIs). We consider the primary audience for the DIG results to be 1AF and potential donors to HDF.

One limitation of this outcome is that it does not take into account the second-order effects that households may incur, such as the re-allocation of land or reduced investment in other businesses. We address this downside of the DIG measure by also measuring household consumption. Our second primary outcome is households' post-harvest monthly non-durable consumption, measured roughly one year after the delivery of the bundle. Consumption is a well-established measure of welfare that allows the HDF pilot to be compared to a wide variety of interventions (The Royal Swedish Academy of Sciences 2015). We consider the primary audience for the consumption results to be the academic community.

For each study participant, we measured one-month of non-durable household consumption at some point between 9-11 months after the intervention, using a standard consumption module measuring food and other common household expenses. We did not include spending on energy in our consumption outcome since we expected the distribution of solar lamps to reduce energy spending. To facilitate recall, we asked households to estimate the value of their consumption of a particular item for the past week, month, or year. We then linearly extrapolated all consumption impacts to the month level.

Since our two primary outcomes were pre-specified and intended for different audiences, we do not correct our inference for multiple hypotheses.

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[6] Labor includes both paid labor as well as household labor. Following Deutschmann et al (2019), we value household labor at 50% of the prevailing labor rate.

[7] The deposit interest rate was 7.1% in Tanzania at the time of analysis according to data from the World Bank. We obtained the real interest rate by subtracting inflation from the Tanzanian deposit interest rate. At the time of analysis, the Tanzanian inflation rate was 3.5%. We thus discounted the value of solar lamps by 3.6% per year.

Secondary outcomes

In addition to our primary outcomes, we assessed a number of other outcomes related to consumption, asset ownership, children's diets, and product utilization. While our primary consumption outcome focuses on months 9-11 only, we also analyze consumption month-by-month, as well as average monthly consumption over the course of a year. This allows us to understand how the treatment effects changed over time.

We were also interested in capturing the HDF pilot's impact on households' ownership of durable assets. Our expectation was that treatment households' increased income might drive households to invest some of their income by purchasing durable assets, such as vehicles, household appliances and electronics, building materials, and farming equipment.

To explore health effects, we included as additional outcomes the proportion of children between the ages of six and 23 months from each household that consumed minimum dietary diversity and consumption of iron-rich food. We calculated these outcomes based on the World Health Organization's Indicators for assessing infant and young children feeding practices definitions. We considered children to have achieved minimum dietary diversity if they received foods from 4 or more food groups in the previous day. We measured consumption of iron-rich foods based on whether they had received iron-rich foods during the previous day. For this study, that was primarily done through looking at flesh foods (meat, fish, etc.) that children had consumed[8] (World Health Organization (WHO) 2008).

Finally, we are interested in understanding the mechanisms through which treatment's impact may have taken place. We thus measured the extent to which households used the products that were part of the HDF bundle as our intermediate outcomes. In terms of nets usage, we calculated the percentage of household members who slept under mosquito nets, as well as the percentage of adults, children aged five to 18, and children under the age of five who did the same. We gathered this data during the second round of our survey (March-May 2020) as it corresponded to Tanzania's rainy season, during which the rates of infection due to mosquitoes tend to increase (Msellemu et al. 2020). For nutrition, we looked at the quantity of CSB powder consumed by children aged two to five and by children under the age of two. In terms of the maize products distributed by 1AF, we show results on a dummy for storing maize (e.g., using sealed harvest bags), and one for using fertilizer. In terms of the chickens distributed by 1AF, we looked at the number of hybrid and local chickens owned by households 9-11 months after distribution and the number of eggs produced by the farmers' flock over the year. For solar lamps, we looked at the percentage of treatment households that used their lamps for charging phones and/or for charging mobile phones. Finally, we calculated the number of tree seedlings that had been planted by treatment farmers and the number of trees that survived the study year.

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[8] We originally planned to measure the minimum acceptable diet as this is a more common measure of assessing feeding practices. However, due to an error in data collection we were unable to determine meal frequency which is a core component of minimum acceptable diet. We replaced this with two other core indicators recommended by the WHO to access infant and young children feeding practices, minimum dietary diversity and consumption of iron-rich foods.

Analytical Specifications

We estimated intent-to-treat effects, and measured the treatment effects for most outcomes, both continuous and binary, using an OLS regression defined as follows:

$$Y_i = \beta_0 + \beta_1 T_i + \beta_2 X_i + \varepsilon_i \text{ (Equation 1)}$$

With Y_i as the outcome of interest for household i, β_0 is a constant, β_1 is the estimated treatment effect of HDF compared to a control group, T_i as a binary variable that indicates assignment to the treatment group, β_2 as a vector of coefficients for the included covariates, X_i as a vector of controls, and ε_i as a residual error term, assumed to be correlated at the village level[9].

To measure the treatment effect for average monthly consumption, we used an ANCOVA regression model, defined as follows:

$$Y_{i,t} = \beta_0 + \beta_1 T_i + \sum_{t=1}^{12} \delta_t + \Theta \overline{Y}_{i,PRE} + \beta_2 X_i + \varepsilon_i \text{ (Equation 2)}$$

With $Y_{i,t}$ as the consumption for household i in month t, β_0 as a constant, β_1 as the estimated treatment effect of HDF compared to a control group, T_i as a binary variable that indicates assignment to the treatment group, δ_t as the time dummies that capture the means for the control arm in each month, θ as the coefficient for the baseline consumption control variable, $\overline{Y}_{i,PRE}$ as the value of consumption for household i at baseline, β_2 as a vector of coefficients for the included covariates, X_i as a vector of controls, and ε_i as a residual error term, assumed to be correlated at the village level[10].

The vector of additional controls X_i included household consumption at baseline, a binary covariate for each district and a dummy for whether the household had children under two.[11]

Households had to have a 2-year-old to receive the CSB powder. We were not able to include covariates for whether farmers had the intention to farm maize (the condition for receiving the HDF maize products), or for whether households already owned a solar lamp at baseline (the condition for receiving an HDF solar lamp). This is because we did not directly ask questions on

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[9] This also corresponds to the *kikundi* level, since one *kikundi* was sampled per village

[10] This also corresponds to the *kikundi* level, since one *kikundi* was sampled per village

[11] Although we had pre-specified that we would control for households' eligibility to receive each of the HDF bundle products, in practice we were only able to include the presence of a 2-year-old as a covariate. Ideally, we would have also included a dummy for households' intention to farm maize (the condition for receiving the HDF maize products), and whether households already owned a solar lamp at baseline (the condition for receiving an HDF solar lamp.) Unfortunately, due to an error in our data collection procedures, we did not collect this data for control households and therefore cannot include these covariates.

these aspects of farmers' lives during the survey and thus did not have data that was robust enough for the covariates to be included in our regressions.

We adjusted standard errors for clustering at the unit of randomization: the village. To decrease the influence of outliers, we winsorized all continuous outcome variables at the 1% upper tail. As mentioned in our pre-analysis plan, to improve power we excluded from the analysis the top 5% of households in terms of baseline consumption.

4. Results

Sample characteristics

Table 2 provides details of the characteristics of the sampled population, as measured before the start of this study. On average, households were made up of 5.90 members. The average household had 0.90 children under five amongst its members and 0.32 children under two. These household members consumed goods worth \$161.40 per month during baseline months, with \$126.60 being spent on non-durable goods (including \$72.50 on food items) and \$34.80 being spent on durable goods. This is equivalent to a monthly consumption of \$27.36 per household member, or just under \$1 per household member per day. There is no significant correlation between treatment status and any baseline characteristic.

Our baseline sample consisted of 1,916 households (33% treatment, 67% control). As highlighted in Table 8 through our four rounds of follow-up there was limited attrition, with response rates per round ranging from 95-98%. 1,764 households (33% treatment, 67% control) completed all four rounds, which is equivalent to 92.10% of the original sample. In our pre-analysis plan, we specified that if attrition did not exceed 10.00% and was uncorrelated with treatment, we would use the non-attrited sample in the final analysis. Given that attrition was low at only 7.90% and uncorrelated with treatment, we carried out all analyses using the non-attrited "complete case" sample. We show attrition statistics in Appendix Table 1.

Direct income gains

Table 4 presents regression estimates for the treatment effect on income derived directly from products in the HDF bundle (net Direct Income Gains, DIG), following Equation 1. Participation in the HDF pilot caused a significant ($p<.01$) increase in DIG by \$144 (from a base of \$72 in the control group).

As shown in Figure 1, the majority (84%) of the DIG treatment effect came from an increase in maize profits. Participation in the HDF pilot meant that treatment households saw a significant ($p<.01$) \$122 increase in their maize harvest profits, from \$46 to \$167. The majority of the maize treatment effect is explained by the fact that treatment households experienced a \$131.50 increase in the income they gained from maize compared to control households, while there was little change in maize expenses.

Participation in the HDF pilot also had a significant (p<.01) positive effect on net income related to energy, rising from $-21.70 to -$5.30. The negative numbers reflect the fact that households spent more on energy than they received in income (for instance, from charging other peoples' phones.) Our headline results from energy includes energy savings from the first year of the study, as well as the estimated flow of future energy savings over the lifetime of the lamp provided as part of HDF.[12] The treatment effect of $16.40 is composed of a $5.80 increase in net energy income over the course of the first year, and an estimated $10.60 in expected future flow of income in future years for lamp-owning households. Energy savings overall accounts for 11.3% of the total DIG gains.

The profits households derived from their chicken flock increased by $7.80 from $46.80 to $54.60, although this increase was only significant at the 90% level (p-value: 0.053). This $7.80 difference accounts for 5.41% of the overall DIG treatment effect. Profits from chickens are composed of the first-year net revenue from chickens, plus the value of chickens 9-11 months after distribution. Treatment households actually had first year chicken-profits that were $7.6 lower than treatment households. This negative effect is driven by treatment households spending much more ($36.90) on feed than control households. Although treatment households also earned $28.80 more income from chickens than control (primarily through the production of eggs, rather than sale or consumption of chickens), these gains were not enough to offset their higher expenses . This is a surprising result, as the hybrid chickens theoretically do not need to be given purchased feed, and households were instructed by One Acre Fund not to purchase feed.

Despite having lower chicken profits in the first year, treatment households did have a larger flock of chickens 9-11 months after distribution, and we estimate the value of their flock at $15.2 higher than that in control. This results in a total increase in chicken profits, despite the hybrid chickens not being profitable in the first year of ownership.

The DIG treatment effects reported here are for a trimmed sample in which farmers in the top 5% of baseline consumption were dropped to improve statistical power, as specified in the pre-analysis plan. Table 8 shows the same analysis conducted on the full sample, without this trimming. We find very similar results to the trimmed analysis, with no change in statistical significance levels and only modest changes in the point estimate of treatment effects on overall DIG and on product-specific DIG.

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[12] As mentioned in the methodology section, we measure the future flow of income of the lamps distributed by HDF by first calculating the treatment-on-the treated impact of HDF on energy profits the first year, and then projecting out the discounted flow of these profits over the next four years. These future profits are assigned to households who report still having working solar lamps from HDF 9-11 months after distribution.

Consumption

While the Direct Income Gains outlined in the previous section show the first-order impact of the HDF products, they do not necessarily give a clear indication of the impact of HDF on household welfare. Although maize profits increased significantly, we do not know if households were substituting away from other income-generating activities. To explore welfare, we look at the results on household consumption and assets. We first look at the results of consumption and assets 9-11 months after distribution, and next present the results from the monthly consumption surveys.

Table 5 presents regression estimates for the average treatment effect for one-month non-durable consumption 9-11 months after distribution. (Non-durable consumption is the second pre-specified primary outcome of this study.) Receiving the HDF bundle increased the amount of non-durable goods consumed by treatment households for one month 9-11 months after distribution by $10.20, relative to control households who consumed $89.00. (p<.01) . Following the pre-analysis plan, the sample was trimmed of farmers in the top 5% of baseline consumption. The 9-11 month consumption treatment effects of a full, untrimmed sample are shown in Appendix Table 4, which finds no change in significance levels between the trimmed and untrimmed analyses and only modest changes in point estimates of treatment effects.

The above treatment effect was greater for the poorest and richest households, as ranked in terms of their total consumption at baseline. The lowest quartile saw treatment effects of $17.70, while the highest quartile saw treatment effects of $16.5, while the two middle quartiles saw low and insignificant treatment effects. This differential treatment effect by baseline consumption is somewhat perplexing (especially given its nonlinearity), and we do not have a good theory to explain this pattern. Given the smaller size of the quartiles and the fact that the differences in impact by quartile were not statistically significant, it is possible that these differences simply occurred by chance.

The HDF intervention did not have a significant impact on the value of households' stock of assets 9-11 months after distribution. If we concentrate just on assets directly related to HDF (solar lamp, chickens, bednets), we do see that households had higher values of these assets (by $17.90), showing that households did continue to own the distributed assets. However, this increase in assets was small compared to the total value of assets owned by households ($2131 in control) and so did not result in a statistically significant increase in total asset value. It is also possible that farmers who acquired HDF-related assets substituted these assets for others- for example, farmers may have chosen to purchase fewer goats because of their larger chicken flocks.

Turning now to the monthly consumption results, Figure 2 graphically presents the treatment effects on household consumption month-by-month. (Regressions related to this graph can be found in Appendix Table 2) As we only surveyed a third of our sample each month, the error bars are large and the monthly results should be interpreted with caution. That being said, some interesting patterns do emerge.

Somewhat perplexingly, we find that treatment households had lower consumption than control in December 2019 (the first month after the bundle was distributed) and higher consumption in January 2020 (the second month after the bundle was distributed.) It is possible that treatment households' lower consumption in December levels were been caused by the fact that they were saving up for the expenses they were expecting to incur as a consequence of the HDF bundle (for example in relation to feeding and housing their chickens) In January, treatment households may have consumed more than control households since the products in the bundle may have replaced some of the expenses (for example on fertilizer and seeds) they would have had to incur without them. This may have freed up income which households then spent on consumption. These explanations are speculative, and we note that they are somewhat contradictory.

After January, the results become more predictable. There were no impacts of consumption from Feb-June. During this time households were experiencing some energy savings, but were also experiencing net negative revenue from chickens, as they were spending money on feed but the chickens were not yet producing. From June-October, treatment households have higher consumption, likely reflecting anticipated and then realized increased income from the maize harvest (which mostly took place in July and August). By November (the last month of the survey), treatment effects on consumption have decreased.

Averaging across all months, treatment households consumed $7.50 more per month, a 6.1% increase over control households. 77% ($5.80) of this treatment effect is explained by changes in the amount of non-durable goods consumed by households each month, with the rest explained by purchases of durable goods. Over the course of 12 months, this means that treatment households increased their consumption by around $90 compared to control[13].

Utilization of income-generating products

Table 6 highlights the effect that treatment had on intermediary outcomes, as well as utilization of products that were part of the HDF bundle.

Despite their larger harvests, treatment farmers were not significantly more likely to use fertilizer, measured by a dummy of fertilizer use. It is possible that treatment farmers used *more* fertilizer than control farmers, but we did not explicitly measure the volume of fertilizer used. explicitly.

Treatment farmers were 15.3 percentage points more likely than control farmers to store at least some of their maize harvest (85.3% in treatment vs 70% in control). This likely reflects both the larger harvest amounts in the treatment group, as well as improved access to storage technology (sealed harvest bags). Treatment farmers stored 29% of their harvest in the sealed

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[13] The $54 difference between the estimated increase in DIG ($144) and the estimated increase in total one-year consumption ($90) may constitute savings, measurement error from our consumption survey, or reduced income from sources not included within DIG.

bags provided by 1AF, which will likely help prevent maize loss to pests and allow farmers to sell some maize later in the year once market prices have increased (Baributsa and Njoroge 2020).

9-11 months after distribution, treatment farmers had a larger number of hybrid chickens in their flock compared to control farmers. Treatment farmers owned an average of 2.6 hybrid adult chickens while control households did not own any. Considering that 10 hybrid chicks were originally distributed to treatment households, this implies that an average of 7.4 chickens per household were eaten, sold or died over the course of the study. Belonging to the treatment group did not significantly influence the number of local adult chickens farmers owned, with both control and treatment farmers owning 3.6 chickens on average. This means that treatment farmers did not substitute their local chickens for the hybrid HDF chickens they received. Perhaps because of the fact that they owned a larger number of chickens or due to hybrid chicken's heightened productivity, treatment households collected 332 eggs over the course of the year, 202 more than control households (who collected 130 eggs).

Treatment households planted the majority of the tree seedlings they received from 1AF, but most of these seedlings had died by the end of the year. Farmers planted an average of 9.1 out of the 10 fruit tree seedlings they received, but only 3.2 trees were still alive 9-11 months after distribution. Farmers planted 8.8 out of the 10 timber tree seedlings they received, but only 2.8 timber trees were still alive 9-11 months after distribution. Farmers planted 8.8 of the 10.00 agroforestry tree seedlings they received but only 2.9 trees were alive 9-11 months after distribution.

95% of households that said they received a solar lamp from HDF used their lamps to light their home at least once during the year following bundle distribution. 83.28% of households used them for both charging phones and for lighting, but no household used their lamp for charging phones only. 5.07% of households did not use their lamps for either lighting or charging phones.

Health

The nets distributed by 1AF had a significant (p<.01) impact on the number of individuals sleeping under mosquito nets during Tanzania's rainy season, though this increase is concentrated among older household members. While 70.0% of household members slept under nets in control households, 79.6% did so in treatment households. This increase is mostly explained by the fact that a larger proportion of children five to eighteen years old slept under nets in treatment households (71.9% in treatment vs 60.0% in control). The proportion of adults sleeping under nets in treatment households also improved as a result of treatment (77.5% in treatment vs 70.0% in control) Receiving the HDF bundle did not have a significant impact on the proportion of children under five sleeping under nets. This is unfortunate considering that this age group is most vulnerable to malaria and other insect-borne diseases (World Health Organization 2018).

The HDF treatment increased the amount of Corn-Soy Blend (CSB) powder consumed in households. Children under two in control households consumed almost no CSB (0.1 KG), while children under two in treatment households consumed 4.10 KG per person over the course of the first six months of the HDF pilot. There were smaller increases (0.6 KG) for children ages 2-5.

Additionally, we observed an improvement in nutritional outcomes for this age group, albeit not significant at the 5% level. 14.2% of children between 6 - 23 months in control households consumed the required minimum dietary diversity (MDD) 9-11 months after the bundle was distributed, while 21.3% in treatment households consumed the required MDD. However, this difference was only statistically significant at the 10% level. There was no difference in the consumption of iron-rich foods between treatment and control for this age group either. The increase in CSB consumption is encouraging, however could have failed to lead to longer term nutritional gains given that there was only enough supply for the first six months of the program. It is possible that these increases in MDD for children could have also been driven from the income and consumption gains or increased egg production and consumption as well from chickens.

5. Discussion

The pre-analysis plan for this evaluation outlined two “definitions of success” for the HDF pilot. The first was that the intervention should have a positive and statistically significant impact on one-month non-durable consumption measured during the endline survey. The second was that the effect of treatment on DIG should be positive and statistically significant, and the point estimate of that effect should be greater than the average cost per farmer of the income-generating components of the bundle ($94). HDF had positive and statistically significant impacts on both endline non-durable consumption and DIG, meaning the program met these pre-established success metrics.

Assessing the HDF Bundle Components

Among the income-generating components of the bundle (maize inputs, hybrid chickens, and solar lamps), maize inputs were by far the largest driver of DIG impact. While, not as impactful, solar lamps could also justifiably be included, since although they only contributed $16.40 of DIG impact (11% of the treatment effect), they may confer non-monetary benefits that were not measured as part of our evaluation (e.g., ability to study at night, increased mobile phone usage). Hybrid chickens, on the other hand, had disappointing impact. The chickens *decreased* farmers’ profits in the first year after being distributed, and were only projected to increase profits by $8 when accounting for future years.

Independent of HDF, the results of this evaluation casts doubt on the viability of hybrid chicken as a means of generating income for poor smallholder farmers. Hybrid chickens were expensive for farmers to keep, costing them an additional $36.90 over the course of a year (equivalent to 2.5% of control households' average annual consumption), $32.40 of which came in the form of additional expenditure on feed. Although HDF training sessions instructed farmers to allow their chickens to forage for insects and scraps from their crop fields, farmers reported anecdotally that they needed to feed their chickens to keep them healthy. Although consistent with a previous study on hybrid chickens in Ethiopia (IDinsight 2018), this finding contradicts the common notion that hybrid chickens should not be expensive for farmers to raise. Perhaps partially because of these costs, farmers did not typically maintain large flocks of hybrid chickens. At the end of the evaluation, HDF farmers reported only owning 2.6 hybrid chickens, even though they initially received 10 chicks. This low "survival" rate does not bode well for the long-term impacts of hybrid chickens. Even if owning them becomes profitable after the first year, as we estimate for HDF, households only yield these benefits from a relatively small number of chickens. That being said, there is a possibility that chickens could yield non-monetary benefits, such as improved nutrition through increased egg consumption. Even so, organizations funding or implementing hybrid chicken interventions should consider whether beneficiaries can avoid the high maintenance costs that characterized the hybrid chicken component of HDF. If not, such programs at best likely offer modest benefits relative to their implementation costs and at worst may actually make farmers worse off.

Although we could not measure the long-term monetary impacts of the non-income-generating products distributed as part of HDF, intermediate outcomes indicate mixed results. HDF increased overall usage of ITNs but did not significantly impact usage among those young children most vulnerable to malaria. This may be due to the fact that there were high levels of bed net usage in Singida. 80% of children under 5 per household slept under beds within the control group, and 70% of people per household overall slept under nets. It is difficult to justify including ITNs in a future version of the HDF bundle based on this modest uptake in usage in locations that already have high ITN penetration. However, it is possible that distributing ITNs as part of a bundle would have a larger impact on the proportion of people sleeping under nets in a region where *ex ante* usage was lower. Even in this context, the results do not mean that the nets distributed via the HDF pilot will have no benefits. Russell et al. (2010) have shown that increased usage among older children can still reduce malaria incidence and slow overall community transmission (Escamilla et al. 2017).

More encouragingly, young children in treatment households consumed most of the CSB they received from HDF. We also found some improvement in dietary outcomes for children under 2, although increases in dietary diversity may have resulted from the provision of maize inputs (increased maize consumption) and hybrid chicks (increased egg consumption) as much as from the provision of CSB.

Additionally, treatment farmers used their sealed harvest bags to store 29% of their maize harvests[14], which may pay dividends during the lean season by providing farmers a food source and enabling them to sell maize at higher prices. Given that harvest bags are also inexpensive

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[14] We did not collect data on storage of maize in sealed harvest bags for control households, so we cannot report a treatment effect.

($1.67 per bag), they are likely worth including as part of the bundle, especially because they are a direct complement to the maize production inputs that yielded such large impacts.

Also disappointingly, more than two-thirds of the tree seedlings distributed to treatment farmers had died 9-11 months after they were distributed - substantially limiting the potential long-term impact of this component of the bundle[15]. Until longer term data on the benefits of distributing seedlings becomes available, this low survival rate is reason enough to exclude trees from future bundle distributions.

As a whole, the non-income generating products included in the HDF pilot may indeed marginally improve longer-term health and economic outcomes for treatment farmers, but some of these products appear to have been more successful than others.

Cost-Effectiveness

We first examine the program's social return on investment (SROI), calculated as the ratio of its one-year DIG impact to its implementation costs[16] at scale[17]. As shown in Table 7, we estimate that the income-generating components of the HDF intervention would achieve an SROI of 1.35 at scale, as the average cost per farmer of purchasing and distributing those products was $106.69 and the effect of treatment on DIG was $144.20. If one includes the cost of non-income-generating products ($17.86) (harvest bags, ITNs, CSB, tree seedlings), the total SROI is lower at 1.16. A hypothetical maize-only version of the HDF bundle would achieve an SROI of 1.87. There is potential for increased SROI in the future if treatment households reinvest some of their extra income into additional productive assets or see positive impacts from products that did not directly generate income in the first year after bundle distribution (e.g., trees, harvest bags).

We use the estimated costs of HDF at-scale in to calculate SROI, because we believe that at-scale SROI is the most relevant metric for donors or implementers who might pursue an scaled-up version of this program. SROI figures calculated using the actual costs of implementing the HDF pilot would be much lower: 0.49 for the full bundle, 0.53 for only the income-generating products, and 0.54 for a maize-product-only version[18]. The pilot costs were higher than expected costs at scale because fixed staffing costs are spread out over a relatively small number of households, and the pilot also required product and delivery tests to fine-tune the bundle and distribution model, which we

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[15] Trees do not begin generating income for farmers within the first year of their lives, so the monetary impacts of the surviving trees remain to be seen.

[16] Implementation costs include the costs of purchasing the bundle products, delivering those products to farmers and training them on proper use, and paying program staff.

[17] We estimate per-household implementation associated with delivering the bundle to all rural households within a single region of Tanzania (90,000 households).

[18] The full bundle would have an average cost per household of $294.54, a bundle including only income-generating products would have an average cost of $273.98, and a maize-product-only version would have an average cost of $225.23.

While we saw encouraging SROI for the HDF product as a whole, these positive results were driven almost exclusively by maize profits. This suggests that an intervention that focused on distributing high-quality maize inputs to poor farming households would achieve a greater "bang for buck" than the HDF pilot, which included a much wider array of products. One could also make the case for including solar lamps - which achieved an SROI greater than 1 - and certain non-income-generating products (such as CSB and sealed harvest bags) which are relatively inexpensive to purchase and distribute . Adding these additional components reduces SROI relative to a maize bundle (as calculated based on short-term DIG impacts), but potentially have non-DIG benefits as well.

The HDF program compares well against other programs intended to increase the welfare of poor households. Sulaiman et al. (2016) calculated benefit-cost ratios for dozens of unconditional cash transfer, livelihood development, and poverty graduation programs. They defined the benefit-cost ratio as a program's annual impact on household consumption divided by its costs (note that this is different from the SROI figures reported above). Notably, this approach only considers benefits for one year, and will underestimate the benefit-cost ratio for programs that provide benefits over multiple years. On average, they find a benefit-cost ratio of 0.3 for cash transfer programs, 0.2 for livelihood development programs, and 0.11 for graduation programs (Sulaiman et al. 2016). We calculate HDF's benefit-cost ratio by multiplying the intervention's average monthly impact on non-durable consumption ($5.80) by 12 to get an annual impact (or "benefit") of $69.60. We use the impact on non-durable consumption as opposed to total consumption because non-durable consumption is the metric used in most of the studies within the Sulaiman et al. meta-analysis. As with our SROI calculations, we use the estimated costs of HDF at scale, as opposed to the actual costs of implementing the HDF pilot. Using this approach, HDF's benefit-cost ratio is 0.65 when only including costs of income-generating products ($106.69) and 0.56 when including the costs of all bundled products ($124.55), much higher than the benefit-cost figures that Sulaiman et al. report.

HDF also compares relatively well against high-performing interventions to which it is especially similar. Deutschmann et al. (2019) concluded that One Acre Fund's core farmer program led to a $54.90 increase in maize profits. By comparison, HDF led to a $121.60 increase in maize profits. That program offered farmers group-liability loans for improved seeds, high quality fertilizer, regular training on modern agricultural techniques, crop and funeral insurance, and help to enable farmers to sell their products at higher prices (Deutschmann et al. 2019). Importantly, 1AF's core program provides farmers with loans, while HDF provides inputs for free. This makes the core program cheaper for 1AF to operate: the Kenya program evaluated by Deutschmann et al (2019) cost 1AF an average of $24 per client to operate, giving it an SROI of 2.29,[19] compared to 1.35 for the income-generating components of HDF (One Acre Fund 2020). However, even though the core program is cheaper for 1AF, it is more expensive for farmers, who need to pay back the costs of their maize inputs. Therefore, the core program's higher

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[19] While the Deutschmann study only considers increases in maize profits towards impact, total SROI may have been higher if impact from other products were considered.

SROI is at least partially due to the fact that HDF transfers some costs that would fall onto farmers in the core program onto program funders.[20] In addition, the HDF pilot included farmers that would not have had sufficient liquidity to participate in 1AF's core program, realizing social returns for individuals that the core program could not have benefitted.

Carter et al. (2019)'s study of a government-implemented agricultural input subsidy program in Mozambique found that it led to a monthly impact on consumption of $2.88 per capita, while HDF led to an increase of $1.26 per capita. While the Mozambique subsidy program led to higher consumption increases than HDF, HDF achieves similar SROI: The subsidy intervention in Mozambique achieved an SROI of 2.0 after the first year of the program based on increases in the value of maize yields among treated households, compared to 1.87 for a hypothetical maize-only version of the HDF bundle. In Mozambique, the SROI increases to 15.1 after two years and after including spillover effects to untreated farmers, but since we only have one year of data for HDF and did not measure spillover effects, we are unable to compare directly against that figure (Carter, Laajaj, and Yang 2019).

Banerjee et al. (2015) studies the benefit-cost ratio of a number of graduation programs. These tend to have low benefit-cost ratios in the first year of the program, but often go above 1 if impacts continue for multiple years. For instance, a study in Ghana[21] showed that a graduation program increased annual non-durable household consumption by $293 in the first year of the program. The total program costs per household were $5,408, making the implied benefit-cost ratio 0.05 for that year, compared to 0.56 for HDF when including the costs of all products in the bundle[22]. It is important to note that graduation programs are designed to achieve sustained benefits over time - Banerjee et al. estimate the Ghana program will have a total long-term impact of $7175 and a benefit-cost ratio of 1.33 (Banerjee et al. 2015). However, it is still unknown whether HDF impacts will persist in the long run.

Overall, the results of the HDF pilot demonstrate that distributing a bundle of productive maize inputs to farmers can lead to benefits (i.e., direct income generation and consumption gains) that substantially exceed the costs of the program, when operated at scale. This model is more cost-effective than other traditional graduation interventions that seek to improve the welfare of rural households and compares relatively favorably against some of the more successful programs that have been studied. Although the 1AF Core program has a higher estimated SROI and other interventions have been more clearly shown to lead to sustained impacts over time and/or positive spillover effects, HDF has the distinct advantage of being easier to implement than these alternatives, since all bundled products can be distributed at once to beneficiaries

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[20] Note that we are considering only donor costs as part of the SROI. If farmer costs were included, it would bring down the SROI of loan programs like 1AF's core program.

[21] The program included savings accounts, health and nutrition education, enrollment in the national health insurance scheme, cash transfers during the lean season, and an asset transfer (the beneficiary chose the asset(s) based on a list provided by the implementing organization).

[22] This HDF benefit-cost ratio only factors in the impact of HDF on non-durable consumption, since this is the measure used within the Banerjee et al. study.

with little to no follow-up[23], and also the potential to reach a population of farmers who are unable to meet the criteria to participate in a loan-based program. HDF-like interventions could therefore be attractive for donors or implementers seeking to reach a large cross-section of rural farming households using a relatively light-touch and low-cost approach, while still obtaining a relatively high “bang for buck.”

External Validity

We believe that the results of the HDF pilot in Singida are fairly representative of the potential of HDF in Tanzania as a whole. Singida was selected as the pilot region because it had the highest annual maize yields in the country of the 10 regions where One Acre Fund does not operate its Core program. Therefore, while the 10 regions where the Core program operates would likely be better suited for HDF (because they produce more maize), nine other regions of the country would likely be worse suited. That being said, the 2020 maize harvest season may not necessarily be representative of all seasons, as it saw abnormally high rainfall. In a dry region like Singida, this caused higher maize yields than normal[24] and potentially increased the return to the maize inputs that drove much of HDF’s impact.

6. Conclusion

Using a randomized controlled trial, we find that the HDF pilot program met its pre-specified goals of delivering income greater than the cost of the bundle, as well as increasing household consumption. Overall, we find that the HDF pilot program in Tanzania delivered substantial benefits to farmers, offering an impressive social return on investment. The benefit-cost and SROI figures from the program compare favorably to those of other agricultural interventions, graduation programs, and cash transfer interventions. Therefore, the HDF model could provide an attractive opportunity for funders or implementers seeking to benefit a large number of poor, agrarian households at a relatively low cost per household and with minimal complexity.

However, the positive impacts from the HDF intervention are by-and-large a result of the maize inputs included in the bundle, rather than the hybrid chickens or solar lamps. These results

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[23] In practice, the HDF pilot was more logistically challenging than expected. The 1AF team conducted numerous trial distributions outside of the study area to fine-tune the composition of the bundle and delivery logistics. In addition, distributing hybrid chickens required a separate visit to farmers, since it was not feasible to distribute them at the same time as the other products. However, we expect that scaling up HDF would need many fewer trial distribution than running the first pilot and that future iterations of HDF will not include hybrid chickens.

[24] In some cases, heavy rain can actually reduce maize yields due, for example, to flooding. However, observations from 1AF’s field team in Singida suggest that the heavy rain during the 2020 maize harvest increased yields.

suggest that a version of the HDF intervention that focused on maize inputs (and potentially a small number of other products) would be more cost-effective than the pilot bundle.

This study leaves several areas open for further exploration. Although the results on maize production were impressive, it's unclear whether they are reliant on the fact that there was excellent rainfall during the study period. We also do not know whether treatment farmers will continue to experience higher maize profits than control farmers in subsequent years (e.g., because they reinvest in improved maize seeds or fertilizers). In addition, although we estimated the impacts of hybrid chickens and solar lamps in future years via proxy measurements, the *actual* future impacts of these products may differ from these estimates. Finally, the long-term health and income impacts of ITNs, CSB, harvest bags, and tree seedlings remain unknown. A follow-up study after the next maize harvest could help shed light on these questions. Such insights would allow for more direct comparisons between HDF and poverty graduation interventions, which aim to increase the long-term welfare of beneficiary households.

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Figure 1. DIG from maize, energy and chicken profits

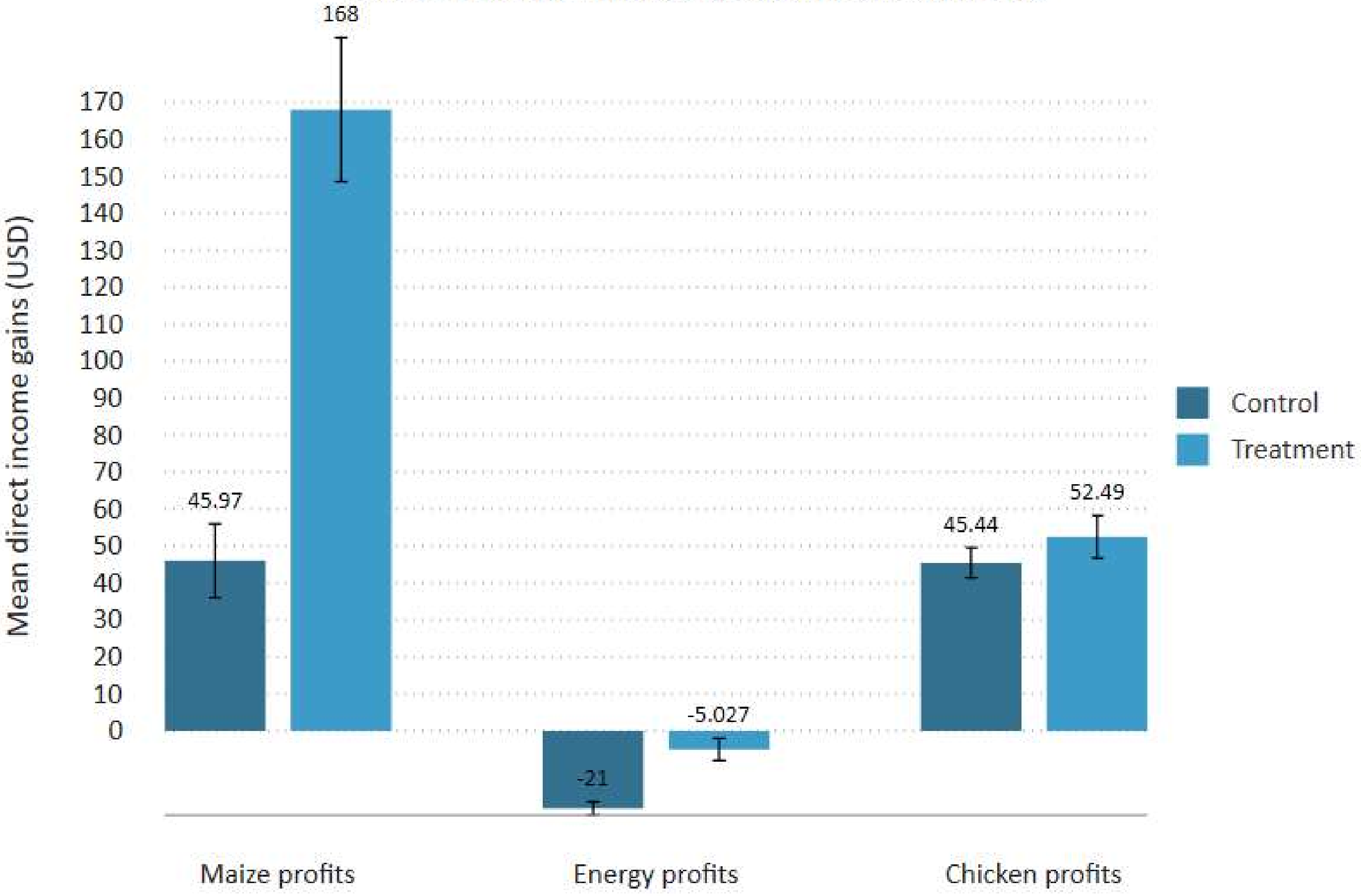

Figure 2. One-month consumption over time

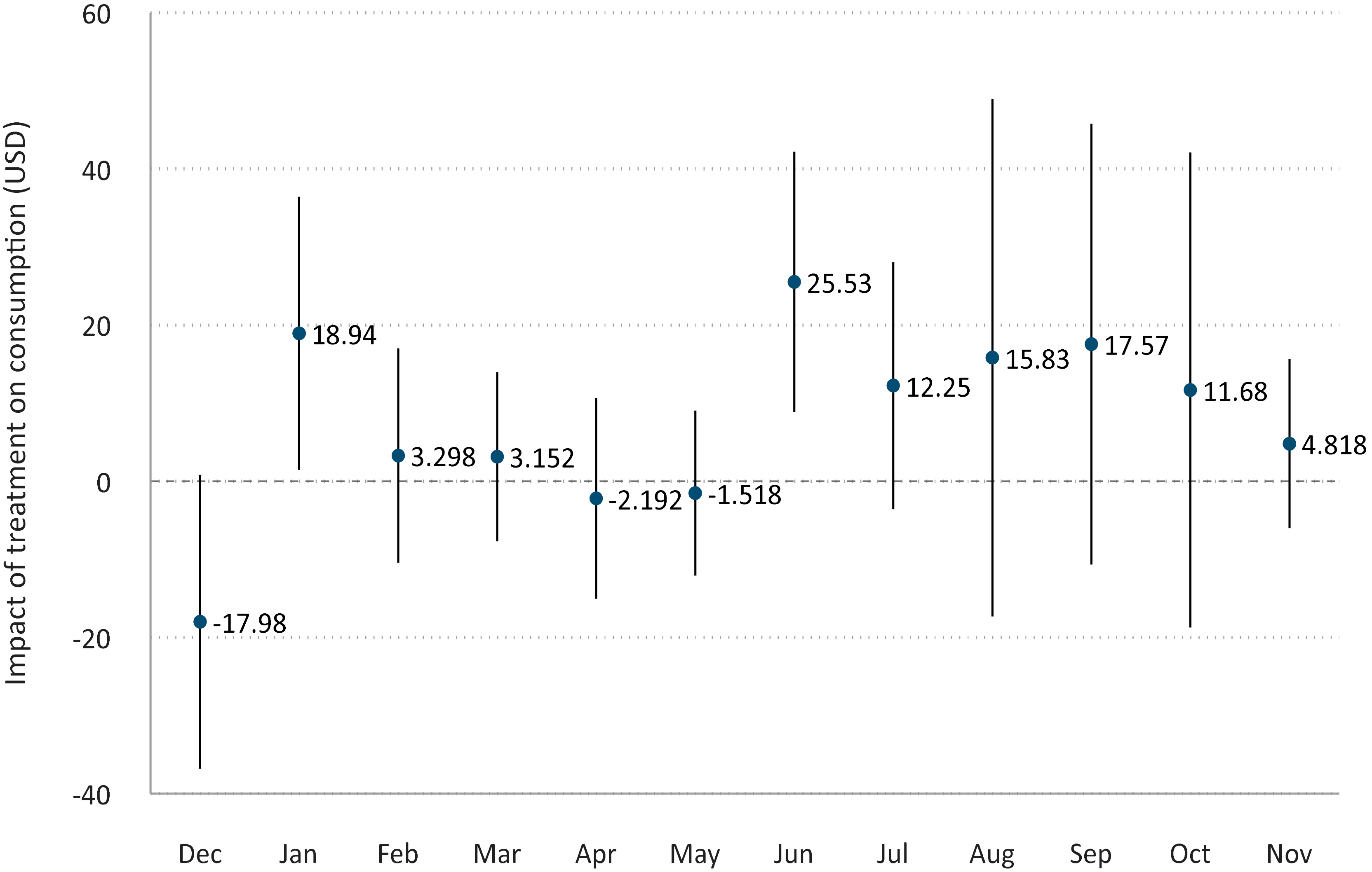

Table 1. HDF pilot implementation costs

Product	Eligibility criteria	Cost per eligible household	% treatment households eligible
10kg hybrid maize seed	Planted 1+ acre of maize in previous season.	$24.15	90%
60kg of Urea fertilizer	Planted at 1+ acre of maize in previous season.	$23.39	90%
30kg of DAP fertilizer	Planted at 1+ acre of maize in previous season.	$13.65	90%
Handheld solar light	Did not own working solar lamp prior to HDF distribution	$24.34	55%
10 Sasso hybrid chicks	All households	$25.91	100%
3 improved harvest bags	All households.	$5.01	100%
6kg of corn soy blend powder	6kg per child aged under 2 years.	$4.32	41%
3 insecticide treated nets	All households	$8.10	100%
30 tree seedlings	All households	$5.70	100%
Product delivery (exc. chicks)	N/A	$33.85	N/A
Chick delivery	N/A	$9.50	N/A
Fixed staffing costs	N/A	$136.25	N/A
Total	N/A	$310.56	N/A

Notes: Cost figures in this table reflect costs incurred by One Acre Fund during the implementation of the HDF pilot in Singida. These not only include costs assocaited with the procurement and distribution of HDF products, but also product tests, distribution dry-runs, and other activities needed to determine the exact products that would be included in the bundle and the distribution process that would be used for the pilot. Staffing costs are especially high, because One Acre Fund allocated two expensive senior-level staff to plan and execute a pilot program targeting a relatively small number of households. Hybrid chicks were delivered separately from the rest of the HDF bundle, which is why the delivery costs for chicks is separate from the rest of the products.

Table 2. Balance between the control and treatment samples' characteristics at baseline

.	Control mean (SD)	Treatment mean (SD)	Control mean - treatment mean	P-value
Household members	5.861	5.969	-0.040	0.436
	[2.610]	[2.787]		
Household members under 5 y/o	0.886	0.920	-0.039	0.459
	[0.865]	[0.943]		
Household members under 2 y/o	0.313	0.325	-0.024	0.640
	[0.499]	[0.524]		
One-moth total consumption (USD)	161.355	161.604	-0.002	0.964
	[106.332]	[108.931]		
One-moth consumption of non-durables (USD)	127.087	125.613	0.019	0.716
	[78.049]	[78.208]		
One-month food consumption (USD)	72.680	71.987	0.015	0.767
	[45.771]	[43.163]		
One-month consumption of durables (USD)	34.268	35.991	-0.030	0.567
	[57.337]	[58.931]		
One-month consumption per member (USD)	30.942	31.514	-0.024	0.649
	[22.694]	[27.162]		
N	1124	553		

Notes: Treat and control means for baseline variables. For each outcome variabe, we report the treatment and control means and their standard deviations in parantheses. Column two reports the mean of the control group, column three the mean of the treatment group, column four the magnitude of the difference between the control and treatment means, and column five the p-value of the comparison between the treatment and control group means. The unit of observation is the household for all outcome variables. The sample is restricted to households that did not expect to move residences before the endline surveys, that responded to all follow-up survey rounds, and are in the bottom 95 percentile of baseline consumption. * denotes significance at the 10 pct., ** at the 5 pct., and *** at the 1 pct. level.

Table 3. Definition of secondary outcomes

Outcome	Definition
Average monthly total household consumption in months 1-12	Average of total one-month consumption in months 1-12
Total one-month consumption	Value of the food produced by the households + expenditure on food consumed outside of the home + expenditure on temptation goods + expenditure on other household items + expenditure on durable goods + other more infrequent expenses
Asset values after 9 months (USD)	Sum of the value of the assets owned by households at endline
Minimum acceptable diet among children 6-23 months old	Children need to have enough dietary diversity and regularity. Non-breastfed children need to be fed milk 2x per day.
Utilization variables	
Percentage of household members sleeping under nets during round 2	Number of household members sleeping under nets / Number of household members
Percentage of children under 5 sleeping under nets during round 2	Number of children under 5 sleeping under nets in each household / Number of children under 5 in each household
Percentage of children 5-18 years old sleeping under nets during round 2	Number of children 5-18 sleeping under nets in each household / Number of children 5-18 in each household
Percentage of adults sleeping under nets during round 2	Number of adults sleeping under nets in each household / Number of adults in each household
Quantity of CSB consumed per child under 2 in each household (KG)	Quantity of CSB consumed by children under 2 in each household / Number of children under 2 in each household
Quantity of CSB consumed per child 2 to 5 years old in each household (KG)	Quantity of CSB consumed by children 2-5 in each household / Number of children 2-5 in each household
Stored maize	Percentage of farmers who stored maize during the previous harvest season
Used fertilizer	Percentage of farmers who used fertilizer during the previous harvest season
Percentage of harvest stored in PICS bags	Percentage of maize harvest stored in PICS bags by treatment farmers
Number of hybrid adult chickens owned	Number of hybrid adult chickens owned by farmers at endline
Number of local adult chickens owned	Number of local adult chickens owned by farmers at endline
Number of eggs produced	Number of eggs produced throughout the study period
Household usage of solar lamps	Percentage of households that used the lamps distributed by 1AF for charging phones and lighting
Number of tree seedlings planted and alive at endline	Number of fruit, timber and agroforestry tree seedlings planted and alive at endline

Table 4. Treatment effects for DIG and its components

.	Control mean	Control SD	Treatment effect	Standard error	N
Net direct income gains (USD)	71.9	212.4	144.2***	(17.7)	1,677
Maize profits (USD)	45.8	177.6	121.6***	(15.7)	1,677
Maize income (USD)	162.1	244.3	131.5***	(21.1)	1,677
Maize expenses (USD)	113.8	127.3	9.3	(10.2)	1,677
Energy profits (USD)	-21.7	32.0	16.4***	(2.1)	1,677
1-year energy profits (USD)	-21.7	32.0	5.8***	(1.8)	1,677
1-year energy expenses (USD)	22.7	32.0	-5.0***	(1.8)	1,677
1-year energy income (USD)	0.7	3.0	0.6***	(0.2)	1,677
Future projected HDF lamp value (USD)	0.0	0.0	10.6***	(0.5)	1,677
Chicken profits (USD)	46.8	73.6	7.8*	(4.0)	1,677
1-year chicken profits (USD)	20.8	60.2	-7.6**	(3.3)	1,677
1-year chicken income (USD)	43.8	55.9	28.8***	(3.1)	1,677
1-year chicken expenses (USD)	21.5	27.5	36.9***	(2.4)	1,677
1-year chicken feed expenses (USD)	19.4	24.4	32.4***	(2.2)	1,677
Future projected value of chicken flock (USD)	25.7	27.8	15.2***	(1.7)	1,677

Notes: OLS estimates of treatment effects. For each outcome variabe, we report the coefficients of interest and their standard errors in parantheses. Column two reports the mean of the control group, column three the standard deviation of the control group's mean, column four the treatment effect i.e. comparing the treatment households to control households within villages, column five the treatment effect's standard error, and column six the number of observations. The unit of observation is the household for all outcome variables. The sample is restricted to households that did not expect to move residences before the endline surveys, that responded to all follow-up survey rounds, and are in the bottom 95 percentile of baseline consumption. We projected the future value of HDF lamps based on an expected lifespan of 5 years per lamp, an annual discount rate equivalent to the real savings interest rate in Tanzania, and an assumption that lamps are as likely to stop working in subsequent years as they were in the first year of ownership. We projected the future value of chicken flocks based on their estimated market value at the end of the evaluation period given chicken sale prices collected during the evaluation. Column four includes controls for baseline outcomes and cluster standard error at the village level. * denotes significance at the 10 pct., ** at the 5 pct., and *** at the 1 pct. level.

Table 5. Treatment effects for consumption outcomes

.	Control mean	Control SD	Treatment effect	Standard error	N
One-month non-durable consumption after 9 months (USD)	89.0	59.8	10.2***	(3.3)	1677
Lowest quarter of baseline consumption	63.3	40.4	17.7***	(5.2)	420
Second quarter of baseline consumption	79.3	43.7	5.9	(4.7)	419
Third quarter of baseline consumption	101.0	65.7	1.3	(6.4)	419
Highest quarter of baseline consumption	112.0	70.2	16.5*	(8.8)	419
Asset values after 9 months (USD)	2123	3043	-33.8	(159.4)	1677
Values of HDF bundle assets after 9 months (USD)	31.0	31.5	17.9***	(2.0)	1677
Average monthly total household consumption (USD)	123.0	106.4	7.5**	(3.7)	6708
Average monthly non-durable household consumption in months 1-12 (USD)	94.7	58.8	5.8**	(2.2)	6708
Average monthly durable household consumption in months 1-12 (USD)	27.5	74.0	1.7	(2.1)	6708

Notes: OLS estimates of treatment effects. For each outcome variabe, we report the coefficients of interest and their standard errors in parantheses. Column two reports the mean of the control group, column three the standard deviation of the control group's mean, column four the treatment effect i.e. comparing the treatment households to control households within villages, column five the treatment effect's standard error, and column six the number of observations. The unit of observation is the household for all outcome variables. The sample is restricted to households that did not expect to move residences before the endline surveys, that responded to all follow-up survey rounds, and are in the bottom 95 percentile of baseline consumption. Column four includes controls for baseline outcomes and cluster standard error at the village level. * denotes significance at the 10 pct., ** at the 5 pct., and *** at the 1 pct. level.

Table 6. Treatment effect for intermediate outcomes

	.	Control mean	Control SD	Treatment effect	Standard error	N
Health outcomes	Percentage of household members sleeping under nets during round 2	0.700	0.300	0.096***	(0.0)	847
	Percentage of children under 5 sleeping under nets during round 2	0.800	0.400	0.023	(0.0)	541
	Percentage of children 5-18 years old sleeping under nets during round 2	0.600	0.400	0.119***	(0.0)	635
	Percentage of children 5-18 years old sleeping under nets during round 2	0.700	0.300	0.075***	(0.0)	846
	Quantity of CSB consumed per child under 2 in each household (KG)	0.1	0.9	4.1***	(0.3)	411
	Quantity of CSB consumed per child 2 to 5 years old in each household (KG)	0.0	0.0	0.6***	(0.1)	806
	Proportion of children 6 - 23 months in a household consuming the minimum dietary diversity	0.1	0.3	0.1*	(0.0)	395
	Proportion of children 6 - 23 months consuming iron-rich foods	0.3	0.4	0.0	(0.0)	395
Maize outcomes	Stored maize	0.700	0.400	0.153***	(0.0)	1.677
	Used fertilizer	0.200	0.400	-0.042	(0.0)	1.677
Chicken outcomes	Number of hybrid adult chickens owned	0.1	0.5	2.6***	(0.1)	1.677
	Number of local adult chickens owned	3.6	4.1	0.1	(0.2)	1.677
	Number of eggs produced	130.0	174.1	202.4***	(15.8)	1.677

Notes: OLS estimates of treatment effects. For each outcome variabe, we report the coefficients of interest and their standard errors in parantheses. Column three reports the mean of the control group, column four the standard deviation of the control group's mean, column five the treatment effect i.e. comparing the treatment households to control households within villages, column six the treatment effect's standard error, and column seven the number of observations. Approximately half of our sample was asked questions about their utilization of nets, leading a complete case sample of 847 households for the nets regressions. Regressions involving a sub-set of our sample (adults, children 5-18 years old, children under 5, children under 2) have a lower number of observations than our complete sample. The CSB consumption regressions exclude households in Ikungi district, none of which received CSB as part of the bundle. The unit of observation is the household for all outcome variables. The sample is restricted to households that did not expect to move residences before the endline surveys, that responded to all follow-up survey rounds, and are in the bottom 95 percentile of baseline consumption. Column five includes controls for baseline outcomes and cluster standard error at the village level. * denotes significance at the 10 pct., ** at the 5 pct., and *** at the 1 pct. level.

Table 7. Social return on investment for income-generating products at scale

.	Average cost/farmer	DIG impact/farmer	SROI
Maize inputs	$55.13	$121.60	2.21
Hybrid chickens	$25.00	$7.80	0.31
Solar lamps	$13.34	$16.40	1.23
Non-income-generating products	$17.86	$0.00	0
Product delivery (excluding chicks)	$8.35	N/A	N/A
Chick delivery (conducted separately)	$3.33	N/A	N/A
Fixed staffing costs	$1.54	N/A	N/A
Maize-product-only bundle	$65.02	$121.60	1.87
Income-generating products	$106.69	$144.20	1.35
Full bundle	$124.55	$144.20	1.16

Notes: Cost figures in this table reflect estimated costs of the HDF program at-scale, as opposed to the actual implementation costs of the pilot that are displayed in Table I. We define an at-scale version of HDF as covering approximately one entire region of Tanzania (300 villages, with 300 households per village) and extrapolate the pilot costs to this large sample of households to estimate costs at scale. We expect that staffing costs per household in particular would be much lower for an at-scale version than the HDF pilot because they would be spread over a much greater number of households and less staff time would need to be allocated to product and distribution process testing activities, which were already conducted during the pilot. Hybrid chicks were delivered separately from the rest of the HDF bundle, which is why the delivery costs for chicks is separate from the rest of the products. In addition to the lower staffing and delivery costs at scale, we expect the per-unit cost of hybrid chickens and tree seedlings to be slightly lower at scale, since HDF could purchase these at bulk via the 1AF Core program instead of procuring them through local suppliers, as was done for the pilot. During the pilot, each bundle of 10 hybrid chicks costed $25.91 and each bundle of tree seedlings costed $5.70; at scale we expect these components to cost $25.00 and $3.00 respectively.

Appendix Table 1. Attrition in sample size

·	Size of treatment group	% of treatment at baseline	Size of control group	% of control at baseline	Total	% of total at baseline
Pre-analysis plan	640	100.5%	1280	100.1%	1920	100.2%
Baseline	637	100.0%	1279	100.0%	1916	100.0%
Round 1	604	94.8%	1237	96.7%	1841	96.1%
Round 2	627	98.4%	1254	98.0%	1881	98.2%
Round 3	623	97.8%	1236	96.6%	1859	97.0%
Round 4	620	97.3%	1229	96.1%	1849	96.5%
All rounds	581	91.2%	1183	92.5%	1764	92.1%

Notes: Sample size by research stage. For each research stage, we report the size of the sample and how it relates to the baseline sample size. Column two reports the size of the treatment sample, column three the treatment sample as a percentage of baseline sample size, column four the size of the control sample, column five the control sample as a percentage of baseline sample size, column six the size of the total sample, and column seven the total sample as a percentage of baseline sample size. Sample sizes reflect the number of households that fully-completed all survey modules for all rounds, before the top 5% of households in terms of baseline consumption were removed.

Appendix Table 2. Treatment effects for consumption per month

.	Control mean	Control SD	Treatment effect	Standard error	N
Total consumption during December (USD)	142.7	107.6	-19.3**	(8.6)	550
Total consumption during January (USD)	129.8	87.8	15.4**	(7.5)	576
Total consumption during February (USD)	132.2	85.8	1.6	(7.3)	551
Total consumption during March (USD)	115.5	71.4	0.6	(5.6)	551
Total consumption during April (USD)	114.5	75.2	-3.1	(6.2)	574
Total consumption during May (USD)	95.5	64.2	-2.1	(4.9)	552
Total consumption during June (USD)	88.6	74.9	27.8***	(9.8)	551
Total consumption during July (USD)	104.5	87.5	13.6	(8.3)	575
Total consumption during August (USD)	170.6	164.8	17.3	(14.8)	551
Total consumption during September (USD)	144.4	145.5	19.2	(15.4)	551
Total consumption during October (USD)	151.7	144.8	11.0	(15.2)	575
Total consumption during November (USD)	86.1	64.5	5.5	(5.5)	551

Notes: OLS estimates of treatment effects. For each outcome variabe, we report the coefficients of interest and their standard errors in parantheses. Column two reports the mean of the control group, column three the standard deviation of the control group's mean, column four the treatment effect i.e. comparing the treatment households to control households within villages, column five the treatment effect's standard error, and column six the number of observations. The unit of observation is the household for all outcome variables. The sample is restricted to households that did not expect to move residences before the endline surveys, that responded to all follow-up survey rounds, and are in the bottom 95 percentile of baseline consumption. Column four includes controls for baseline outcomes and cluster standard error at the village level. * denotes significance at the 10 pct., ** at the 5 pct., and *** at the 1 pct. level.

Appendix Table 3. Treatment effect for DIG, by baseline consumption quantiles

.	Control mean	Control SD	Treatment effect	Standard error	N
Lowest quarter of baseline consumption	69.2	198.1	142.6***	(20.6)	420
Second quarter of baseline consumption	38.8	117.4	148.4***	(24.0)	419
Third quarter of baseline consumption	74.8	224.4	148.9***	(28.7)	419
Highest quarter of baseline consumption	105.2	274.6	136.0***	(39.2)	419

Notes: OLS estimates of treatment effects for DIG. The sample is split into quantiles, based on consumption at baseline. For each outcome variabe, we report the coefficients of interest and their standard errors in parantheses. Column two reports the mean of the control group, column three the standard deviation of the control group's mean, column four the treatment effect i.e. comparing the treatment households to control households within villages, column five the treatment effect's standard error, and column six the number of observations. The unit of observation is the household. The sample is restricted to households that did not expect to move residences before the endline surveys, that responded to all follow-up survey rounds, and are in the bottom 95 percentile of baseline consumption. Column four includes controls for baseline outcomes and cluster standard error at the village level. * denotes significance at the 10 pct., ** at the 5 pct., and *** at the 1 pct. level.

Appendix Table 4. Comparison between treatment effects for trimmed and untrimmed samples

	Trimmed sample			Full sample		
	Treatment effect	se	p-value	Treatment effect	se	p-value
One-month non-durable consumption after 9 months (USD)	10.2	3.3	0.00	10.9	3.6	0.00
Net direct income gains (USD)	144.2	17.7	0.00	145.5	18.7	0.00
Maize profits (USD)	121.6	15.7	0.00	123.1	16.5	0.00
Maize income (USD)	131.5	21.1	0.00	131.1	22.3	0.00
Maize expenses (USD)	9.3	10.2	0.37	8.1	10.8	0.45
Energy profits (USD)	16.4	2.1	0.00	15.4	2.0	0.00
1-year energy profits (USD)	0.6	0.2	0.01	0.6	0.2	0.01
1-year energy income (USD)	11.0	0.6	0.00	10.8	0.6	0.00
1-year energy expenses (USD)	-5.0	1.8	0.00	-4.2	1.7	0.02
Future projected HDF lamp value (USD)	10.6	0.5	0.00	10.3	0.5	0.00
Chicken profits (USD)	7.8	4.0	0.05	8.7	4.1	0.03
1-year chicken profits (USD)	-7.6	3.3	0.02	-7.0	3.3	0.03
1-year chicken income (USD)	28.8	3.1	0.00	28.6	3.2	0.00
1-year chicken expenses (USD)	36.9	2.4	0.00	36.3	2.5	0.00
Future projected value of chicken flock (USD)	15.2	1.7	0.00	15.5	1.7	0.00

Notes: OLS estimates of treatment effects for DIG. The "Trimmed sample" figures denote treatment effects, standard errors, and p-values for each outcome variable in the leftmost column after excluding the top 5% of households as ranked by total one-month consumption measured during the baseline survey. The "Full sample" figures denote treatment effects, standard errors, and p-values for each outcome variable without excluding the top-consuming households. Both samples are restricted to households that did not expect to move residences before the endline survey and that responded to all follow-up survey rounds. The unit of observation is the household.