Spousal Information Sharing, Food Safety, and Value Chains in Northern Ghana

by

Sean Posey

(Under the Direction of Nicholas Magnan)

Abstract

Ensuring food safety is crucial for enhancing healthcare in low and middle-income countries. This dissertation proposes a direct approach to improving food safety through the implementation of a voluntary food grading system and incentivized contracts. Additionally, we examine the sharing of information within households to identify the appropriate target audience for information campaigns, especially those related to food safety. Our findings suggest that men are more likely to share information with their spouses if income is shared, while women share information equally regardless of income sharing. In cases where income is shared evenly between the couple, training leads to an increase in knowledge on the extensive margins but not the intensive margins. These results highlight the importance of income control in determining how information is shared within households, particularly how men acquire and share information with their wives.

We observed that training and enrollment in a voluntary food grading program prompted producers to shift their behavior, resulting in a decrease in the average aflatoxin levels and a sustained increase in production and sales. However, in the short run, consumers' behavior changed but reduced significantly over time. Lastly, we discovered that establishing contracts that incentivize the adoption of aflatoxin-reducing practices in the Ghanaian groundnut value chain was challenging and unsustainable, as aggregators and processors were unwilling to cooperate.

Index words: [gender, norms, beliefs, information sharing, international development, food safety, experiment, household behavior]

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Dedication

I would like to express my heartfelt gratitude and dedicate this dissertation to my parents, whose unwavering support has been instrumental in my academic journey and the pursuit of my PhD. Their encouragement and belief in my abilities have been invaluable.

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I am sincerely grateful to all those who have played a significant role in shaping my academic journey and making this dissertation possible.

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This paper is still in progress. Please use the following link to obtain the most recent copy of the paper. Posey & Magnan, 2023

Abstract

It is often assumed that information obtained by one member of the household is transmitted to other members of the household. If this assumption is incorrect, information campaigns may be inefficiently conducted or increase the information gap between men and women. We use an abstract incentivized game to observe information sharing between spouses under two income control settings: individual earnings and shared earnings. We find that information sharing differs significantly for men when income is shared. We also find that women behave similarly across payment treatments and share information at a lower rate than men. Finally, there were no differences in household earnings among households where men were trained and households where women were trained. Targeting women during information campaigns or extension trainings reduces the information gap between men and women without adverse effects on the household.

0.1 Introduction

Adopting modern agricultural technologies and practices has led to higher yields, increased profits, and higher nutrition uptake in developing rural countries. Awareness of new technology or practice is the first stage of technology adoption (Lambrecht et al., 2014). Access to information is vital for individuals, especially rural smallholder farmers, to become aware of new technologies and practices. In many countries, information is first introduced to farmers through extension agents, local traders, or market agents. Despite attempts by governments, extension agents rarely meet the demand for services leaving many households without a significant source of information. Subsistence households infrequently interact with local traders and vendors, reducing access to information. Recent interventions attempting to reduce smallholder farmers' barriers to information focus on extension access (Kondylis et al., 2016), peer-to-peer (P2P) training (BenYishay & Mobarak, 2019; Fafchamps, 2019), and leveraging social networks to improve diffusion (Banerjee et al., 2014; Beaman et al., 2018). This paper adds to this literature by observing intra-household information sharing, a topic often excluded from information dissemination studies.

Although these interventions successfully increased the dissemination of information, they disproportionally benefitted men (Beaman & Dillon 2018, BenYishay et al. 2020). Few studies on information diffusion attempt to observe how information is shared among members within a household. These studies either assume information is shared among the members in the household once one member has been trained or given information or focus on the individual farmer within the household to which the information is most relevant, leaving the question of how information is shared within the household unanswered. The assumption that information is shared within a household has not been shown to be true in the past. Fletschner & Mesbah (2011) find that when it comes to credit opportunities, women within the household are far less aware of the opportunities available to their household than men are. **?** finds a gap in knowledge and awareness of agricultural technologies between men and women within the same household. By assuming that information is accessed and shared within a household, information diffusion studies may overestimate their impact and unintentionally increase the technology awareness gender gap.

The assumption that information would be shared in the household appears to be obvious on the surface. Sharing information on improved crop varieties can increase food security within the household, increase income, and increase household welfare. However, there could be many reasons why spouses may not share information with each other. Sharing requires time, an effort to train, and an effort to learn from the other. Furthermore, information may not be perceived as valuable or relevant. Women may have difficulty sharing information because housework and child-rearing responsibilities fall primarily on them. Even if women can find the time, men may discount their information (BenYishay et al. 2020; **?**) or not listen to them making it not worth the time or effort to train.

Norms over how income is shared or how plots are managed in a household can reduce the incentives to share information. In Northern Ghana, households can independently or jointly manage their agricultural production and income. The management structure of the plot impacts the allocation of resources and the benefits a member of the household receive. Plots managed by women are under-supplied inputs, primarily labor, and plots jointly managed and male-managed are over-supplied labor (**?**, Udry 1996). These studies focus on physical inputs such as seeds, fertilizer, and labor, but are unable, due to a lack of data, to directly observe whether plot management structure impacts information sharing in the household.

Using a lab-in-the-field experiment, our research aims to shed light on spousal information sharing in groundnut-producing households in Northern Ghana. We invited couples where both partners produce groundnuts to participate in two meetings. In the first meeting, we trained one spouse to solve a 4-disk version of the Tower of Hanoi game for a cash prize. Then, we gave a 24-hour period before asking the other spouse to play the same game for a cash prize without any training from our research team. Each household was assigned to a treatment group, which decided on the payment method and the individual to be trained.

We collected data on the performance in the game, along with two surveys, to observe information sharing between spouses and the impact of income control on information sharing. Our results show that men and women do not share information equally when income is controlled jointly. However, they perform and share information at similar rates when income is controlled individually. Women and men performed similarly when trained by the research team, but women outperformed men when trained by their spouses. Women reported being trained by their husbands significantly more under joint payment than under individual payment.

Moreover, our findings show that household earnings from the experiment do not differ by whether men or women are trained in the household. However, we find that households where men were trained and payment was distributed jointly earned the least.

The rest of the paper is organized as follows: Section 2 provides the context for the experiment's setting, Section 3 outlines the experimental design, Section 4 presents the theoretical model and hypotheses, Section 5 focuses on the data and empirical analysis, Section 6 discusses the results, Section 7 compares information sharing in practice to in-game performance, and Section 8 concludes the findings.

0.2 Context

Our research focuses on groundnut-farming couples in Northern Ghana, which is the country's main groundnut-producing region (Masters et al., 2015). Traditionally, groundnuts have been considered a "woman's crop" in Ghana, but the rising price of groundnuts has increased men's involvement in groundnut production.

In Northern Ghana, farm management is typically categorized as either "individual" or "joint". In households where the husband and wife manage their own plots separately, women have full ownership of their crops and can sell and plant them as they choose. Men's income from their yields is theirs alone, and the same is true for women. In contrast, in households where men and women jointly manage the plots, income is considered household income, and production decisions are made jointly. These insights were gathered from focus groups conducted in Northern Ghana in the spring of 2020.

Despite groundnuts being traditionally gendered, men have increasingly started cultivating and marketing them alongside other cash crops such as maize and cassava. As a result, new technologies such as improved seeds and calcium and potassium-rich fertilizers have become more widely available to improve pod fill and shell development. However, aflatoxin contamination remains a major issue for groundnuts in Ghana. Low awareness of aflatoxin has led to low adoption of aflatoxin-reducing agricultural practices. Magnan et al. (2021) has found that providing information to small-holder farmers increases the adoption of these practices, which include drying on a tarpaulin, proper storage, and sorting out damaged and moldy grains. These practices also apply to other crops at risk of aflatoxin contamination, such as maize.

In our study, information on groundnut production is relevant for both husbands and wives. Although our lab experiment does not involve groundnut training or information sharing, the households we are studying are engaged in agricultural production, and information sharing is important for them. We use groundnut production and technologies to examine information and knowledge gaps between spouses. We then examine information sharing in the game and information sharing in practice to fully capture whether the results from the experiment are observed in groundnut production.

0.3 Experimental Design

0.3.1 Treatment Design

Our study involved a sample of 410 households from 14 communities in Northern Ghana, with a total of 820 participants comprising a husband and wife from each household. For the purposes of this study, we defined a household as a single living unit to reduce the potential for information sharing between households living in the same house.

Each household was assigned to one of four treatment groups, which we divided into two categories: spouse and payment. The spouse treatment had two groups, Husband Trained and Wife Trained. In households assigned to the Husband (Wife) Trained group, the husband (wife) received formal training from our research team to complete a task for a cash prize, while the wife (husband) did not receive any training and relied on their spouse to inform them about the game.

The payment treatment also had two groups, individual and joint payment. In the individual payment treatment, participants received an envelope of cash corresponding to their individual performance in the task, which simulated a management scheme where individuals manage their own plots and control the income from those plots. In contrast, the joint payment treatment replicated the income ownership of a joint management scheme, where the household's earnings were combined and split evenly between spouses.

Treatment assignment for the spouse treatment was randomly assigned at the household level, while the payment treatment was stratified by the household production management reported in the household survey. The 2x2 treatment design and sample size in each group are shown in Figure 1.

Table 1: Treatment Design

	Individual Payment	Joint Payment
Husband Trained	106 Households	97 Households
Wife Trained	101 Households	106 Households

0.3.2 Game and Cash Prizes

The task each participant was asked to complete was the game Tower of Hanoi. The Tower of Hanoi is a puzzle game where participants are asked to move a set number of disks from the first to the third tower without moving more than one disk at a time and not placing a larger disk on a smaller disk. We chose the four-disk version of the game, which can be completed in no fewer than fifteen moves. Figure 1 shows the Tower of Hanoi and a step-by-step 15-move solution to the game.

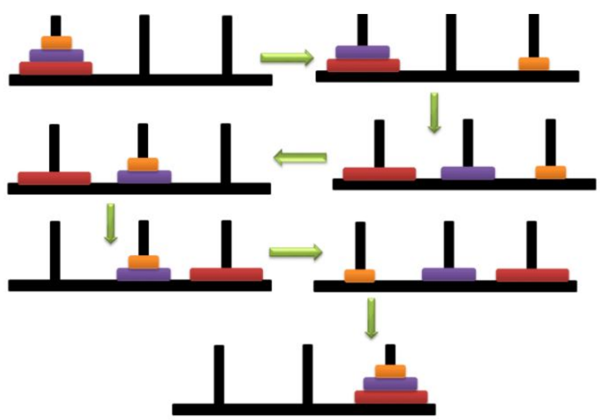


Figure 1: Tower of Hanoi
Source: https://www.javainterviewpoint.com/tower-hanoi-java-recursion

This game was chosen for two primary reasons, it follows the learning process of technology adoption and requires effort to train with performance improving as training effort increases. As participants learn about the game, they update how they move each piece and how to reduce the total amount of moves needed to achieve a more optimal outcome. This game lends itself well to

Table 2: Cash Prizes

Moves	15	≤20	≤25	≤30	≤35	≤40	≤45
Prizes	30GhC	28GhC	26GhC	24GhC	22GhC	20GhC	18GhC
Moves	≤50	≤55	≤60	≤65	≤70	>70	Forfeit
Prizes	16GhC	14GhC	12GhC	10GhC	8GhC	6GhC	5GhC

testing information sharing and learning. Participants who are trained should perform significantly better than individuals who are not trained. The Tower of Hanoi requires effort to train and is not as simple as sharing a statement or general information similar to agricultural practices. The more effort an individual puts into training, the more knowledge will be transferred, and the better the other will perform.

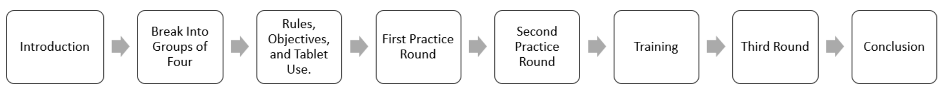
The prize amount an individual could win was directly related to the number of moves the player needed to complete the game. Figure 2 shows how the cash prizes were awarded. The cash prizes were broken into bins to reduce the complexity of how much money each participant won and to avoid any confusion by the participant while playing. Traditionally using a non-linear payment system can lead to players stopping after a certain point where they no longer believe they can make it to the next prize bracket despite their ability to do better, or a player may strategically play in such a way to counter the researcher's intended goals. Neither of these issues was a concern in this experiment. Any player who can strategically make a certain number of moves to maximize their pay with respect to the effort has a dominant strategy to complete the game in 15 moves. We don't expect any outcomes where participants strategically play the game that doesn't align with the dominant strategy of the game, which is to complete the game in 15 moves. A cost-per-move payment system was seen to be an overly confusing system without any additional benefits.

In the experiment, to set a limit and reduce fatigue, we capped the ability to lose any more cash at 75 moves; however, we do incentivize finishing the game by giving an additional $1 GhC. We expect the likelihood of forfeiting after 75 moves to be high; we also expect the likelihood of random guessing to increase significantly more after 75 moves in the hopes of stumbling across the finish. If an individual has forfeited the round, they will receive a score equal to the highest number of moves by an individual who solved the game. In the final round, we only experience two players exceeding 70 moves and zero forfeits.

0.3.3 Meetings

Households were asked to attend two meetings that were held on consecutive days. Only one participant from each household was allowed to attend each meeting. The participant selected to attend the meeting corresponded to the spouse treatment the household was assigned. Households under the Husband Trained treatment group would have the husband come to the first meeting, where they would be trained and asked to complete the task for a cash prize. Before the first meeting, households were informed which spouse should come to which meeting. Figure 3 outlines the events and their order in the first meeting. Meetings were conducted at the community and payment treatment levels. Within each community on each day, two meetings occurred simultaneously; one was for households in the joint payment, and the other was for households in the individual payment. Husband Trained and Wife Trained households attended the same meeting.

Figure 2: First Meeting



During the introduction, participants were told they will be completing a task for a cash prize and how the cash prize would be given, either jointly or individually. They were also told that on the following day, their spouse would come and be asked to complete the same task for the same cash prize. The meeting was then split into groups of four to be monitored by an enumerator. Each participant was given an Android-based tablet and logged into the game with their given ID number. Each enumerator went over the rules and how to use the touchscreen. Once all the participants showed an understanding of the rules and objectives of the game and were comfortable using the touchscreen, they were given two practice rounds before beginning the training.

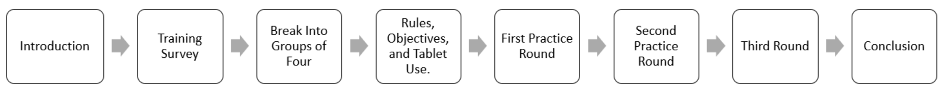
The training consisted of two components, slowly showing the participants the exact moves needed and the sequence needed to complete the game in 15 moves twice. An enumerator would show each participant the 15 moves sequence, slowly explaining in words which disk needs to be moved where and in what order. This is the memorization component, where if participants could simply memorize the sequence shown, they would perform optimally. However, if a participant could not memorize, then the training would be unhelpful if they make an error. The next component is breaking down the moves into achievable goals and teaching how to understand where to go from where you are. Instead of telling them they need to move disk 1 to tower 3. We explain that to win you first need to make a tower of 3 disks on tower 2; to do that, you must first create a stack of 2 on the 3rd tower. In order to do this, you must move the first disk to tower 3. This would break down the game into achievable goals and help them understand how to intuitively work backward from the objective to where they are to complete the game. This is the understanding component. These two components were used in training to help maximize the knowledge that the training gives to the participant. After the training, participants are given a final chance to complete the task in as few moves as possible for a cash prize.

Once the participants have finished the final round, they are informed of their score and the prize money they won. All prize money was given at the end of the second meeting. This was due to households under joint payment treatment not being able to receive their cash prizes until their spouse had played. We did not want the timing of the payments to drive the results, so all payments were given after all participants had completed the game. Before the participant leaves, they are reminded of their spouse attending the meeting the next day to perform the same game for the same cash prize, but won't be receiving training from the research team. We do not tell the participants to train their spouses or inform them we are studying information sharing between spouses. We withhold this information to reduce the experimental effect it will have on information sharing.

Participants who attended the first meeting were given a day to train their spouse at home outside of a designated experimental time, allowing for a more realistic setting for information to be shared. In order to increase information sharing on a game that is new and abstract, we teach the participants who attended the first meeting how to play the game in the sand using stones or bottle caps as discs. We do not tell them to go home and play this game with their wife, but we show them how to play it at home and inform them that kids are likely to enjoy this game. This allows each participant to go home and train their spouse using materials readily available to them.

The second-day meeting closely resembles the first-day meeting except for a survey and no training. Figure 3 outlines the sequence of events during the second meeting. Before the meeting starts, each participant in the second meeting is surveyed on whether their spouse trained them on the game, how they trained them, whether they received information from someone other than their spouse, and questions about the task they would know if they received training. After the survey, participants were given the same introduction as the participants on the first day. After they were given this introduction, they were given two practice rounds and then a third and final round for a cash prize, with no formal training from the research team. After they completed the third and final round, they were given cash in an envelope, and their spouse was given their cash prize either at the house or asked to come to the meeting once it was completed.

Figure 3: Second Meeting



0.4 Theoretical Framework and Empirical Models

The theoretical framework of this paper outlines an incentivized game involving two participants: Player 1 and Player 2. This mirrors our experimental design discussed in the preceding section. The game advances through two stages. In the initial stage, Player 1 identifies the extent of effort they wish to commit to learning from the research team. The level of effort deployed by Player 1 is directly measurable through their performance in the game.

In the subsequent stage, both players jointly determine the amount of effort allocated to the training process. This training effort represents a shared endeavor, and its effectiveness is visible in Player 2's performance. While our methodology does not permit us to differentiate whether the training effort contributed by Player 1 or Player 2 was more substantial, the final level of training effort can be inferred from Player 2's performance.

Figure 4 provides a visual depiction of these decision-making options.

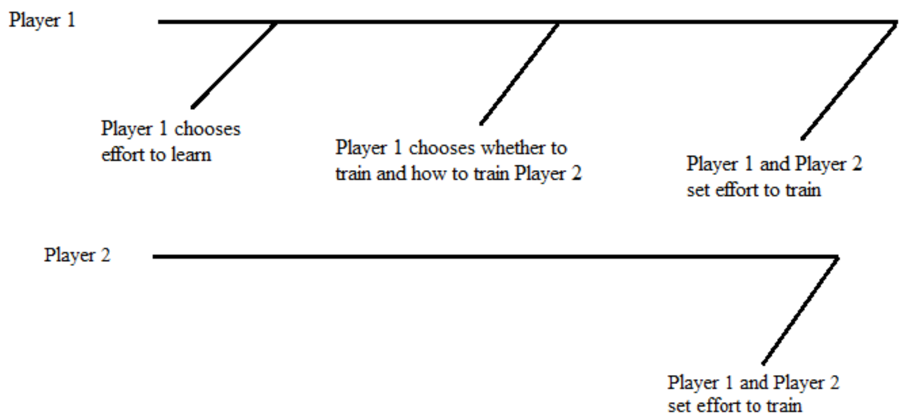


Figure 4

Player 1 chooses a level of effort to learn and train, while Player 2 only chooses a level of effort for training that maximizes their respective utilities. We model both Players' maximization decisions as follows:

$$\max_{\theta_1,\varepsilon} U_1 = (\alpha+\phi_1(1-\alpha))P_1(\theta_1)+(\phi_1\alpha+(1-\alpha))P_2(\theta_1,\varepsilon)-L_1(\theta_1)-T_1(\varepsilon) \tag{1}$$

$$\max_{\varepsilon} U_2 = (\alpha+\phi_2(1-\alpha))P_2(\theta_1,\varepsilon)+(\phi_2\alpha+(1-\alpha))P_1(\theta_1)-T_2(\varepsilon) \tag{2}$$

0.4.1 Larger Model

P_1 and P_2 represent the prize money earned by Players 1 and 2, respectively. P_1 is a function of Player 1's effort to learn from the research team, while P_2 is a function of Player 1's learning effort and the mutual training effort between the players.

The redistribution factor of the prize money between the two players, as determined by the research team, is denoted by α. When rewards are shared equally, α is set to $\frac{1}{2}$, whereas α assumes a value of 1 when rewards are allocated individually.

Further, the scalars ϕ_1 and ϕ_2 convert the income of Player 2 and Player 1 into respective utilities for Player 1 and Player 2. Our model assumes that both ϕ_1 and ϕ_2 fall within the $[0, 1)$ range, signifying that neither player values the other's income more than their own.

$L(\theta_1)$ represents Player 1's cost of learning from the research team, relative to their exerted effort level, θ_1. The cost of training for Player 1 and Player 2 are denoted by $T_1(\varepsilon)$ and $T_2(\varepsilon)$, respectively. As both players participate in the training together, deciding on a specific duration and intensity, the training parameter, ε, is identical for both. This common ε is the output of an intra-household bargaining function.

0.4.2 Modeling Effort to Train

In reality, Players 1 and 2 will bargain to determine the level of training effort to be deployed. The players mutually strive to achieve an optimal level of effort where the incremental benefits align with the incremental training costs. Hence, the players select a level of effort such that $\varepsilon^F = \Psi\varepsilon_1^* + (1 - \Psi)\varepsilon_2^*$, where ε^F is the agreed-upon ε upon the conclusion of bargaining. Ψ embodies Player 1's bargaining power.

As Player 1's bargaining power diminishes, ε tends toward ε_2, while an increase in Player 1's bargaining power drives ε towards ε_1.

$$\frac{\partial U_1}{\partial \varepsilon} : (\phi_1\alpha + (1 - \alpha))\frac{\partial P_2(\theta_1, \varepsilon)}{\partial \varepsilon} = \frac{\partial T_1(\varepsilon)}{\partial \varepsilon}$$

$$\frac{\partial U_2}{\partial \varepsilon} : (\alpha + \phi_2(1 - \alpha))\frac{\partial P_2(\theta_1, \varepsilon)}{\partial \varepsilon} = \frac{\partial T_2(\varepsilon)}{\partial \varepsilon}$$

In our experiment, Player 2 is kept uninformed about the game specifics, the payment arrangement, and the cash rewards. All this information is initially granted to Player 1, with Player 2 only gaining awareness about these aspects through Player 1's disclosure or during their attendance at the second meeting. The level of effort Player 2 puts into training, represented as ε, hinges on whether Player 1 shares the meeting details.

If Player 1 foresees that informing Player 2 could result in a negative utility through the final training effort, ε^F, they may opt to withhold information about the meeting, thereby bypassing the bargaining process, or they may choose to reduce the intensity of the training. For instance, if Player 1 anticipates that Player 2 will demand a high level of training effort, they might resort to a less costly form of instruction, such as verbal explanation, instead of a comprehensive game walkthrough.

For the sake of simplicity, we have omitted the modeling of the bargaining outcomes and instead analyzed the model's implications under two extreme scenarios. In Scenario 1, where $\Psi = 1$, and Scenario 2, where $\Psi = 0$. In addition, we postulate a more stringent assumption: Scenario 1 is expected to correspond to households in the Husband Trained group, and Scenario 2 represents households in the Wife Trained group. This implies that we assume men within the household wield greater bargaining power than women. From this point forward, we mention only Husband Trained and Wife Trained treatment groups to refer to Scenario 1 and Scenario 2, respectively.

0.4.3 Effort to Learn

The two-stage design of our experiment allows us to isolate the two choice variables, effort to learn and effort to train. The effort to learn is directly observed in Player 1's performance which is tied to Player 1's prize money $P_1(\theta)$. As Player 1's effort to learn increases, $P_1(\theta)$ increases, or simply $\frac{\partial P_1(\theta)}{\partial \theta} > 0$.

Player 1 chooses a level of effort that satisfies the first-order condition of Equation 1.

$$\frac{\partial U}{\partial \theta} : (\alpha + \phi_1(1-\alpha))\frac{\partial P_1(\theta)}{\partial \theta} + (\phi_1\alpha + (1-\alpha))\frac{\partial P_2(\theta,\varepsilon)}{\partial \theta} - \frac{\partial L_1(\theta)}{\partial \theta} = 0$$

Which can then be broken down into two payment treatments; Joint and Individual.

$\alpha = 1$

$$\frac{\partial U}{\partial \theta} : \frac{\partial P_1(\theta)}{\partial \theta} + \phi_1\frac{\partial P_2(\theta,\varepsilon)}{\partial \theta} - \frac{\partial L_1(\theta)}{\partial \theta} = 0$$

$\alpha = \frac{1}{2}$

$$\frac{1+\phi_1}{2}(\frac{\partial U}{\partial \theta} : \frac{\partial P_1(\theta)}{\partial \theta} + \frac{\partial P_2(\theta,\varepsilon)}{\partial \theta}) - \frac{\partial L_1(\theta)}{\partial \theta} = 0$$

We can compare how Player 1 will choose effort to learn across payment treatments by comparing the first order conditions under $\alpha = 1$ & $\alpha = \frac{1}{2}$. Player 1 will choose a higher effort to learn under individual payment treatment, $\alpha = 1$, than Joint Payment treatment, $\alpha = \frac{1}{2}$, if:

$$\frac{\partial P_1(\theta)}{\partial \theta} \geq \frac{\partial P_2(\theta, \varepsilon)}{\partial \theta} \tag{3}$$

Player 1 will choose a higher level of effort under Individual Payment treatment if a marginal increase in their performance is higher than the marginal increase in Player 2's performance from an increase in effort to learn. This outcome requires our first assumption of imperfect knowledge transfer.

Assumption 1: $\frac{\partial P_1(\theta)}{\partial \theta} \geq \frac{\partial P_2(\theta,\varepsilon)}{\partial \theta}$

From **Assumption 1**, we create our first testable hypothesis:

Learning Hypothesis 1: Effort to learn will be higher among players under Individual Payment treatment than Joint Payment treatment.

In our experiment, we examine two main scenarios Husband Trained, where men are trained on the optimal game-solving strategy and are tasked with training their wives, and Wife Trained, where women are trained on the optimal game-solving strategy and are tasked with training their husbands. As mentioned previously, in our theoretical framework, we examine both scenarios when men choose the level of effort to train.

In the Wife Trained treatment group, women's choice of learning directly impacts the level of effort men choose for training. To capture women's optimal level of learning, we must solve this new maximization problem:

$$\max_{\theta} \ U_f = (\alpha + \phi_f(1-\alpha))P_f(\theta_f) + (\phi_f \alpha + (1-\alpha))P_m(\theta_f, \varepsilon_m(\theta_f)) - L_f(\theta_f) - T_f(\varepsilon_m(\theta_f))$$

This new maximization problem does not impact the outcome of *Hypothesis 1*. However, it does impact the outcomes when comparing across training treatments. Men under Individual Payment treatment will choose an effort to learn that is higher than women when:

$$\frac{\partial P_m(\theta_m)}{\partial \theta_m} - \frac{\partial P_f(\theta_f)}{\partial \theta_f} + \phi_m \frac{\partial P_f(\theta_m, \varepsilon_m)}{\partial \theta_m} - \phi_f \frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \varepsilon_m(\theta_f)} \frac{\varepsilon_m(\theta_f)}{\theta_f}) \geq \frac{\partial L(\theta_f)}{\partial \theta_f} - \frac{T(\partial \varepsilon_m(\theta_f))}{\partial \varepsilon_m(\theta_f)} \frac{\partial \varepsilon_m(\theta_f)}{\partial \theta_f} - \frac{\partial L(\theta_m)}{\partial \theta_m} \tag{4}$$

To create a second hypothesis from the outcome of Equation 4, we must make additional assumptions about differences in learning across gender, knowledge transfer across gender, and differences in utility men and women receive from their spouse's income.

There remains a gender gap in both education levels and performance. Women have lower participation rates in education, lower access to education, and perform worse than men due to social norms, time commitments, and general male preferences in household investments (**??**). Due to these systemic issues, we expect that men will have higher benefits from the effort they put into learning.

Assumption 2: $\frac{\partial P_m(\theta)}{\partial \theta} \geq \frac{\partial P_f(\theta)}{\partial \theta}$

Our third assumption focuses on how well knowledge is transferred between spouses once information has been shared. Many factors can impact the transfer of knowledge between spouses, such as the quality of training provided or the willingness to be trained by the recipient. Although we cannot directly observe these two factors, they impact our observable performance outcomes and the likelihood of information sharing. As observed in previous studies, men discount information they receive from women (BenYishay et al. (2020)), even from their wives (**?**). From the outcomes of these studies, we assume that knowledge transfer will be lower when women train men than when men train women.

Assumption 3: $\frac{\partial P_f(\theta,\varepsilon)}{\partial \theta} \geq \frac{\partial P_m(\theta,\varepsilon)}{\partial \theta}$

We use the literature on women's time poverty to assess the differences in the cost of training. Women have a higher demand on their time and face higher rates of time poverty than men, especially married women (**?**;**?**; **?**). We assume that the cost of training is higher for women than men due to the high demand for their time.

Assumption 4: $\frac{\partial L_f(\theta,\varepsilon)}{\partial \theta} \geq \frac{\partial L_m(\theta,\varepsilon)}{\partial \theta}$ and $\frac{\partial T_f(\theta,\varepsilon)}{\partial \varepsilon} \geq \frac{\partial T_m(\theta,\varepsilon)}{\partial \varepsilon}$

Finally, we explore differences in how men and women benefit from their spouse's income. Multiple studies have shown that as women increase their share of income in the household, consumption of adult goods such as alcohol reduces. This is a familiar story in Africa, if you give men money, they will use it on alcohol, tobacco, or other vices, but if you give money to women, they will spend it on food and household goods (**?**; **?**) [1]. If income from men is spent on personal goods, women may not value their husband's income. However, men directly benefit from increased food purchases from their wives' income. However, since they consume personal goods, men may highly value their income relative to their spouses. Since women are more likely to consume household goods when given their income, this leads to a lower personal utility than their husbands. This makes assumptions on the ϕ parameter difficult as both stories are compelling reasons why one spouse may value the other spouse's income higher relative to their own. However, women receive direct payments to them from their husband's income. This term is referred to as "chop payments" and therefore, women may not care who receives income in the household as they will continue to receive chop payments regardless.

[1] Duflo & Udry (2004) find that on-farm income from individually farmed crops, either by men or women, increases household expenditure on adult and prestige goods. Still, certain crops are designated for household income.

Learning Hypothesis 2: Among households assigned to the Individual Payment treatment, men will perform better than women on the first day.

Next, we examine whether or not men or women will put forth more effort to learn with the joint payment treatment. The differences between genders hold across payment treatment, and following assumptions 1-4, we can construct our third hypothesis:

Learning Hypothesis 3: Among households assigned to the Joint Payment treatment, men will perform better than women on the first day.

Although we hypothesize that men will outperform women in both payment treatments due to lower costs, higher ability (through higher education), and higher knowledge transfer to their spouses, we hypothesize that the payment treatment effect will be smaller for women than for men. This is due to the additional costs women face under individual payment treatment from their husbands' demand for higher effort to train, lowering women's willingness to learn from the research team and the higher willingness to learn from the research team under joint payment treatment to increase their husbands demand for training seen in equation **??** in the Appendix. Following this outcome, we construct our final hypothesis for the effort to learn.

Learning Hypothesis 4: The difference in the effect of payment treatment on the effort to learn will be smaller among women than men.

Empirical Model Effort to Learn

From the theoretical framework for the effort to learn, we focus on how much effort each player across the treatment groups exerts to learn as the choice variable. However, we cannot directly observe the effort to learn. We measure the effort to learn through individual performance in the game. A player's performance in the game is highly correlated to the Player's effort to learn such that a higher effort to learn will lead to higher performance. Therefore, we test each hypothesis using the following econometric model:

$$\begin{aligned} Y_{ij} = \beta_1(Male_{ij} * Individual_j) + \beta_2(Male_{ij} * Joint_j) + \\ \beta_3(Female_{ij} * Individual_j) + \beta_4(Female_{ij} * Joint_j) + \\ X_{ij} + \Gamma_j + \varepsilon_{ij} \end{aligned} \tag{5}$$

Equation 5 includes only individuals that attended the first meeting. Y_{ij} are the outcome variables Score, Perfect game, and total moves made before an error. Score is their overall performance in the game where a higher score indicates a better performance, Perfect game is a dummy variable equaling one if player i of household j obtained a perfect score, and total moves before error is the number of moves player i of household j made before deviating from the optimal sequence of moves needed for a perfect game. $Male_{ij}$ is a dummy variable equaling 1 if individual i from household j is male. $Female_{ij}$ is a dummy variable equaling 1 if individual i from household j is female. $First_{ij}$ is a dummy variable equaling 1 if individual i from household j is attended the first day. $Joint_j$ is a dummy variable equaling 1 if household j was in the joint payment treatment. $Individual_j$ is a dummy variable equaling 1 if household j was in the individual payment treatment X_{ij} is a vector of individual controls. These controls are education and age. Γ_j is a vector of household controls; these controls include production scheme and household composition. Finally, ε_{ij} is a random error term with an expected value of 0. Standard errors for the coefficients will be clustered at the household level, which is the level of randomization.

Using the above empirical model, we directly test each hypothesis using the following linear combinations.

Hypotheses	Linear Combination of Estimators
Learning Hypothesis 1	$(\beta_1 - \beta 2) + (\beta_3 - \beta_4) = 0$
Learning Hypothesis 2	$\beta_1 - \beta_3$=0
Learning Hypothesis 3	$\beta_2 - \beta_4$=0
Learning Hypothesis 4	$(\beta_1 - \beta_2) - (\beta_3 - \beta_4) = 0$

0.4.4 Effort to Train

In our experiment, players are not given time to train during the meetings, but instead, we mirror information sharing in practice by allowing players to train outside of designated meeting times at their own homes. Although this prevents us from directly observing the training, the type of training, and the intensity of training, we capture a more realistic outcome of information sharing between spouses.

As mentioned previously, we examine two extreme scenarios in our theoretical framework where men choose the level of effort to train rather than modeling a complex bargaining process. This simplifies our theoretical framework while still approximating the true chosen level of effort to train under the assumption that men have significantly higher bargaining power than their wives in our study area.

Therefore, we do not model women's choice for the effort to train but instead model men's choice for the effort to train under the four treatment groups. We then examine the effort to learn by observing the difference in performance under Player 2, $P_2(\theta, \varepsilon)$, controlling for θ using Player 1's performance to isolate the effort of training's impact on Player 2's performance.

Using the maximization problem in equation 1, men assigned to the Husband Trained treatment group will choose a higher level of effort to train their spouse under Individual Payment treatment than Joint Payment treatment when:

$$\varepsilon^{\alpha=1} \geq \varepsilon^{\alpha=\frac{1}{2}}$$

$$\frac{\phi_m - 1}{2} \frac{\partial P_f(\theta_m, \varepsilon)}{\partial \varepsilon} \geq 0 \tag{6}$$

Under the original assumption that $\phi < 1$, the right-hand side of Equation 33 is less than 0. Therefore the inequality does not hold, and we can construct our first training hypothesis:

Training Hypothesis 1: In households assigned to the Husband Trained treatment group, women under the Joint Payment treatment will outperform women under the Individual Payment treatment.

Training Hypothesis 1 seems intuitive; men who are in the Husband Trained treatment group receive a direct benefit from training their wives and therefore have a stronger incentive to do so. We expect this incentive to reverse for households in the Wife Trained treatment group. Men in the wife First treatment group receive their full income from their prize money and will set a higher level of effort to be trained under Individual Payment treatment than under Joint Payment treatment, where their income is shared with their wives. The second training hypothesis is:

Training Hypothesis 2: In households assigned to the Wife Trained treatment group, men under the Individual Payment treatment will outperform men under the Joint Payment treatment.

Training Hypothesis 2 seems as intuitive as *Training Hypothesis 1* in that men will choose a higher level of effort for training when they benefit the most from it. However, it is possible we find low rates of training for men as the cost of training may be high for women leading to women not informing their husbands and choosing to opt out of training completely to avoid costs. Furthermore, if men in our sample discount information from their wives, women may choose not to train as they know their husbands will not listen or choose to ignore their suggestions. If this is the case, the difference between men's performance when assigned to the Wife Trained treatment group will not be significantly different across payment treatments.

The effort to train across Wife Trained treatment and Husband treatment is more straightforward, requiring fewer assumptions than the effort to learn across training treatments due to analyzing only the men's choice of effort to train. For Households assigned to the Individual Payment treatment, men under the Husband Trained treatment will put forth more effort for training than men under the Wife Trained treatment when:

$$\phi_m \frac{\partial P_f(\theta_m, \varepsilon)}{\partial \varepsilon} \geq \frac{\partial P_m(\theta_f, \varepsilon)}{\partial \varepsilon} \tag{7}$$

Equation 45 demonstrates that under Individual Payment treatment, men assigned to the Husband Trained treatment group will set a higher effort to train than men assigned to the Wife Trained treatment if the marginal benefits men receive from their wives' prize money are greater than the marginal increase in their own prize money from training. Following **Assumption 3**, this inequality does not hold, leading to our third training hypothesis:

Hypothesis 3: For households assigned to the Individual Payment treatment, men assigned to the Wife Trained treatment group will outperform women assigned to the Husband Trained treatment group.

For households assigned to the Joint Payment treatment group, men assigned to Husband Trained treatment group will put forth more effort for training than men assigned to the Wife Trained treatment group when:

$$\frac{\partial P_f(\theta_m, \varepsilon)}{\partial \varepsilon} \geq \frac{\partial P_m(\theta_f, \varepsilon)}{\partial \varepsilon} \tag{8}$$

The outcome of Equation 53 is exactly **Assumption 3** and leads to our fourth training hypothesis:

Training Hypothesis 4: For households assigned to the Joint Payment treatment, women assigned to the Husband Trained treatment group will outperform men assigned to the Wife Trained treatment group.

Finally, similar to the choice of effort to learn, we expect that the impact of payment treatment for men's choice of effort for training will differ across training treatments. For households assigned to the Husband Trained treatment group, the impact of payment treatment on men's choice of effort for training will be larger than the impact of payment treatment on men's choice of effort for training under households assigned to the Wife Trained treatment when:

$$\phi_m \frac{\partial P_f(\theta_m, \varepsilon)}{\partial \varepsilon} \geq \frac{\partial P_m(\theta_m, \varepsilon)}{\partial \varepsilon} \tag{9}$$

The inequality from Equation 9 does not conclude clearly from the assumptions we have made. If the transfer of knowledge, $\frac{\partial P_2(\theta,\varepsilon)}{\varepsilon}$ is similar between men and women, then we expect the inequality to fail and the impact of payment treatment will be higher among Wife Trained treated households than Husband Trained treated households. The inequality can hold if men heavily discount information from their spouse, but the utility from their spouse's income is similar to their own income. If we find high rates of discounting in our results and men receive low utility from their spouse's income, then it could result in no significant difference in the payment treatment effect across training treatments. However, from results from the information discounting and household expenditure literature, our fifth training hypothesis is:

Training Hypothesis 5: The difference in the effect of payment treatment on the effort of training will be larger among households assigned to the Husband Trained treatment group than households assigned to the Wife Trained treatment group.

Empirical Model Effort of Training

$$\begin{aligned} Y_{ij} = \delta_1(Male_{ij} * Individual_j) + \delta_2(Male_{ij} * Joint_j) + \\ \delta_3(Female_{ij} * Individual_j) + \delta_4(Female_{ij} * Joint_j) + Y_{ij1} + \\ X_{ij} + \Gamma_j + \varepsilon_{ij} \end{aligned} \tag{10}$$

Equation 10 includes only participants that attended the second meeting. Y_{ij} are the outcome variables Score, Perfect game, and total moves made before an error. $Male_{ij}$ is a dummy variable equaling 1 if individual i from household j is male. $Female_{ij}$ is a dummy variable equaling 1 if individual i from household j is female. $Joint_j$ is a dummy variable equaling 1 if household j was in the joint payment treatment. $Individual_j$ is a dummy variable equaling 1 if household j was in the individual payment treatment. Y_{ij1} is the outcome variable for individual i of household j's performance on the first day. The inclusion of Y_{ij1} controls for the effort to learn set by Player 1 in the first meeting to capture the effort of training Player 2 directly. X_{ij} is a vector of individual controls. These controls are education and age. Γ_j is a vector of household controls; these controls include production scheme and household composition. Finally, ε_{ij} is a random error term with an expected value of 0. As in Equation 5, standard errors for the coefficients will be clustered at the household level, which is the level of randomization.

Using the above empirical model, we directly test each hypothesis using the following linear combinations.

Hypotheses	Linear Combination of Estimators
Training Hypothesis 1	$\delta_3 - \delta_4 = 0$
Training Hypothesis 2	$\delta_1 - \delta_2 = 0$
Training Hypothesis 3	$\delta_1 - \delta_3 = 0$
Training Hypothesis 4	$\delta_2 - \delta_4 = 0$
Training Hypothesis 5	$(\delta_3 - \delta_4) - (\delta_1 - \delta_2) = 0$

0.4.5 Data

All data were collected on Android-based tablets. Each player was assigned a household ID and person ID. The android tablets recorded the total number of moves, each move made, the time it took to complete, the date they attempted the task, and whether they forfeited. We surveyed all participants individually and asked spouses to answer the survey separately away from each other to avoid issues of spouses answering for each other. Table 3 breaks down age, education, and household composition by treatment group and gender.

Men are, on average older and more educated than women. We see the same pattern between joint and individual payment treatment. We asked each participant to name the main source they get information about groundnut varieties, inputs, prices, and selling opportunities. 33.41% Women reported their spouse being the main source for information for groundnuts, while only 4.88% of men surveyed reported their spouse was the main source for information for these things. This descriptive statistic shows the importance of studying information sharing within the household. If their spouse is the main source of information for women, it is imperative to understand how information is shared between spouses and how we can increase information sharing.

Table 3: Descriptive Statistics by Treatment Group

		Husband Trained				Wife Trained			
		Joint		Individual		Joint		Individual	
		Male	Female	Male	Female	Male	Female	Male	Female
Age									
	18-25	3.1%	20.6%	7.6%	17.9%	6.6%	14.2%	7.9%	21.8%
	26-35	34.0%	35.1%	28.3%	36.7%	17.9%	35.9%	28.7%	42.6%
	36-46	30.9%	33.0%	28.3%	28.3%	43.4%	42.5%	35.6%	17.8%
	46-55	23.7%	9.3%	22.6%	8.5%	25.5%	7.6%	17.8%	13.9%
	56-65	8.3%	2.1%	13.2%	6.6%	6.6%	0%	9.9%	4.0%
Education									
	None	88.7%	95.9%	86.8%	94.3%	84.9%	92.5%	81.2%	88.1%
	Primary	2.1%	2.1%	4.7%	4.7%	2.8%	3.8%	9.9%	7.9%
	Secondary	9.3%	2.1%	8.5%	0.9%	12.3%	3.8%	8.91%	4.0%
Household Composition	*Children*	3.9		3.5		4.6		4.2	
	Male 18+	1.8		1.4		1.6		1.3	
	Female 18+	1.9		1.2		1.6		1.3	
Information Source									
	Extension Agent	20.6%	10.0%	8.2%	8.1%	16.4%	10.1%	17.2%	5.6%
	Friend	5.5%	3.8%	3.1%	.9%	4.7%	3.7%	5.6%	4.3%
	Spouse	1.4%	25.1%	0%	27.0%	0%	19.5%	0%	24.1%
	Family	9.6%	9.6%	15.4%	15.1%	16.0%	13.8%	13.5%	11.9%
	Aggregators	.3%	0%	0%	0.3%	0.0%	2.2%	2.0%	.3%
	Local Trader	3.4%	3.4%	4.1%	2.5%	1.9%	2.2%	2.6%	2.3%
	Farmers	12.0%	10.3%	14.47%	9.7%	14.2%	14.8%	13.5%	11.2%
	Radio	35.1%	27.8%	40.6%	28.3%	34.3%	25.8%	33.3%	28.7%
Observation		97	97	106	106	106	106	101	101

0.5 Results

0.5.1 Training

On the second day of the experiment, each player was asked to complete a survey about the information they received from their spouse regarding the game. We used the survey responses to measure the effort put into training in three ways: whether participants reported being trained, the time spent training, and the use of items or drawings during training. The first outcome measured the impact of the treatment on the extensive margin of training effort, while the latter two measured the impact on the intensive margin.

Figure 5b, 5c, 5d present the reported training times, training rates, and hands on training rates. The training was defined as any information provided by the spouses about how to play the game, ranging from a simple explanation of the game's goals to in-depth training. hands on training involved any training that included using items or drawings to recreate the game. Most players reported receiving some form of training from their spouse, with women reporting a 20% higher training rate than men. Men increased their effort to train their wives when they directly benefited from their performance. Women under the joint payment treatment reported the highest training rate (74.5%), a significant increase compared to women under individual payment treatment, where only 60% of women reported being trained by their spouse.

The pattern is similar for hands on training, with 41.2% of women in the joint payment treatment reporting receiving training using items or drawings. In contrast, only 16% of women under individual payment treatment received hands on training from their spouse. Women were less incentivized by the joint payment treatment to train their husbands. 52% of men in the individual payment treatment reported being trained by their spouse, which is insignificantly different from men under the joint payment treatment, where 60.8% reported being trained by their spouse. The low difference in training by women is also seen in hands on training rates, where 11.9% of men in the individual payment treatment and 18.9% of men in the joint payment treatment reported being trained using improved methods.

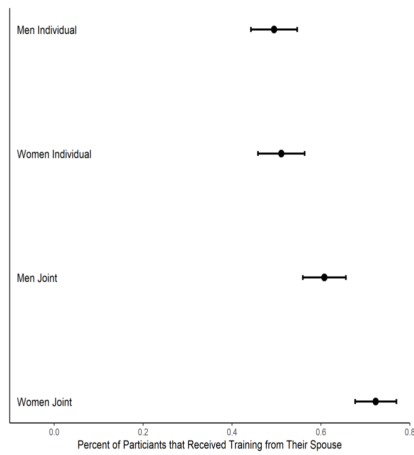
The average training time was 4.42 minutes, with players in the joint payment treatment receiving lower training times on average. Men and women under the individual payment treatment reported training times of 4.51 and 4.47 minutes, respectively, while men and women under the joint payment treatment reported lower training times of 3.51 and 5.24 minutes, respectively. We observe higher training rates under individual payment treatment for men and higher training times for women under joint payment treatment.

The reported training closely aligns with the theoretical model's outcomes. In Huband Trained treated groups, men attend the first meeting and choose the level of effort to train their wives. Under individual payment treatment, our theoretical framework concluded that men would put less effort into training their spouses since they do not directly benefit from the training. We observe that for households where men attended the first meeting, the training and hands on training rates are significantly higher under joint payment treatment than under individual payment treatment, with training times being higher but not significantly (p-value=0.59). In households assigned to the Wife Trained treatment group, women attend the first meeting, and their husbands choose the level of effort to be trained. Under individual payment treatment, we expected men to set a high level of effort to be trained, leading to women refusing to train their spouses to avoid high training costs. Training and hands on training rates are the lowest among men under individual payment treatment, but the training times are the second-highest among all groups. Under joint payment treatment, men will set a low level of effort, while women will want to train their spouses to benefit from their performance. Men under joint payment treatment reported higher rates of training (p-value=.11), higher rates of hands on training (p-value=.16), and lower training times (p-value=.39) than men in the individual payment treatment.

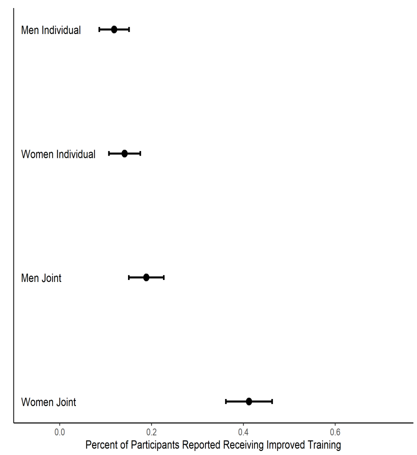
Figure 5: Reported Training and Hands on Training Rates

Reported Mean and 95% CI from OLS Regression

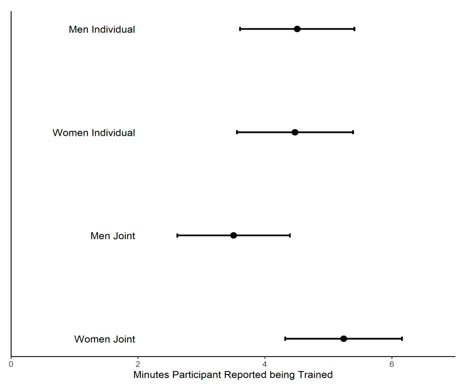
(b) Reported Training Rates



(c) Reported Hands on Training Rates



(d) Reported Training Times



0.5.2 In-Game Results

In-game performance measures a player's knowledge of the game, which can be influenced by both the effort to learn and the effectiveness of knowledge transfer. To capture this, we measure performance across three outcomes: (1) total moves made above 15, (2) binary perfect score attainment, and (3) the total number of correct moves made before an error.

The first outcome, total moves made above 15, shows how well people performed overall, regardless of whether they completed the game perfectly. As a player increases their knowledge of the game, they are more likely to obtain a perfect score, but they will also reduce the number of moves needed to complete the game. Therefore, this outcome allows us to test variation in-game knowledge beyond a perfect score.

A perfect score is 15 moves, but many individuals are unlikely to complete the game in 15 moves. By observing whether or not an individual attained a perfect score, we can minimize the effect of outliers on the group's mean. This outcome also measures how effective knowledge transfer was between spouses. Even among intelligent individuals, obtaining a perfect score without prior practice or knowledge of the game is difficult. By isolating whether or not an individual received a perfect score, we can reduce the effect of ability on performance and isolate the impact of information sharing.

The final outcome variable for in-game performance is the total number of correct moves made before an error. The Tower of Hanoi has a single sequence of 15 moves that must be completed in order to score a perfect game. We count how many moves each player made before deviating from this sequence. This allows us to understand whether the individual was able to achieve a lower score despite having a low understanding of the game or if they truly understood the game. Completing a larger percentage of the sequence indicates a higher game knowledge. Unlike the first outcome of total excess moves made, an individual may have made three errors at the beginning but could reduce the overall number of moves they made despite not being familiar with the correct sequence.

Men

Figures 6b, 6c, and 6d present the in-game performance outcomes for all three measures across both days: total moves made above 15, a binary outcome indicating if the player obtained a perfect score of 15, and the total number of correct moves made before an error. On the first day, men reacted significantly to the payment treatment, with men in the individual payment treatment completing the game in 3.67 fewer moves than those in the control group (p-value = 0.01). The promise of keeping their prize money motivated them to learn from the research team. However, their increased knowledge did not necessarily transfer to their wives, as shown in Figure 6c. Women in the individual payment treatment were less likely to obtain a perfect score, despite completing the game in similar moves to women in the joint payment treatment.

Men in the joint payment treatment did not reduce their overall effort despite their poor performance on the first day. Instead, they shifted their focus away from learning about the game from the research team and toward training their wives. On the second day, women in the joint payment treatment outperformed all other treatment groups, making on average 8.05 moves above a perfect score. They completed the game in 4.15 fewer moves than their husbands, who were trained by the research team and subsequently trained their wives.

The theoretical model predicted that men would decrease their effort to learn from the research team and increase their effort to train under joint payment treatment compared to individual payment treatment. We do observe this result as men shift their efforts away from learning from the research team and instead devote their resources to training their wives. This outcome, although predicted by the theoretical model, seems counter-intuitive. Men learned the game well enough to train their wives to perform well, but they chose to reduce their own efforts to play and receive a lower prize. It is likely that this outcome is due to men reacting negatively to the news that their prize money would be shared and responding by reducing their efforts to learn about the game. However, as time passes, the initial negative reaction subsides, and men extensively train their wives to compensate for their low performance.

Women

Overall, women do not react significantly to the payment treatment. This is evident in the effort to learn from the research team, the rate of training and hands on training for men, and men's performance on the second day. the largest gaps in women's performance across payment treatment is seen on the first day. Women are more likely to achieve a perfect score and are more likely to make more moves before making an error than women in the joint payment treatment. The gap in performance, although not significant, is aligned with the outcomes of our theoretical model, where women, in the first meeting, will perform better under individual payment treatment than joint payment treatment.

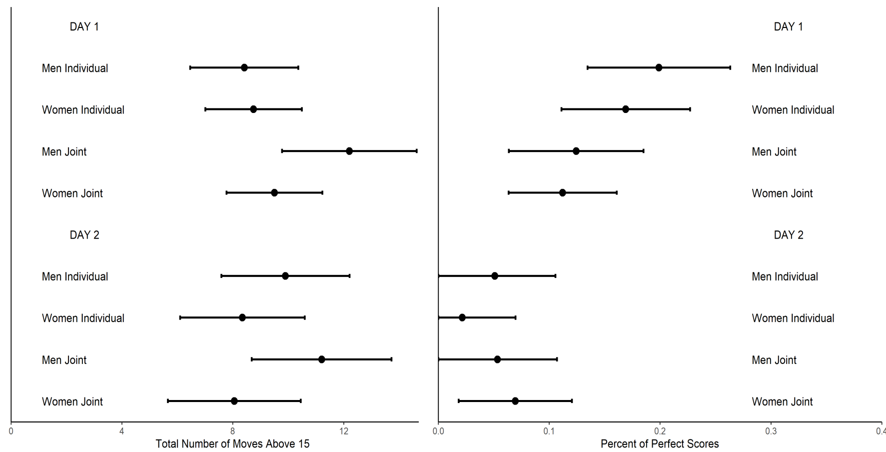
A potential reason why women do not change their level of effort to learn across payment treatments is if the household income sharing rule overrides the payment treatment and women receive the same income regardless of the payment treatment. It is possible that despite our efforts to create a setting where income is controlled jointly or individually, the money is redistributed according to the actual household sharing rules once the experiment ends. If this is true, men would also not perform differently across payment treatments, as they would know the true income-sharing rule would hold. However, men reacted significantly to the payment treatment, which means the income-sharing rules of the household did not override the payment treatment.

Women likely do not change their behavior across payment treatments because they treat their income and their spouse's income as the household's income. In the theoretical model, when Player 1 receives similar utility from Player 2's income as they do from their own, they will not shift their effort to learn or train across payment treatments. Women treat their spouse's income as similar to their own income. Despite the empirical evidence that an increase in men's income is associated with an increase in the consumption of personal and adult goods (**?**; **?**), women in our study do not behave as though this is true. Another explanation for why women may learn at similar rates is that the utility women receive from the prize money is so high that they set their willingness to learn at a maximum regardless of payment treatment. However, we do not observe the same level of effort in the training. Women are allotted the time to sit and learn the game during the meeting. However, they are expected to continue their normal workload once they leave the meeting, which is time-consuming. Therefore, the cost of training may be so high that the additional benefits of training their spouses do not increase their willingness to train. Men in the individual payment treatment received the lowest rate of training, despite increasing their effort to learn (as seen by the increase in training time).

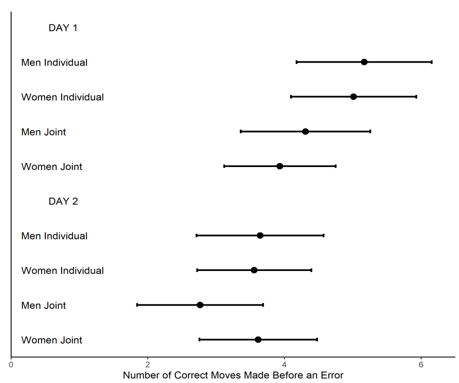
Figure 6: Outcomes by Treatment Group and Day

Reported Mean and 95% CI from OLS Regression

(b) Moves Made Above 15 (c) Percent who made a Perfect Score



(d) Total Moves Made Before Error



Information Sharing

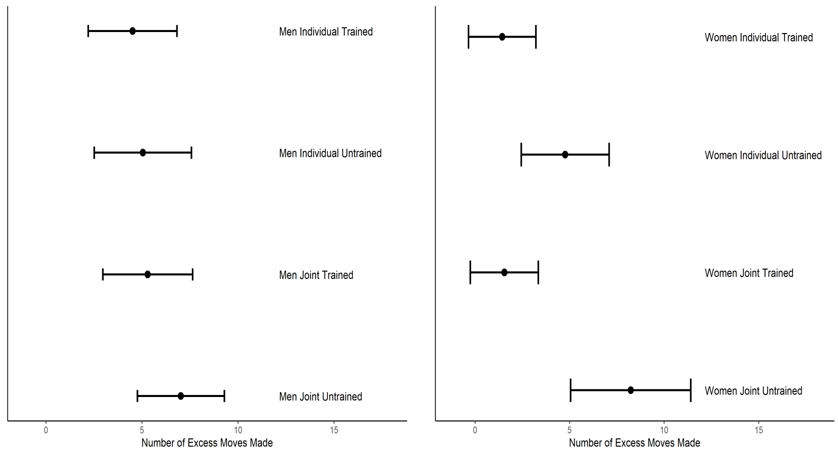
Although men perform worse on the second day, it may not be directly due to women not sharing information. Instead, men may discount the information that they receive from their wives (**?**; BenYishay et al. 2020), leading to lower levels of knowledge transfer. Despite men in the joint payment treatment receiving higher rates of training on average than men and women in the individual payment treatment, they consistently perform worse. If women were bad teachers, men in the individual payment treatment would perform worse than men in the joint payment treatment. Instead, we see that men in the individual payment treatment consistently perform better on average than men under the joint payment treatment. Men's poor performance is not consistent with poor teaching but with men not wanting to learn from their wives when they are forced to share their prize money.

The outcomes of the game and the reported training rates and times are consistent with our assumption that men have more influence on training. We can see evidence of men playing the game to benefit themselves directly and not making much effort to improve their wives' performance if it doesn't help them. Men's performance in the first meeting under individual payment treatment shows this. Women tend to behave similarly across payment treatments and train their spouses at similar rates regardless of whether they directly increase their own income.

In other studies, when women train men or share information with men, men discount this information reducing the transfer of knowledge, even among spouses (?; BenYishay et al. 2020). In Figure 7b, we observe how training impacted performance among men and women. Despite finding an overall positive impact of training on players, we expand this to observe training impacts on men and women. We find results that agree with that hypothesis; Figure 7a displays men's and women's performance under each payment treatment and whether or not they reported being trained. Despite most men reporting being trained, it appears that the transfer of knowledge from women to men is very low. The gap between trained and untrained men under joint payment treatment widens but is small and statistically insignificant. Contrary to men, women have a significant and positive impact when trained by their husbands. We continue to see a larger performance gap for women assigned to the joint payment treatment. On average, women who reported being trained make 6.7 fewer moves than untrained women in the joint payment treatment. Although the choice to train your spouse is endogenous, the performance differences could be driven by men only training their wives when they believe their wives will understand the game. We do not make causal claims about training and individual performances. The lack of difference in performance between untrained and trained men is shocking and has large implications for how information is shared in the household. Despite the benefits men would receive and the higher rates of training times for men under individual payment treatment, men who were trained performed no differently than if they were never trained.

Figure 7: Impact of Training on Performance by Gender

Reported Meand and 95% CI from OLS Regression



(a) Male Performance by Reported Training

(b) Female Performance by Reported Training

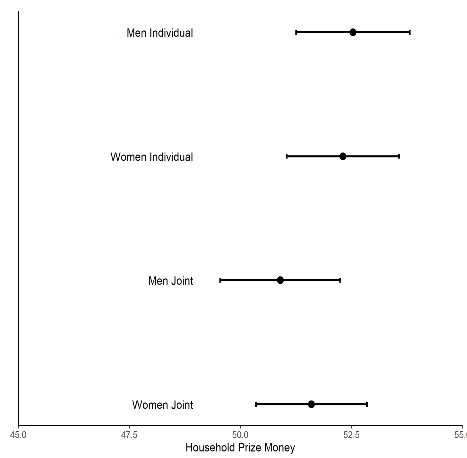
Our experiment examined how men and women differ in their willingness and effectiveness to learn and share information with their spouses. This experiment aimed to learn whether or not training men led to a significant decrease in information sharing and learning in the household. Although we find that men and women train their spouses at different rates and the outcomes of that training are significantly different, it is important to know whether or not training the husband or the wife impacts how well the household performs to understand the impact on household welfare. Using household earnings, we can observe whether or not households are worse off, and earn less income, when men or women are trained.

Figure **??** displays the number of excess moves each household made above a perfect score of 30 moves. We do not see any adverse effects on which spouse was chosen to be trained. Despite men in the joint payment treatment having a lower willingness to learn or try themselves on the first day, the shift in their effort to train their wives' led to a similar household performance. In our study, whether men or women are chosen to be trained leads to a similar outcome at the household level but has significant implications for information sharing and the gender knowledge gap among spouses.

Although the choice of which spouse to train did not significantly impact household performance, distributing prizes jointly negatively impacted household performance. This negative effect is primarily caused by men's poor performance in the joint payment treatment. In households where men were trained first, earnings were slightly decreased among households assigned to the joint payment treatment (p-value=0.09). The difference in household earnings across payment treatments is small and insignificant for households where women were trained first (p-value=0.36). Despite this outcome, we find no stochastically dominant strategy for training either men or women. Household performance is not significantly different (p-value=0.35), and the variance of household performance is also not significantly different (p-value-.20). The choice to train either men or women has significant implications for improving women's access to information and reducing the gender knowledge gap, with no adverse impact on household income.

Figure 8: Household Performance by Treatment Group

Reported Mean and 95% CI from OLS Regression



0.6 Information Sharing in Practice

0.6.1 Introduction

The aim of this field lab was to investigate the sharing of information among spouses in a complex system using mechanisms that simulate real-life scenarios. Our focus was on groundnut technology, a crop traditionally grown by women in Ghana but increasingly produced by men due to growing market demand. As both spouses in a household often produce groundnuts for either consumption or marketing, sharing information about groundnut practices, technologies, and marketing opportunities could enhance overall household welfare.

To measure the level of knowledge sharing, we examined two outcomes: first, the current knowledge of groundnut technologies and practices, including groundnut varieties, inputs, and aflatoxin prevention, and second, the knowledge of each spouse's production practices. It is important to note that overall knowledge of groundnut practices and technologies is low in Northern Ghana (Masters et al., 2015), leading to lower overall levels of knowledge in our sample. Nonetheless, households with higher information sharing should have lower gaps in knowledge between spouses and have a higher understanding of their spouse's production practices.

In this field lab, we hypothesized that individuals who share information during the experiment would also share information about groundnut technology with their spouses. By exploring information sharing between spouses in practice, we aimed to determine which spouse should be targeted for new information and how income control affects information sharing. While our study did not focus on gender-specific results, we examined reported household production and compared our outcomes across different production scenarios.

In this experiment, we focused on information sharing between spouses to understand whether or not the information is shared between spouses, which spouse we should target for new information, and how income control impacts information sharing. However, this section presents household results, not specific gender results. Therefore, we isolated our analysis to reported household production and compared our outcomes across the reported production. Our analysis is structured as follows: first, we investigate the relationship between self-reported household production and in-game performance and training. Next, we compare household information sharing using reported knowledge of groundnut technologies and practices and their spouse's groundnut practices. We then compare the knowledge gap between spouses to the gap in performance in the experiment. Finally, we examine whether income hiding in practice is associated with larger gaps in performance or training across spouses.

In the experiment, income control had a significant impact on performance. Both men and women reacted negatively in the first meeting when they were told that they would be sharing their prize money with their spouse, with men significantly reducing their performance. Table 4 shows in-game performance across joint and individual households. The outcomes are reported as the gap between Player 1 and Player 2, with a negative outcome indicating an increase in Player 2's performance relative to Player 1. Households that reported being an individual production household had a lower gap between spouses' performance for the total moves made above 15. No significant difference exists among joint and individual household production for gaps in perfect score or total moves before an error.

Table 5 reports the training outcomes across household productions. We restrict our sample to the second-day participants, as those are the participants who reported whether or not they received training. Despite previously seeing that the gap in performance was lower for individual production households, in nearly every category of training outcomes, joint households reported higher training and hands on training rates.

Table 4: Household Production and In-Game Performance

VARIABLES	Household Production		P-Value (Joint=Individual)
Excess Moves			
(Player 1-Player 2)	Joint	-0.21	
		(2.52)	0.06
	Individual	-2.85	
		(2.19)	
Perfect Score			
(Player 1-Player 2)	Joint	0.07	
		(0.07)	0.42
	Individual	0.10	
		(.07)	
Moves Before Error			
(Player 1-Player 2)	Joint	1.22	
		(1.10)	0.33
	Individual	1.81	
		(1.04)	
Observations		410	

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5: Household Production and Training Outcomes

VARIABLES	Household Production	Coeff Index (Second Player)	P-Value (Joint=Individual)
Trained			
	Joint	.75***	
		(0.08)	0.07
	Individual	.65***	
		(.08)	
Training Time			
	Joint	7.83***	
		(1.82)	0.13
	Individual	6.35***	
		(1.55)	
Hands on Training			
	Joint	.32***	
		(.07)	0.01
	Individual	0.20***	
		(.06)	
Observations		381	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

0.6.2 Knowledge, Practice Knowledge, and Income hiding

We construct the knowledge index by:

$$\text{Knowledge Index}_{ij} = (\sum_{k=1}^{K}[((Awareness_{ijk}) + (Knowledge_{ijk}]$$

Where $Awareness_{ijk}$ is a dummy variable that equals one if individual i of household j says they are aware of technology k. $Knowledge_{ijk}$ is a variable consisting of the percent of right answers individual i from household j got correct about technology k. The Knowledge index is summed over k technologies and agricultural practices.

The practice knowledge index measures the difference in husbands' and wives' knowledge of each other's groundnut practices. Where $PracticeKnowledge_{ijk}$ is a dummy variable equal to 1 if individual i of household j correctly identified their spouse's groundnut practice k.

$$PracticeKnowledgeIndex_{ij} = [(\sum_{k=1}^{K} PracticeKnowledge_{ijk})]$$

Table 6 reports the Practice Knowledge Index and Knowledge Index for men and women and is broken down by reported household production. We do not see any significant difference between men's and women's knowledge of their spouse's practice nor their knowledge of current groundnut practices and technologies. However, we do see that knowledge of spousal practices is higher under individual production households, but knowledge of current groundnut technologies and practices is higher under joint production households.

Table 6: Household Production and Performance

	Practice Knowledge Index	Knowledge Index	Income Hiding
Women (Whole Sample)	10.27	4.99	3.03
Men (Whole Sample)	10.31	5.49	1.24
Women in Individual Production Households	10.48	4.89	2.17
Women in Joint Production Households	10.08	5.10	3.98
Men in Individual Production Households	10.62	5.51	1.21
Men in Joint Production Households	10.01	5.48	1.28

We use the following equations to test the link between information sharing in practice and the game. The first equation measures the gap in knowledge of current groundnut technologies and practices and the gap in performance:

$$KnowledgeIndex_{1j} - KnowledgeIndex_{2j} = \beta_1 X_{1jJ} - X_{2jJ} + \beta_2 X_{1jI} - X_{2jI} + \Gamma_j + \varepsilon j \quad (11)$$

In our experiment, we primarily investigate the impact of household income control on information sharing between spouses. However, it is important to note that income hiding is often linked to lower levels of information sharing. Therefore, we also measure income hiding in our study to better understand the relationship between income control and information sharing. To do so, we follow the methodology of Castilla & Walker (2012) and ask both husbands and wives about their groundnut yields from the previous season. We then compare their responses to calculate the difference in reported yields between spouses, which we use as a proxy for income hiding. We construct an income-hiding variable from these responses.

$$IncomeHiding_{ij} = [\widehat{SpouseIncome}_{ij} - SpouseIncome_{ij}]$$

Where $\widehat{SpouseIncome}_{ij}$ is individual i of household j's belief about their spouse's groundnut income. $SpouseIncomeij$ is individual i of household j's spouse's self-reported income from their groundnut production.

The outcome variable in Equation 11 is the gap in the knowledge index between Player 1 and Player 2. By not using absolute values, we maintain two dimensions of our outcome variable, size and direction. $X_{1jJ} - X_{2jJ}$ is the gap of in-game performance between Player 1 and Player 2 of joint production household j. $X_{1jI} - X_{2jI}$ is the gap of in-game performance between Player 1 and Player 2 of individual production household j.

The Practice Knowledge Index uses Player 2's outcomes for in-game performance and information sharing in practice. Since the spouse practices knowledge index is a measurement of the gap in knowledge of spousal practices, we do not compare the gap in the practice knowledge index across spouses of the same household. Since the gap in performance in the game indicates a gap in knowledge between Player 1 and Player 2, we restrict our sample to only participants that participated in the second meeting (Player 2). This allows us to compare in-game performance gaps to in-practice information sharing directly.

$$PracticeKnowledgeIndex_{i2j} = beta_1 X_{1jJ} - X_{2jJ} + \beta_2 X_{1jI} - X_{2jI} + \gamma_{i2j} + \varepsilon_{ij} \tag{12}$$

The next set of equations compares the likelihood of training and the knowledge index. We expect that as the gap in knowledge decreases, the likelihood of training would increase, meaning higher levels of information sharing.

$$KnowledgeIndex_{1j} - KnowledgeIndex_{2j} = \beta_1 X_{2jJ} + \beta_2 X_{2jI} + \gamma_{ij} + \varepsilon ij \quad (13)$$

$$PracticeKnowledgeIndex_{i2j} = \beta_1 X_{2jJ} + \beta_2 X_{2jI} + \gamma_{ij} + \varepsilon ij \quad (14)$$

Equations 13 and 12 test the correlation in knowledge and practice knowledge gap with in-game training outcomes. Tables 8 and 9 report the results from the Equations above. A decrease (or more negative) in the Excess Moves gap (Player 1- Player 2) indicates a lower transfer of knowledge. Poor knowledge transfer would increase the total moves needed to complete the game. The more moves Player 2 would need to complete the game relative to Player 1 would decrease the total outcome. Alternatively, an increase in the gap between Player 1 and Player 2 for the outcomes Perfect Score and Moves Before Error indicates a larger gap in knowledge transfer. If Player 2 was less likely to obtain a perfect score or was more likely to make an error early on than Player 1, this would increase the outcome gap and indicate poor knowledge transfer. For performance in the experiment to reflect reported household information sharing, we would expect a negative coefficient for excess moves, but positive coefficient for perfect score and moves before error for the outcome variable Knowledge Index Gap. For the training outcomes, we would expect to see that as the knowledge index gap increases, Player 1 would be less likely to train their spouse. We expect to see negative coefficients for all training outcomes. However, a higher Practice Knowledge Index indicates higher information sharing; therefore the coefficients should be reversed from the Knowledge Index Gap.

We use the following equations to test for information sharing in the game and income hiding in practice. Equation 15 measures the correlation of income hiding in practice with the gap in performance between spouses. Equation 16 measures the correlation of income hiding in practice with the likelihood of training in the game.

$$IncomeHiding_{i2j} = \beta_1 X_{1jJ} - X_{2jJ} + \beta_2 X_{1jI} - X_{2jI} + \Gamma_j + \varepsilon j \quad (15)$$

$$IncomeHiding_{i2j} = \beta_1 X_{2jJ} + \beta_2 X_{2jI} + \gamma_{ij} + \varepsilon ij \quad (16)$$

Table 7: Expected Coefficients for Information Sharing in Practice and In-Game

Variables	Knowledge Index Gap	Practice Knowledge Index	Income Hiding Index
Excess Moves (Player 1- Player 2)	Negative	Positive	Positive
Perfect Score (Player 1- Player 2)	Positive	Negative	Negative
Moves Before Error (Player 1- Player 2)	Positive	Negative	Negative
Trained	Positive	Negative	Negative
Training Time	Positive	Negative	Negative
Improved Train	Positive	Negative	Negative

Similar to production practice knowledge, income hiding index is already a measurement of information sharing. The larger the gap between self-reported income and their spouse's beliefs about their income indicates higher income hiding. For income hiding we do not keep the directionality of the index. Instead, we look at only distance. The purpose of this is to not associate over estimating your spouse's income with higher knowledge of your spouse's income. The expected signs on the coefficients for in-game performance is positive for excess moves gap, and negative for perfect scores gap, moves before error gap, and all training variables. Table

0.6.3 Tables and Results

Knowledge Gap & Practice Knowledge Tables 8 & 9

Tables 8 and 9 report the correlation between in-game information sharing and in-practice information sharing. We do not see a strong correlation between the in-game performance gaps and knowledge index gaps. Overall, it appears that hosueholds that report joint production are more likely to behave in the game as they do in practice. This can be seen with the small but negative coefficient on excess moves and knowledge index gap. This indicates that as the knowledge index gap grows, Player 2 performs worse than player 1. Households that report individual production have oppostite outcomes. For individual production households, the higher the knowledge index gap the better Player 2 performs in relation to Player 1 showing higher information sharing. This holds for the outcome of Practice Knowledge Index. For individual production households, Player 2 having higher knowledge of their spouses' groundnut production practices is associated with a poorer performance relative to their spouse.

Households overall were less likely to train their spouse if they had a higher knowledge index gap and were more likely to train their spouse if they had higher knowledge of their spouse's production practices. Unlike in Table 8, joint and individual production households only deviate significantly in behavior on whether they train. Overall, we saw lower levels of training under individual production households, and lower gaps in information sharing. It appears that individual production households are more likely to share information in practice than within the game, but joint production households behave similarly.

Table 8: In-Game Performance and Household Knowledge and Practice Knowledge Outcomes

VARIABLES	Household Production	Knowledge Index (Player 1-Player 2)	P-Value Joint=Individual	Practice Knowledge Index (Second Player)	P-value Joint=Individual
Excess Moves					
(Player 1-Player 2)	Joint	0.009		.027	
		(.009)	0.92	(.024)	0.11
	Individual	0.011		-0.023	
		(.008)		(.020)	
Perfect Score					
(Player 1-Player 2)	Joint	0.482		-0.79	
		(.438)	0.07	(.573)	0.01
	Individual	-0.445		1.63**	
		(.278)		(.774)	
Moves Before Error					
(Player 1-Player 2)	Joint	0.007		-0.08*	
		(.026)	0.31	(.045)	0.001
	Individual	-0.024		0.14***	
		(.017)		(.051)	
Observations		397		369	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Training Performance and Household Knowledge and Practice Knowledge Outcomes

VARIABLES	Household Production	Knowledge Index (Player 1-Player 2)	P-Value Joint=Individual	Practice Knowledge Index (Second Player)	P-value Joint=Individual
Trained					
	Joint	-0.30		1.34	
		(.20)	0.18	(.28)	0.02
	Individual	0.05		-0.12	
		(.17)		(.285)	
Training Time					
	Joint	-0.008		-0.038***	
		(.014)	0.94	(.014)	0.55
	Individual	-0.009		- 0.060*	
		(.010)		(.034)	
Hands on Training					
	Joint	-0.060		-0.359	
		(.258)	0.92	(.265)	0.95
	Individual	-0.018		-0.317	
		(.335)		(.619)	
Observations		397	369		

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Finally, Tables 10 and 11 reports the correlation between income hiding and in-game performance. We do not see significant correlation between gaps in performance outcomes and income hiding, but we do see a positive and significant correlation between income hiding and the likelihood of training. This is the opposite of what we would expect to see. Overall, we would expect to see that households with higher gaps in income hiding would be less likely to share information and in turn reduce the overall likelihood of training.

We do not see a clear and significant correlation between in-practice information sharing and information sharing in the game. This is not surprising as in-practice information sharing can be affected by social norms, timing, reporting biases, and participants forgetting about learning certain technologies and practices. This section highlighted the need for experimentally observed information sharing as self-reported knowledge is prone to reporting biases as well as participants answering based on what they think the researchers want to hear.

Table 10: In-Game Performance and Income Hiding

VARIABLES	Household Production	Income Hiding Index (Second Player)	P-Value (Joint=Individual)
Excess Moves			
(Player 1-Player 2)	Joint	-0.02	
		(.03)	0.49
	Individual	0.00	
		(.021)	
Perfect Score			
(Player 1-Player 2)	Joint	0.90	
		(1.08)	0.62
	Individual	0.31	
		(.46)	
Moves Before Error			
(Player 1-Player 2)	Joint	-0.02	
		(.07)	0.24
	Individual	0.09	
		(.06)	
Observations		372	

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 11: Training and Income Hiding

VARIABLES	Household Production	Income Hiding Index (Second Player)	P-Value (Joint=Individual)
Trained			
	Joint	2.31***	
		(0.75)	0.14
	Individual	1.11**	
		(.48)	
Training Time			
	Joint	0.03	
		(.04)	0.18
	Individual	-0.02**	
		(.01)	
Hands on Training			
	Joint	2.06*	
		(1.20)	0.14
	Individual	0.10	
		(.63)	
Observations		372	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

0.7 Discussion

This study aimed to investigate the role of information sharing and knowledge transfer within households and explore the impact of income control on these processes. Specifically, we aimed to answer the following research questions: (1) Does information sharing occur between spouses in rural agricultural households? (2) Which spouse is more likely to share information and knowledge? (3) How does income control affect information sharing and knowledge transfer?

To address these questions, we conducted a lab-in-the-field experiment that simulated information sharing in the context of groundnut production, a vital source of income and nutrition for many households in Northern

Ghana. We compared the outcomes of the game to actual information-sharing practices among both spouses in the household.

Our findings revealed that men were more likely to share information with their spouses if they received direct benefits from sharing. However, men and women trained their spouses at similar rates when income was given individually. When income was given jointly, women were significantly less likely to train their spouses than men. This discrepancy was driven by a large increase in training by men under joint payment treatment compared to individual payment treatment, while women did not significantly change their willingness to train across payment treatments. Our results suggest that women behave according to a unitary household model where income is considered household income, while men behave according to a non-cooperative household model where they increase their effort only when it benefits them and reduce it when it benefits their spouses.

Our findings are consistent with previous studies that show men discounting their spouse's information. Although training rates were similar across men and women, men were less likely to perform differently if they were trained or not, while women performed significantly better when trained by their spouses. We believe that men's behavior is due to their tendency not to listen to their wives, rather than women's poor training skills. Nevertheless, we could not verify this due to the experimental design, which allowed for information sharing to occur outside the supervision of researchers, and training to occur only between men and women.

Despite the lower knowledge transfer from women to men, there was no significant difference in household earnings between households where men were trained, or women were trained by the research team. This result suggests that targeting women for agricultural practices and technologies will not reduce overall household welfare, but will reduce the gender agricultural knowledge gap.

Our study also revealed that joint production households had larger knowledge gaps and lower training rates than individual production households. However, higher rates of income hiding were associated with higher training rates in both joint and individual production households.

Overall, our study highlights the importance of information sharing and knowledge transfer in rural agricultural households, particularly in the context of groundnut production. Our findings have important implications for policymakers and development practitioners who seek to promote sustainable agriculture and improve household welfare in rural communities.

0.8 Abstract

0.8.1 Player Utility Curve

We model both Players' utility curves as follows:

$$U_1 = (\alpha + \phi_1(1-\alpha))P_1(\theta_1) + (\phi_1\alpha + (1-\alpha))P_2(\theta_1, \varepsilon) - L_1(\theta_1) - T_1(\varepsilon) \tag{17}$$

$$U_2 = (\alpha + \phi_2(1-\alpha))P_2(\theta_1, \varepsilon) + (\phi_2\alpha + (1-\alpha))P_1(\theta_1) - T_2(\varepsilon) \tag{18}$$

Husband Trained Maximization Choices

$$\frac{\partial U_1}{\partial \varepsilon} : (\phi_1\alpha + (1-\alpha))\frac{\partial P_2(\theta_1, \varepsilon)}{\partial \varepsilon} = \frac{\partial T_1(\varepsilon)}{\partial \varepsilon} \tag{19}$$

$$\frac{\partial U_2}{\partial \varepsilon} : (\alpha + \phi_2(1-\alpha))\frac{\partial P_2(\theta_1, \varepsilon)}{\partial \varepsilon} = \frac{\partial T_2(\varepsilon)}{\partial \varepsilon} \tag{20}$$

Wife Trained Maximization Choices

$$\frac{\partial U_m}{\partial \varepsilon} : (\alpha + \phi_m(1-\alpha))\frac{\partial P_m(\theta_f, \varepsilon)}{\partial \varepsilon} = \frac{\partial T_m(\varepsilon)}{\partial \varepsilon} \tag{21}$$

$$\begin{aligned} \frac{\partial U_f}{\partial \theta_f} : (\alpha + \phi_f(1-\alpha))\frac{\partial P_f(\theta_f)}{\partial \theta_f} + \\ (\phi_f\alpha + (1-\alpha))(\frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f, \varepsilon(\theta_f)}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) \\ = \frac{\partial L(\theta_f)}{\partial \theta_f} + \frac{\partial T(\varepsilon_m(\theta_f))}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f} \end{aligned} \tag{22}$$

$$\frac{\partial U_m}{\partial \theta_m} : (\alpha+\phi_m(1-\alpha)\frac{\partial P_m(\theta_m)}{\partial \theta_m}+(\phi_m\alpha+(1-\alpha))\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \theta_m} = \frac{\partial L(\theta_m)}{\partial \theta_m} \tag{23}$$

$$\frac{\partial U_m}{\partial \varepsilon_m} : (\phi_m\alpha + (1-\alpha))\frac{\partial P_f(\theta_m,\varepsilon}{\partial \varepsilon} = \frac{\partial T(\varepsilon)}{\partial \varepsilon} \tag{24}$$

0.8.2 Husband Trained Payment Treatment Effects

$\theta^{\alpha=1}$:

$$\frac{\partial P_m(\theta_m)}{\partial \theta_m} + \phi_m\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \theta_m} = \frac{\partial L(\theta_m)}{\partial \theta_m} \tag{25}$$

$\theta^{\alpha=\frac{1}{2}}$:

$$\frac{(1+\phi_m)}{2}\frac{\partial P_m(\theta_m)}{\partial \theta_m} + \frac{(1+\phi_m)}{2}\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \theta_m} = \frac{\partial L(\theta_m)}{\partial \theta_m} \tag{26}$$

$\theta_m^{\alpha=1} \geq \theta_m^{\alpha=\frac{1}{2}}$

$$\frac{1-\phi_m}{2}\frac{\partial P_m(\theta_m)}{\partial \theta_m} \geq \frac{(1-\phi_m)}{2}\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \theta_m} \tag{27}$$

$$\frac{\partial P_m(\theta_m)}{\partial \theta_m} \geq \frac{\partial P_f(\theta_m,\varepsilon)}{\partial \theta_m} \tag{28}$$

$\varepsilon^{\alpha=1}$:

$$\phi_m\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \varepsilon} = \frac{\partial T(\varepsilon)}{\partial \varepsilon} \tag{29}$$

$\varepsilon^{\alpha=\frac{1}{2}}$:

$$\frac{(1+\phi_m)}{2}\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \varepsilon} = \frac{\partial T(\varepsilon)}{\partial \varepsilon} \tag{30}$$

$\varepsilon^{\alpha=1} \geq \varepsilon^{\alpha=\frac{1}{2}}$

$$\phi_m\frac{\partial P_f(\theta_m,\varepsilon}{\partial \varepsilon} \geq \frac{1+\phi_m}{2}\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \varepsilon} \tag{31}$$

$$\frac{\phi_m-1}{2}\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \varepsilon} \geq 0 \tag{32}$$

$\varepsilon^{\alpha=\frac{1}{2}} \geq \varepsilon^{\alpha=1}$

$$\frac{\phi_m-1}{2}\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \varepsilon} \leq 0 \tag{33}$$

0.8.3 Wife Trained Payment Treatment Effect

$\theta_f^{\alpha=1}$:

$$\frac{\partial P_f(\theta_f)}{\partial \theta_f} + \phi_f(\frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f, \varepsilon(\theta_f)}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) = \frac{\partial L(\theta_F)}{\partial \theta_f} + \frac{\partial T(\varepsilon_m(\theta_f))}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f} \tag{34}$$

$\theta_f^{\alpha=\frac{1}{2}}$:

$$\frac{1+\phi_f}{2}\frac{\partial P_f(\theta_f)}{\partial \theta_f} + \frac{1+\phi_f}{2}(\frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f, \varepsilon(\theta_f)}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) = \frac{\partial L(\theta_f)}{\partial \theta_f} + \frac{\partial T(\varepsilon_m(\theta_f))}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f} \tag{35}$$

$\theta_f^{\alpha=1} \geq \theta_f^{\alpha=\frac{1}{2}}$:

$$\frac{\partial P_f(\theta_f)}{\partial \theta_f} + \phi_f(\frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f, \varepsilon(\theta_f))}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) \geq \frac{1+\phi_f}{2}\frac{\partial P_f(\theta_f)}{\partial \theta_f} + \frac{1+\phi_f}{2}(\frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f, \varepsilon(\theta_f)}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) \tag{36}$$

$$\frac{1-\phi_f}{2}\frac{\partial P_f(\theta_f)}{\partial \theta_f} \geq \frac{1-\phi_f}{2}(\frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f, \varepsilon(\theta_f))}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) \tag{37}$$

$$\frac{\partial P_f(\theta_f)}{\partial \theta_f} \geq (\frac{\partial P_m(\theta_f, \varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f, \varepsilon(\theta_f))}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) \tag{38}$$

$\varepsilon^{\alpha=1}$:

$$\frac{\partial P_m(\theta_f, \varepsilon)}{\partial \varepsilon} = \frac{\partial T(\varepsilon)}{\partial \varepsilon} \tag{39}$$

$\varepsilon^{\alpha=\frac{1}{2}}$:

$$\frac{1+\phi_m}{2}\frac{\partial P_m(\theta_f, \varepsilon)}{\partial \varepsilon} = \frac{\partial T(\varepsilon)}{\partial \varepsilon} \tag{40}$$

$\varepsilon^{\alpha=1} \geq \varepsilon^{\alpha=\frac{1}{2}}$

$$\frac{\partial P_m(\theta_f, \varepsilon)}{\partial \varepsilon} \geq \frac{1+\phi_m}{2}\frac{\partial P_m(\theta_f, \varepsilon)}{\partial \varepsilon} \tag{41}$$

$$\frac{1-\phi_m}{2}\frac{\partial P_m(\theta_f,\varepsilon)}{\partial \varepsilon} \geq 0 \tag{42}$$

0.8.4 Individual Payment Treatment Spousal Training Effect

$\theta_m^{\alpha=1} \geq \theta_f^{\alpha=1}$

$$\frac{\partial P_m(\theta_m)}{\partial \theta_m}+\phi_m\frac{\partial P_f(\theta_m,\varepsilon_m)}{\partial \theta_m}-\frac{\partial L_m(\theta_m)}{\partial \theta_m} \geq \frac{\partial P_f(\theta_f)}{\partial \theta_f}+\phi_f\frac{\partial P_m(\theta_f,\varepsilon_m)}{\partial \theta_f}-\frac{\partial L_f(\theta_f)}{\partial \theta_f} \tag{43}$$

$$\frac{\partial P_m(\theta_m)}{\partial \theta_m}-\frac{\partial P_f(\theta_f)}{\partial \theta_f}+\phi_m\frac{\partial P_f(\theta_m,\varepsilon_m)}{\partial \theta_m}-\phi_f\frac{\partial P_m(\theta_f,\varepsilon_m)}{\partial \theta_f} \geq \frac{\partial L_m(\theta_m)}{\partial \theta_m}-\frac{\partial L_f(\theta_f)}{\partial \theta_f} \tag{44}$$

$\varepsilon_{m_1}^{\alpha=1} \geq \varepsilon_{m_2}^{\alpha=1}$

$$\phi_m\frac{\partial P_f(\theta_m,\varepsilon_{m_1})}{\partial \varepsilon_{m_1}} - \partial\frac{T_m(\varepsilon_{m_1})}{\partial \varepsilon_{m_1}} \geq \frac{\partial P_m(\theta_f,\varepsilon_{m_2})}{\partial \varepsilon_{m_2}} - \partial\frac{T_m(\varepsilon_{m_2})}{\partial \varepsilon_{m_2}} \tag{45}$$

$$\phi_m\frac{\partial P_f(\theta_m,\varepsilon_{m_1})}{\partial \varepsilon_{m_1}} - \frac{\partial P_m(\theta_f,\varepsilon_{m_2})}{\partial \varepsilon_{m_2}} \geq \frac{\partial T_m(\varepsilon_{m_1})}{\partial \varepsilon_{m_1}} - \frac{\partial T_m(\varepsilon_{m_2})}{\partial \varepsilon_{m_2}} \tag{46}$$

0.8.5 Joint Payment Treatment Spousal Training Effect

$$\theta_m^{\alpha=\frac{1}{2}} \geq \theta_f^{\alpha=\frac{1}{2}}$$

$$\frac{\partial P_m(\theta_m)}{\partial \theta_m} + \phi_m\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \theta_m} - \frac{\partial L(\theta_m)}{\partial \theta_m} \geq \frac{\partial P_f(\theta_f)}{\partial \theta_f} + \phi_f(\frac{\partial P_m(\theta_f,\varepsilon_m(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f,\varepsilon(\theta_f)}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) - \frac{\partial L(\theta_f)}{\partial \theta_f} - \frac{\partial T(\varepsilon(\theta_f)}{\partial \varepsilon_m}\frac{\varepsilon(\theta_f)}{\partial \theta_f} \tag{47}$$

$$\frac{\partial P_m(\theta_m)}{\partial \theta_m} - \frac{\partial P_f(\theta_f)}{\partial \theta_f} \tag{48}$$

$$\phi_m\frac{\partial P_f(\theta_m,\varepsilon}{\partial \theta_m} - \phi_f(\frac{\partial P_m(\theta_f,\varepsilon(\theta_f))}{\partial \theta_f} + \frac{\partial P_m(\theta_f,\varepsilon(\theta_f)}{\partial \varepsilon}\frac{\partial \varepsilon(\theta_f)}{\partial \theta_f}) \tag{49}$$

$$\frac{\partial L(\theta_f)}{\partial \theta_f} + \frac{\partial T(\varepsilon(\theta_f)}{\partial \varepsilon_m}\frac{\varepsilon(\theta_f)}{\partial \theta_f} - \frac{\partial L(\theta_m)}{\partial \theta_m} \tag{50}$$

$\varepsilon_{m_1}^{\alpha=\frac{1}{2}} \geq \varepsilon_{m_2}^{\alpha=\frac{1}{2}}$

$$\frac{(1+\phi_m)}{2}\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \varepsilon} - \frac{\partial T(\varepsilon)}{\partial \varepsilon} \geq \frac{(1+\phi_m)}{2}\frac{\partial P_m(\theta_f,\varepsilon)}{\partial \varepsilon} - \frac{\partial T(\varepsilon)}{\partial \varepsilon} \quad (51)$$

$$\frac{(1+\phi_m)}{2}\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \varepsilon} \geq \frac{(1+\phi_m)}{2}\frac{\partial P_m(\theta_f,\varepsilon)}{\partial \varepsilon} \quad (52)$$

$$\frac{\partial P_f(\theta_m,\varepsilon)}{\partial \varepsilon} \geq \frac{\partial P_m(\theta_f,\varepsilon)}{\partial \varepsilon} \quad (53)$$

0.8.6 Training

$$(\phi_m\alpha + 1 - \alpha)P_f(\theta_m,\varepsilon) < T_m(\varepsilon) \quad (54)$$

In Scenario 2, women will not train their spouses if:

$$(\phi_f\alpha + 1 - \alpha)P_m(\theta_f,\varepsilon) < T_f(\varepsilon) \quad (55)$$

Under individual payment treatment, we will see higher rates of training by men if:

$$\phi_m P_f(\theta_m,\varepsilon) - T_m(\varepsilon) > \phi_f P_m(\theta_f,\varepsilon) - T_f(\varepsilon) \quad (56)$$

$$\frac{(1+\phi_m)}{2}P_f(\theta_m,\varepsilon) - T_m(\varepsilon) > \frac{(1+\phi_f)}{2}P_m(\theta_f,\varepsilon) - T_f(\varepsilon) \quad (57)$$

Chapter 1

Food safety voluntary training and grading programs for informal processed food markets in Northern Ghana

1.1 Introduction

The consumption of food in developing countries heavily relies on informal markets, which play a crucial role in providing affordable food options and employment opportunities for the poor (Jaffee et al., 2018). Unfortunately, studies have consistently shown that food sold in these informal markets tends to have higher contamination levels and greater safety risks compared to formally marketed products, including staples like milk and maize flour (Kariuki & Hoffmann, 2019; Wanjala et al., 2018). While imposing strict regulatory standards designed for export markets on informal food businesses is unlikely to be effective and could potentially harm food security and livelihoods, alternative approaches that focus on providing information, guidance, and incentives to food business operators, coupled with mechanisms for consumers to identify safer food options, have been proposed as more suitable strategies to improve food safety in informal markets (Jaffee et al., 2018).

This study focuses on implementing and evaluating a voluntary food safety training and grading system among roadside snack producers in Tamale, a city located in Northern Ghana. The primary objective of this system is to enhance the safety of the food produced and sold by providing training to producers on best practices and equipping them with food safety grade signs that can be prominently displayed for marketing purposes. This approach serves as an initial step towards establishing context-appropriate regulatory oversight for the informal sector. Successful examples of voluntary food safety certification and public grading systems from other countries, such as Thailand's Clean Food Good Taste program and Brazil's temporary food safety inspection and grading system during the FIFA World Cup, have demonstrated the positive impact of such initiatives on food safety (Kongchuntuk, 2002; tha, 2019; Da Cunha et al., 2016). However, it is essential to carefully evaluate the effectiveness of these interventions in diverse contexts to ensure their appropriateness and efficacy.

The study specifically focuses on the production of kulikuli, a popular groundnut-based snack widely consumed in Ghana and other West African regions. Kulikuli is predominantly produced and sold by small-scale, informal processors and vendors who operate outside formal regulatory frameworks. Due to the informal nature of the kulikuli market, there is a significant risk of high aflatoxin levels in the product. The processing techniques used in kulikuli production often mask the morphological and flavor characteristics of low-quality groundnuts, allowing aflatoxin-contaminated nuts to enter the food system. Previous research has already indicated substantially higher aflatoxin levels in kulikuli compared to roasted groundnuts, highlighting the urgent need to address this food safety concern (Opoku et al., 2021).

To tackle this issue, the study implements a two-pronged intervention. Firstly, information and training sessions are provided to kulikuli producers to raise awareness about the health risks associated with aflatoxin contamination and to educate them on strategies to improve the safety of their product. Secondly, a food safety grading system is developed, utilizing aflatoxin testing as the basis for assigning grades to producers. The producers are provided with signage displaying their food safety grade, enabling consumers to identify and choose products from producers who have participated in the food safety training and achieved a good safety grade. Furthermore, kulikuli consumers are also provided with information about the risks associated with aflatoxin and guidelines on how to identify producers who have undergone food safety training and have received favorable food safety grades.

The impact of the voluntary food safety program is evaluated from two perspectives: the business outcomes of participating producers and the demand for the program among nearby producers. Some producers are offered free entry into the grading program, allowing for an assessment of the program's influence on their business operations. Additionally, the study measures the demand for the program among other nearby producers by presenting them with a choice between a cash payment and inclusion in the program. This comprehensive analysis aims to shed light on the scalability and effectiveness

The rest of paper goes as follows, the next section discusses aflatoxins and their persistent issues in West Africa. The third section outlines the experimental design. The fourth section discusses the randomization and treatment assignment. The fifth section focuses on data collection methods and baseline data from all treatment groups. The sixth section outlines the empirical methodology. The seventh section reveals the results of the studies. The eighth section analyzes potential spillover effects and treatment intensity. The ninth section examines the results of the demand to enroll in voluntary food grading. Finally, the tenth section concludes the paper.

1.2 Background

1.2.1 Aflatoxins

Aflatoxins, which are mycotoxins produced by the fungus Aspergillus flavus, pose a significant concern as they can contaminate various agricultural products such as cereals and nuts (Florkowski et al., 2014). The consumption of aflatoxins has been linked to an increased risk of liver cancer (World Health Organization, 1993; Williams et al., 2004; Liu et al., 2010, 2012; Tchana et al., 2010). Furthermore, exposure to aflatoxins during early childhood or in utero can lead to stunted growth in children (Gong et al., 2004; Turner et al., 2007).

Despite being aware of the health risks associated with aflatoxins, West Africa continues to face a persistent problem due to factors such as low awareness, underdeveloped supply chains, and challenging environmental conditions (Jolly et al., 2009; Awuah et al., 2008; Masters et al., 2015; Florkowski et al., 2013). Aflatoxin contamination is not easily detectable by consumers as it is invisible and tasteless, making it difficult to identify contaminated products. Additionally, the adverse health effects of aflatoxin exposure often manifest after long-term exposure, making it challenging to recognize immediate symptoms (Florkowski et al., 2013). This lack of awareness among consumers provides little incentive for producers to address the issue and reduce aflatoxin levels in their products. Ghana, in particular, has experienced high levels of aflatoxin contamination in low-cost food items targeted towards improving children's health (Achaglinkame et al., 2017).

1.3 Experimental Design

1.3.1 Sample

Our study takes place in the greater Tamale area of Northern Region, Ghana. Northern Region is where the vast majority of groundnuts in Ghana are produced, and Tamale is the regional capital with a population of approximately one million. Kulikuli consumption is widespread in this area. The sample frame consists of kulikuli producers and consumers in Tamale and the nearby towns of Tolon (24 km from Tamale center) and Savelugu (25 km from Tamale center).

We have identified 80 market clusters within the study area, each represented by a circle with a 1 km radius. These clusters follow known neighborhoods. Larger neighborhoods only contain one cluster that contains the most producers possible. In densely populated areas, a cluster may comprise of multiple smaller neighborhoods. The reason behind choosing a 1 km radius is that kulikuli is typically purchased and consumed within close proximity, and rarely would it be obtained from a producer more than 1 km away. Usually, kulikuli is sold directly to consumers from the producer's home or on the street by the producer's children towards the end of the day. We have identified all kulikuli producers within each cluster, resulting in a sample frame of 821 producers. Each cluster contains anywhere from 3 to 19 producers, with a median of 12. Apart from producers, we have interviewed 10-12 consumers in each market cluster, resulting in a total sample size of 936. You can find the market clusters used for this study in Figure A.2.

1.3.2 Producer intervention

The producer intervention has three components: training, testing, and grading.

Training

Current and former University for Development Studies students trained groups of selected producers in centralized meeting areas located in or near selected clusters. The training covered what aflatoxin is, the risks it poses, and how to reduce the risk of aflatoxin contamination in kulikuli. Specifically, the producers were trained on the importance of using high-quality groundnuts in their stock and sorting out nuts with morphological traits that are correlated with aflatoxin contamination. These traits include discoloration, mold, shriveling, and insect damage. The producers were provided with photo charts showing these traits to take home with them. To gain experience, the producers were asked to sort a sample of groundnuts and receive feedback from the trainers. After receiving feedback, they were asked to sort once more to demonstrate that they could identify low-quality groundnuts. The producers were trained to discard the sorted-out nuts to prevent their re-entry into the food supply. The study team will offer to purchase the sorted-out nuts at the prevailing market price for the lowest quality nuts (which can be found in local markets) for safe disposal.

At the conclusion of the training, producers were given a sign saying they had completed training on producing safe kulikuli. The sign has a designated area to display a color-coded food safety grade card that can be changed according to aflatoxin testing results. In this area, if there is no grading card the sign will read, the sign will read “aflatoxin grade is not being displayed by the producer”. Images of the photo guide, sign, and grade cards given to producers can be found in figures A.3, 1.15, and 1.16.

As part of the program, producers will have their kulikuli tested several times (see below). They will be trained on how to communicate their knowledge of aflatoxin and quality credential to better market their kulikuli. Training will take a total of 3-4 hours per group, and participating producers will be compensated for transport and time and provided snacks and drinks.

Testing

After training, we collected kulikuli samples from the producers who attended the training for aflatoxin testing. This was enough time for producers to go through their existing groundnut stock and acquire new stock. During training, producers were told that samples would be collected occasionally, but not the sampling dates or intervals. Producers were also told that we might purchase other similar groundnut-based products (kulikulizim or groundnut paste) if they have these for sale, so that producers do not divert bad nuts to these other products. Trained technicians tested all samples in the Opoku Lab at the University for Development Studies.

Grading

We assigned three grades for kulikuli safety: safest (green), safer than the majority (yellow), and less safe than the majority (orange). Grades were given based on the prevailing aflatoxin levels among producers in the control group not initially invited to participate in the training and grading program. Producers with product that tested below 10 PPB, the Ghanaian aflatoxin standard for groundnuts, or whose result is below the 25th percentile of control group levels, received a green grade.[2] A yellow grade will be given to kulikuli that is between the 25th and 50th percentile of the control group (and not below 10 PPB), and the orange grade will be given to all other producers.

[2] The official threshold for whole groundnuts is 10 PPB, whereas the threshold for groundnut snacks is 4 PPB. Given the high levels of aflatoxin observed in Ghanaian groundnuts, and the fact that kulikuli is made nearly entirely of groundnuts, 4 PPB does not seem reasonable to attain. It is also important to note that there is little to no aflatoxin testing in Ghana's formal or informal domestic food markets, making these thresholds largely irrelevant.

1.3.3 Consumer intervention

Coinciding with the initial testing and grading cycle, the study team conducted a consumer information campaign in treatment market clusters. An enumeration team went door to door in a selected area in the treated cluster to provide information to a select number of households that consume kulikuli. The enumeration team then went and identified consumers not in that area to survey. The goal was to survey consumers that were not told directly by the enumeration team about the project. Households that do not consume kulikuli (based on an introductory screening question) were excluded from the intervention.

The consumer information campaign consisted of informing consumers about the risks of aflatoxin in kulikuli, the program to train some producers to make kulikuli safer, and the measures these producers are taking to reduce aflatoxin risk. The consumers were shown the same flyer producers received in training to identify potentially dangerous nuts, a photo of the signs trained producers received, and the three color-coded food safety grade cards that should be displayed on these signs. Enumerators gave each consumer an informational flyer to keep as a reminder (figure 1.13).

1.4 Randomization and intervention roll out

1.4.1 Producers

We randomized our interventions at the market cluster level first. Treatment clusters received producer and consumer intervention, and control clusters received no intervention.

Next, we randomly selected half of the producers in treated market clusters and invite them to the training, testing, and grading program. The other half will be invited to join the program at the end of the study. This allows us to test for differences in product aflatoxin level and business outcomes among participating and non-participating producers, who may be affected by information spillovers, consumer preference shifts, or changing prices. At the end of the study, we measured producer demand for enrolling in the food safety grading program for untreated and control producers.

We stratified the randomization across market clusters based on geography and the number of producers in the cluster. We first arrange the sample into five geographic bins containing 16 market clusters each. We then order these 16 market clusters by the number of producers, and divide them into four bins accordingly. We then randomly select two of the four market cluster to the treatment group as recommended by Abadie et al. (2017).

We chose geographical stratification as it was the best determinant of where a producer source their groundnuts, which is the factor we believe is the most highly correlated with aflatoxin levels. We stratified on the number of producers per cluster to get a treatment group (treated and untreated producers in treated market clusters) and a control group of equal size. Because we only stratified on these variables, we can assign treatment before collecting baseline data which allowed us to invite treatment producers to training upon completion of the baseline survey.

1.4.2 Consumers

Coinciding with producer training, we implemented a consumer intervention in all treated market clusters. Since there is no staggering of treatment, our estimates are the combined effect of a producer and consumer intervention, which we believe is the most likely way a program like this would be implemented in practice. This design does not allow us to estimate the effects of the producer intervention alone, or to estimate the *additional* effect of the consumer intervention when the produce intervention is in place. However, it gives us maximum power to estimate the (combined) treatment effect we are most interested in.

1.4.3 Timeline

Figure 1.1 contains a study timeline for the intervention roll-out and data collection activities (described below).

Figure 1.1: Study timeline

Month		Sept		Oct				Nov				Dec	
Week		3	4	1	2	3	4	1	2	3	4	1	2
t			0				1		2		3		4
Producers (n = 900)													
Treatment	Training	LB		FS									
(n=225)	Survey		PS				PS		PS		PS		PS
	Test		T		T	R	T	R	R	R	R	R	T
Untreated in treatment	Training	LB											
(n=225)	Survey		PS				PS		PS		PS		PS
	Test		T				T						T
Control	Training	LB											
(n=450)	Survey		PS				PS		PS		PS		PS
	Test		T				T						T
Consumers (n=900)													
Treatment (n=450)	Training				FS								
	Survey				CS			CS		CS		CS	
Control (n=450)	Survey				CS			CS		CS		CS	

Notes: LB refers to training on using a logbook to record sales. FS refers to food safety training. T refers to aflatoxin tests that will be used to estimate treatment effects. R refers to re-tests for producers earning a yellow or orange grades. PS refers to a producer survey and CS refers to a consumer survey.

1.5 Data collection

1.5.1 Producer data

Before inviting any producers to participate in the training and grading program, we collected baseline data from all kulikuli producers. One week before baseline data collection, enumerators provided all producers with a notebook to help them log kulikuli production and sales and household kulikuli consumption and train them on how to do so. Enumerators (current and former UDS students) collected data on production practices, groundnut procurement, quantity produced, home kulikuli consumption, and kulikuli marketing and sales using the log data when possible.

The study includes three post-intervention surveys for all producers. The first of these surveys took place two weeks after the initial round of testing and certification, with subsequent surveys taking place every six weeks. Originally we planned to conduct the surveys every two weeks. However, inflation and, specifically, the spike in groundnut prices led to many producers slowing down production, making sample collection difficult. We expanded the timing between surveys to ensure the highest number of kulikuli samples could be obtained.

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Aflatoxin Levels (IHS)	5.00	4.91	5.16	-0.34**	456	-0.04	289	-0.28*	445
				(0.14)		(0.14)		(0.14)	
Aflatoxin Below 10PPB	0.13	0.12	0.08	0.06*	456	0.02	289	0.04	445
				(0.03)		(0.04)		(0.03)	
Knowledge of Health Risks Associated with Aflatoxins	-0.12	-0.10	0.10	-0.13	626	-0.00	390	-0.13	622
				(0.14)		(0.09)		(0.15)	
Aware of Aflatoxins in Kulikuli	0.03	0.03	0.01	0.03	626	-0.01	390	0.03	622
				(0.03)		(0.01)		(0.03)	
Mean Daily Consumption	1.23	0.90	1.54	0.24	372	0.27	223	-0.08	359
				(0.31)		(0.25)		(0.24)	
Compared Multiple Vendors	0.72	0.70	0.79	-0.06	574	0.02	358	-0.08	558
				(0.05)		(0.04)		(0.05)	
Consumes Outsorts	0.86	0.89	0.82	0.01	575	-0.03	359	0.07*	562
				(0.04)		(0.04)		(0.04)	
Discards Outsorts	0.05	0.05	0.08	-0.01	575	0.01	359	-0.03	562
				(0.03)		(0.02)		(0.03)	
Price of Output	0.24	0.24	0.23	0.01	570	-0.00	356	0.01	554
				(0.01)		(0.01)		(0.01)	
Price per Weight (Pesewas per Gram)	0.44	0.53	0.47	-0.02	500	-0.08***	318	0.04	472
				(0.03)		(0.02)		(0.04)	
Mentions Food Safety as Goal	0.08	0.07	0.10	-0.03	626	0.02	390	-0.04	622
				(0.04)		(0.03)		(0.04)	
Mean Daily Production	12.61	9.74	17.58	1.79	372	2.56	223	-1.40	359
				(2.96)		(2.34)		(2.62)	
Vendor-Assessed Output Quality	0.51	0.44	0.59	-0.06	626	0.06	390	-0.12*	622
				(0.07)		(0.05)		(0.07)	
Chose Vendor for Quality	0.68	0.65	0.75	-0.10	574	-0.01	358	-0.12*	558
				(0.07)		(0.04)		(0.06)	
Enumerator-Assessed Input Quality	1.68	1.68	1.66	0.00	576	-0.01	360	0.00	562
				(0.09)		(0.04)		(0.08)	
Mean Daily Sales	10.19	15.61	14.08	1.49	372	-5.62*	223	3.79	359
				(2.68)		(5.08)		(4.94)	
Purchases Nuts out of Shell	0.92	0.92	0.98	-0.04	573	-0.01	358	-0.04	561
				(0.03)		(0.03)		(0.03)	
Correctly Identifies At Risk Nut Characteristics	0.12	0.05	-0.08	0.09	569	0.09	356	0.06	559
				(0.15)		(0.09)		(0.15)	
% Groundnuts Sorted Out	0.17	0.17	0.18	0.02	382	-0.00	232	0.02	368
				(0.02)		(0.01)		(0.02)	
Price of Groundnut Stock(GhC)	0.56	0.49	0.66	-0.05	374	0.09	224	-0.13	362
				(0.09)		(0.06)		(0.10)	
Time Spent Sorting(Hrs)	27.52	26.76	28.66	0.37	567	0.09	368	-0.45	551
				(1.32)		(0.52)		(1.48)	
Currently Selling Kulikuli	2.07	2.25	2.54	-0.34	543	-0.19	317	-0.32	524
				(0.36)		(0.26)		(0.36)	
Purchases Unbroken Nuts	0.86	0.88	0.87	0.03	573	-0.02	358	0.04	561
				(0.07)		(0.03)		(0.07)	
Visually Sorts Nuts	0.93	0.90	0.90	0.02	626	0.03	390	-0.02	622
				(0.03)		(0.03)		(0.03)	
Weight per Unit(Grams)	61.85	54.54	58.13	3.77	524	7.34***	337	-2.33	495
				(3.35)		(2.42)		(3.94)	
Total Observations	197	193	429						

1.5.2 Consumer data

To understand whether and how the interventions described above increases awareness and changes behavior we collected data from kulikuli consumers. We will select one area (an easily identifiable road) in each market cluster to be set aside from the consumer information intervention. We obtained a consumer sample size in each cluster that corresponded to the number of producers in each area.

The survey includes questions on consumers' kulikuli selection criteria, where they purchase kulikuli, their knowledge of food safety concerns (specifically aflatoxin) in kulikuli, and their knowledge of the food safety training and grading system. All subsequent surveys were conducted by a phone.

	(1) Treated	(2) Control	(3) Control - Treated (2)-(1)
Purchased Kulikuli for Convenience	0.345	0.432	0.087***
	(0.48)	(0.50)	(0.03)
Purchased Kulikuli for Price	0.149	0.155	0.007
	(0.36)	(0.36)	(0.02)
Purchased Kulikuli for Taste	0.743	0.791	0.049*
	(0.44)	(0.41)	(0.03)
Purchased Kulikuli for Food Safety	0.255	0.304	0.048
	(0.44)	(0.46)	(0.03)
No Formal Education	0.620	0.613	-0.007
	(0.49)	(0.49)	(0.03)
Completed Some Elementary	0.089	0.081	-0.008
	(0.29)	(0.27)	(0.02)
Completed Elementary	0.087	0.063	-0.024
	(0.28)	(0.24)	(0.02)
Completed Some Secondary	0.061	0.035	-0.027*
	(0.24)	(0.18)	(0.01)
Completed Secondary	0.143	0.209	0.066***
	(0.35)	(0.41)	(0.03)
Female=1	0.612	0.541	-0.071**
	(0.49)	(0.50)	(0.03)
Age	33.978	35.274	1.296
	(11.44)	(11.80)	(0.79)
Perceives Quality Difference Across Producer	1.208	1.339	0.131***
	(0.74)	(0.77)	(0.05)
Total Price Paid for Kulikuli	1.874	1.783	-0.091
	(1.73)	(0.99)	(0.10)
Aware of Food Safety Issues	0.204	0.267	0.063**
	(0.40)	(0.44)	(0.03)
Knowledge of Aflatoxin Health Issues	0.022	0.021	-0.001
	(0.15)	(0.14)	(0.01)
Aware of Aflatoxin	0.031	-0.036	-0.067
	(1.19)	(0.72)	(0.06)
Knowledge of Health Issues from Kulikuli	-0.063	0.073	0.136**
	(0.95)	(1.05)	(0.07)
Youngest Consumer of Kulikuli in the House	31.021	31.990	0.969
	(13.93)	(14.18)	(0.94)
Rings of Kulikuli Purchased	7.968	7.605	-0.363
	(9.68)	(4.27)	(0.48)
Purchases Kulikuli Daily	0.034	0.063	0.029**
	(0.18)	(0.24)	(0.01)
Purchases Kulikuli More than Once a Week	0.087	0.077	-0.011
	(0.28)	(0.27)	(0.02)
Purchases Kulikuli Once a Week	0.376	0.415	0.039
	(0.48)	(0.49)	(0.03)
Purchases Kulikuli Less than Once a Week	0.501	0.445	-0.056*
	(0.50)	(0.50)	(0.03)
Observations	505	431	936

1.5.3 Demand for training and certification

To understand whether producers see value in the voluntary grading program, we estimated the demand for participation among producers not initially invited to participate. We offer training to all producers who were not originally treated. During the training, we explained the voluntary grading program. After the training, the producers will receive monetary compensation or the option to enroll in the program accompanied by a smaller monetary compensation. Producers will get the choice of a random cash amount between 10GhC and 90GhC, or they can opt-out of the program and receive 100GhC. From this we derive a demand curve for the voluntary grading program.

1.6 Empirical Model

1.6.1 Producer Model

Period by Period

To compare treated producers to control producers, we regress each outcome on a variable for producer i in market cluster j being treated (TT_{ij}), excluding data from untreated producers in treatment market clusters from the estimation sample. We control for the outcome at baseline (Y_{0ij}), market cluster strata bin dummies (λ_b), and a vector of time-invariant controls (X_{ij}) selected using PDSLASSO (Belloni et al., 2014). Candidate control variables include age, experience producing kulikuli, an indicator for any formal education, baseline values for aflatoxin knowledge, aflatoxin level, the quantity of groundnuts used, whether or not they sorted nuts before making kulikuli, and all outcome variables measured at baseline. We cluster standard errors at the market cluster level, which is the level of treatment for this comparison. The model is specified as:

$$Y_{ijt} = \alpha_t TT_{ij} + \beta_t Y_{ij0} + \mathbf{X'_{ij0}}\theta_\mathbf{t} + \sum \lambda_{bt} + \varepsilon_{ijt}. \tag{1.1}$$

The estimate for α_t is the ITT effect of the joint producer and consumer intervention on treated producers at time t relative to control producers.

To compare untreated producers in treatment clusters to control producers, we regress each outcome on a variable for producer i in treatment market cluster j being untreated (UT_{ij}), excluding data from treated producers. Again we cluster standard errors at the market cluster level. The model is:

$$Y_{ijt} = \alpha_t UT_{ij} + \beta_t Y_{ij0} + \mathbf{X}'_{\mathbf{ij0}}\theta_{\mathbf{t}} + \sum \lambda_{bt} + \varepsilon_{ijt}. \tag{1.2}$$

The estimate for α_t is the ITT effect of the joint producer and consumer intervention on untreated producers in treated market clusters at time t relative to control producers.

Finally, to compare treated and untreated producers in treatment clusters we will regress each outcome on a variable for producer i in market cluster j being treated, excluding data from control producers. Here we do not include strata bin dummies or cluster standard errors because treatment was assigned at the individual level. We include all market clusters in the study area instead of sampling a random subset (Abadie et al., 2017). The model is:

$$Y_{ijt} = \alpha_t TT_{ij} + \beta_t Y_{ij0} + \mathbf{X}'_{\mathbf{ij0}}\theta_{\mathbf{t}} + \varepsilon_{ijt}, \tag{1.3}$$

The estimate for α_t is the ITT effect of the joint producer and consumer intervention on treated producers relative to untreated producers in treated market clusters at time t.

Average Treatment Effects

Using repeated measures of outcomes with low autocorrelation to estimate treatment effects (averaged over post-intervention time periods) can improve statistical power (McKenzie, 2012). We include observations from all post-treatment periods in our estimation model to estimate these effects. To compare treatment producers to control producers, we estimate:

$$Y_{ijt} = \alpha TT_{ij} + \beta Y_{ij0} + \mathbf{X}'_{\mathbf{ij0}}\theta + \sum \phi_t + \sum \lambda_b + \varepsilon_{ijt}, \tag{1.4}$$

excluding untreated producers in treatment clusters from the estimation sample. We cluster standard errors by market cluster. To compare untreated producers in treatment market clusters to control producers, we estimate:

$$Y_{ijt} = \alpha UT_{ij} + \beta Y_{ij0} + \mathbf{X'_{ij0}}\theta + \sum \phi_t + \sum \lambda_b + \varepsilon_{ijt}, \tag{1.5}$$

excluding treated producers from the estimation sample. We again cluster standard errors by market cluster. To compare treated and untreated producers in treatment market clusters, we estimate:

$$Y_{ijt} = \alpha TT_{ij} + \beta Y_{ij0} + \mathbf{X'_{ij0}}\theta + \sum \phi_t + \varepsilon_{ijt}, \tag{1.6}$$

1.6.2 Consumer Model

As with our producer analysis, we will first estimate treatment effects period-by period, allowing us to see post-intervention trends. For outcomes with four rounds of post intervention data we will also estimate treatment effects averaged across all post-treatment rounds of data to increase power.

Period by period

For all consumer outcomes we will estimate:

$$Y_{ijt} = \alpha_t T_{ij} + \beta_t Y_{ij0} + \mathbf{X'_{ij0}}\boldsymbol{\theta_t} + \sum \lambda_{bt} + \varepsilon_{ijt}, \tag{1.7}$$

including all consumers in the estimation sample. T_{ij} indicates that producer i is in treated market cluster cluster j. Because treatment is assigned at the market cluster level we will cluster standard errors at that level. In equation 1.7, α_t is the ITT effect for period t.

Post-treatment averages

To estimate post-treatment average effects we include observations from all post-treatment periods our estimation model:

$$Y_{ijt} = \alpha T_{ij} + \beta Y_{ij0} + \mathbf{X'_{ij0}}\theta + \sum \phi_t + \sum \lambda_b + \varepsilon_{ijt}, \tag{1.8}$$

The estimate of α is the average treatment effect of the consumer intervention across all rounds of post-intervention data.

In equations 1.7 and 1.8 we will control for the outcome at baseline (Y_{0ij}), market cluster strata bin dummies (λ_b), and a vector of time-invariant controls (X_{ij}) selected using PDSLASSO (Belloni et al., 2014). Candidate control variables will include baseline values for frequency of kulikuli purchase (dummy variables), quantity purchased, the reason for purchasing from selected producer (dummy variables), aflatoxin awareness, age, gender, education level (dummy variables), and all outcomes measured at baseline. In equation 1.8 we include round fixed effects (ϕ_t).

1.7 Results

1.7.1 Producer Results

Period by Period

Tables 1.20, 1.21, 1.22, 1.23, and 1.24 illustrate the treatment effects averaged over three phases. Each figure contrains three components producers who received training and food grading (treated), producers who were in the same market cluster as treated producers but were not offered training or access to the food grading program (untreated producers), and producers who were not offered training or access to the food grading program and were not in treated clusters (control group). The initial round of surveys and assessments took place shortly after the baseline survey, once all participants in the treatment group had completed their training. Conducted in early October, the training was followed by the first round of surveys in November, thereby enabling producers to utilize their remaining groundnut reserves and implement the practices learned during the training. Given the recent completion of the training, we anticipated the most substantial behavioral changes to emerge following this initial survey.

Figure **??** displays significant behavioral modifications among treated producers relative to their control counterparts. Notably, these changes encompass practices such as discarding sorted-out nuts, enlarging the proportion of sorted-out nuts, accurately identifying nut characteristics linked to higher aflatoxin levels, reducing in-house consumption of sorted-out groundnuts, procuring shelled groundnuts, and predominantly buying unbroken groundnuts. However, while the training and food grading program significantly impacted reported behavioral changes in the short run, no substantial decline in aflatoxin levels was observed. We do observe a reduction in total production as well as sales for treated producers. This is likely due to the reduction in total nuts left after sorting, lowering the total groundnut stock left in which to produce kulikuli.

Spillover effects were also evident. As it was widely known within the treated communities about the ongoing training and food grading program, several producers, though not selected for the training, endeavored to attend it and likely sought out trained producers to learn from them. Figure **??** provides evidence of this phenomenon, showing that untreated producers adopted many practices taught in the training. However, despite these reported behavioral changes, aflatoxin levels were not statistically different than the control group.

Figure **??** presents outcomes from the second survey round, which didn't involve sample collection, resulting in no aflatoxin and weight outcomes. This round commenced in January, providing a two-month gap between survey rounds. As anticipated, we observed a decrease in behavioral changes due to the waning initial training effects. A significant outcome, however, was the reduced consumption of sorted-out nuts among both treated and untreated producers, thereby limiting the intake of high-aflatoxin groundnuts, particularly among children and young adults. We see continued behavioral changes among untreated producers. Untreated producers were more likely to visit multiple vendors when searching for groundnuts, purchased mostly unbroken and shelled groundnuts, reported food safety being a major factor in production, and reported lower consumption of sorted-out groundnuts. Although the average level of aflatoxin decreases for both the treated and untreated producers compared to the control group, it remains statistically insignificant.

The final survey round, conducted in March, maintained the two-month interval between rounds. Figure 1.4 reveals the third-round outcomes, approximately five to six months post-training. Notably, we find significant impacts on aflatoxins in the long run as producers fully adopt the practices and reap the program's full benefits. The results indicate an overall production and sales reduction, with no price increase. However, treated producers reduced the weight of the sold kulikuli to decrease costs while boosting profit margins.

In conclusion, the results show an initial and long-term behavior change reported by producers who participated in the training and food grading program. Despite early findings revealing no impact on aflatoxin levels, significant reported behavioral changes resulted in a large decrease in aflatoxin levels. This program holds potential to incentivize producers to reduce aflatoxins and enhance their chances of meeting the Ghanaian FDA's strict standards.

Average Treatment Effect

Figure **??** shows the average treatment effect across all three rounds following Equation 1.4. We find that Treated producers have a higher price per weight than non-treated producers. The difference is an increase of 10.22 pesewas per gram. The average price per gram of kulikuli is 4.84 pesewas per gram therefore, treated producers saw a 111.16% increase in price by weight. We see a similar price-by-weight increase for untreated producers of 5.65 pesewas per gram. Although we do not see an average decrease in the overall aflatoxin levels, we do see a 1.6% increase in treated producers' obtaining kulikuli aflatoxin levels below 10ppb compared to the control group.

We see an average treatment effect of higher sales, lower production, and lower consumption of kulikuli among treated producers. Finally, treated producers, as well as untreated producers, were more likely to mention food safety as a major factor in their production decisions as well as purchasing mostly unbroken groundnuts.

1.7.2 Consumer Results

In conjunction with the producer treatment, we implemented an extensive consumer awareness campaign in treated market clusters. In October 2022, we selected specific areas within each market cluster and conducted interviews with kulikuli consumers to gather information about their kulikuli consumption preferences, awareness of aflatoxins, familiarity with the campaign, and knowledge regarding food safety issues related to kulikuli.

After establishing a baseline of consumer knowledge, we focused on multiple locations within each treated market cluster for an information campaign, excluding the areas where the initial consumer interviews took place. This campaign involved personally visiting households in these clusters, distributing informative flyers, and educating consumers about the health risks associated with aflatoxin consumption. Additionally, we provided guidance on identifying trained producers and identifying lower aflatoxin kulikuli products.

For the first round of interviews, conducted two months after the initial information campaign in December 2020, we opted for phone interviews to minimize attrition caused by the difficulty of locating the same consumers within market clusters.

During the final assessment, we expanded our inquiry into purchasing behavior to include more detailed questions focused not only on the frequency of kulikuli purchases but also on the number of times consumers had purchased kulikuli in the past week. We also inquired about the quantity and price of kulikuli purchases during the entire week. However, as these questions were only asked at the endline, we lacked average treatment effects, first-round survey effects, or baseline data for these specific outcomes.

Figure **??** presents the outcomes from the first and second rounds of surveys, along with an average treatment effect that combines data from both survey rounds. Overall, our findings indicate relatively small treatment effect sizes and a limited number of significant effects resulting from the information campaign.

In the first survey, conducted two months after the information campaign, consumers reported increased knowledge about aflatoxins, greater awareness of the health risks associated with aflatoxin consumption, and a higher likelihood of considering producer training and food safety as important factors in their vendor selection. Surprisingly, despite the increased knowledge about aflatoxin consumption, we observed a decrease in the age of the youngest consumers in the treated clusters. Our expectation was to see a reduction in children consuming kulikuli following aflatoxin awareness efforts, but it is possible that households were more inclined to purchase low aflatoxin kulikuli, considering it safer for children.

The second round of surveys took place approximately two months after the first round. We noticed a decrease in reported kulikuli prices among consumers in treated market clusters, accompanied by an average increase in the total quantity of kulikuli purchased. There were no significant differences in aflatoxin knowledge and awareness, nor in the awareness of food safety issues. However, as expected, a significantly higher number of consumers in the treated market clusters reported being aware of the kulikuli safety training and food grading program. Despite our efforts to influence consumer behavior, the information campaign did not result in significant shifts in consumer behavior but rather led to a temporary increase in aflatoxin awareness and a preference for food safety as a primary factor when selecting a producer.

We found no significant average treatment effects, despite increased awareness of quality differences among kulikuli vendors. Information campaigns may yield no effect if either there is no true effect or if the information does not reach consumers in the control group. In our study, consumers were vaguely asked about any program associated with kulikuli producers in the final survey. The final survey was conducted five to six months after the initial information campaign. Consumers in the treated clusters were more likely to report awareness of the training program, with only 22%of consumers indicating knowledge about the program with producers. In contrast, only 8% of consumers in the control group received such information.

1.8 Treatment Intensity and Spillover Effects

In this study, we take advantage of the experimental setup to examine the impact of treatment intensity on the outcomes of interest in the vicinity of each producer. By manipulating the proportion of treated producers, we can estimate the effect of treatment intensity on nearby producers.

To analyze the effects specific to each round, we employ the following model:

$$Y_{ijt} = \phi_t I_{d,ij} + \gamma_t none_{d,ij} + \beta_t Y_{ij0} + \mathbf{X'_{ij0}} \theta_\mathbf{t} + \sum \lambda_{bt} + \varepsilon_{ijt}, \quad (1.9)$$

Here, I_d represents the proportion of study producers (including those within and outside the producer's cluster) assigned to the treatment group within a distance d ($d \in 50\text{m}, 100\text{m}, 200\text{m}, 300\text{m}, 400\text{m}, 500\text{m}$). Note that we only display results up to 500 meters for brevity, although the effects were estimated up to 1 kilometer. Additionally, $none_d$ serves as an indicator for the absence of any study producers within the specified distance. To account for clustering, standard errors are clustered by the unit of randomization (market cluster).

For the estimation of post-treatment average effects, we utilize the following model:

$$Y_{ij} = \phi I_{d,ij} + \gamma none_{d,ij} + \beta_t Y_{ij0} + \mathbf{X'_{ij0}}\theta + \sum \lambda_b + \varepsilon_{ijt}, \qquad (1.10)$$

We test the hypothesis that $\phi = 0$ while limiting the sample to treated and untreated producers to examine heterogeneous treatment intensity effects.

Figures **??** and **??** illustrate the effects of treatment intensity in the first round for all producers. The results indicate significant treatment intensity effects when there are more treated producers within 50 meters. Specifically, a higher concentration of treated producers within this range is associated with a substantial decrease in groundnut stock prices, an increased likelihood of producers searching for groundnuts, reduced sorting times, a lower preference for vendors based on quality, and less discarding of groundnuts. These findings are surprising, as the treatment effects led to higher prices, a higher likelihood of discarding sorted-out nuts, and an increased likelihood of identifying characteristics associated with higher aflatoxin levels. Furthermore, the treatment effect diminishes rapidly after 50 meters, suggesting that the treatment's influence is constrained by proximity and dissipates quickly. However, there is a persistent effect on the consumption of sorted-out nuts up to 400 meters, significantly reducing the consumption of aflatoxins at home, excluding kulikuli consumption. The negative effect on kulikuli production and sales caused by training and voluntary grading contradicts the lower reported groundnut prices and reduced sorting effects shown in Figure **??**.

Figures **??** and **??** present the results from the second round of surveys conducted on producers. The effects continue to dissipate shortly after 50 meters, but the treatment intensity within this range remains substantial and significant, even months after the training. We observe reduced sorting time, a lower percentage of sorted-out groundnuts, and a decreased likelihood of selecting vendors based on quality. However, there is a spike in groundnut stock prices and higher reported consumption of sorted-out nuts within 50 meters, although this effect diminishes beyond that range. We also notice a decline in kulikuli production but an increase in sales resulting from the treatment. Overall, producers near treated producers experience a net positive effect on sales, a reduction in kulikuli weight (likely due to competition from producers not participating in the grading program), and an increased ability to correctly identify groundnuts associated with aflatoxin levels.

Figures **??** and **??** display the results of the final round of producer surveys and testing. We find persistent treatment effects on behavior changes as producers are in closer proximity to treated producers. Notably, we observe strong and significant effects in terms of producers discarding sorted-out nuts rather than consuming them, an increased ability to identify characteristics of groundnuts with high aflatoxin levels, and producers being more likely to rate their kulikuli higher. At 200 meters, we observe a significant and substantial increase in aflatoxin levels, but no effects are observed at other distances. Similar to the first round of surveys, there is a large but insignificant decrease in kulikuli sales. Furthermore, as the total number of treated producers within 50 meters increases, there is a significant drop in the price producers pay for groundnuts.

1.8.1 Treatment Intensity Effects on Treated Producers

The analysis of treatment intensity effects on treated producers focuses on examining the differences in outcomes for producers located in areas with a higher concentration of treated producers compared to those in more isolated areas. Unlike the previous section that analyzed effects on the entire sample, this analysis isolates the impact of treatment intensity on those who received treatment. We anticipate that as the concentration of producers increases, there will be greater competition among treated producers, potentially leading to lower prices and sales. However, we also expect to observe higher behavioral changes as producers strive to reduce aflatoxin levels to enhance the quality of their products compared to other treated producers. Figures **??**, **??**, **??**, **??**, **??**, and **??** present the results of treatment intensity on treated producers across all three survey periods.

Overall, the findings indicate that the intensity of treatment effects diminishes rapidly beyond a 50-meter radius. We do not find evidence to suggest that producers reduce their prices or experience lower sales in areas with a higher concentration of treated producers, which would indicate a shift in customers' preferences toward higher-quality kulikuli. However, we do observe a reduction in kulikuli weight as the concentration of treated producers within 50 meters increases in the third round, indicating that producers attempt to compete in size rather than price with other producers in the area. This effect only emerges several months after the treatment. As the radius expands to 300 meters and beyond, we observe a reversal in this pattern. With greater distance between producers, the competition dynamics shift, leading producers to increase the size of their kulikuli to attract consumers transitioning from traditional producers to treated producers. This effect is independent of size within the 50-meter range, where treated producers directly compete with each other and may focus on cost rather than size.

1.8.2 Intensity of Treatment on Untreated Producers in Treated Areas

Figures **??**, **??**, **??**, **??**, **??**, and **??** present the results of treatment intensity on untreated producers across all three survey periods. In the first round of surveys, we observe small but significant changes in behavior among untreated producers as the concentration of treated producers increases. Untreated producers are more likely to rate their kulikuli lower as the concentration of treated producers increases, indicating a perceived inferiority of their own products compared to those of the treated producers. They are also more likely to reduce the prices of their own kulikuli to compete with the treated producers. Furthermore, untreated producers who are closer to a higher concentration of treated producers are more likely to sort out a larger percentage of their groundnuts to achieve lower aflatoxin levels, indicating their efforts to improve the quality of their products. Additionally, untreated producers experience lower sales and production as the concentration of treated producers increases, suggesting that the competition from the treated producers affects the market share of the untreated producers.

In the second round of surveys, the effects are less pronounced, but untreated producers gain more confidence in the quality of their own kulikuli compared to the first round. However, as the concentration of treated producers within 50 meters increases, producers are less likely to prioritize food safety as a primary factor in their production. This may be due to the perceived competition and the need to emphasize other aspects of their products to attract customers. We continue to observe an increase in the time spent sorting and notice a shift in sales and production. As the concentration of treated producers within 50 meters increases, untreated producers report higher sales and production, possibly indicating their adaptation to the competition by improving their efficiency and productivity.

Finally, in the third round of surveys, the effects continue to diminish. However, there are negative behavioral effects observed among untreated producers. They are less likely to discard sorted-out nuts and less likely to identify characteristics associated with high aflatoxin levels, indicating a potential decrease in their diligence in maintaining quality standards. Despite this, there is a decrease in average aflatoxin levels as the concentration of treated producers increases, suggesting that the overall treatment program has had a positive impact on reducing aflatoxin contamination. Although untreated producers are less likely to explicitly state all the characteristics associated with low-quality nuts, they effectively sort out nuts and improve the quality of the kulikuli they sell. However, due to the competition between treated and untreated producers, lower sales and production of kulikuli are observed, indicating the challenges faced by the untreated producers in the treated areas.

1.8.3 Spillover Effects Results

To test for potential spillover effects from treated to untreated market clusters, we regress producer and consumer outcomes on variables capturing proximity to treated producers among control producers.

$$Y_{ijt} = \phi_t S_{d,ij} + \gamma_t none_{d,ij} + \beta_t Y_{ij0} + \mathbf{X'_{ij0}}\theta_\mathbf{t} + \sum \lambda_{bt} + \varepsilon_{ijt}, \qquad (1.11)$$

where S_d is equal to the number of study producers outside of the producer's cluster assigned to the treatment group within distance $d \in$ 1 km, 1.5 km, 2 km, 2.5 km, and $none_d$ is an indicator for the absence of any study producers within the specified distance. We tested spillover effects up to 10km, but the effects quickly dissipate soon after 2 Km, so we restrict our reporting to 2.5 km. Standard errors will be clustered by the unit of randomization (market cluster). We will test the hypothesis that $\phi_t = 0$ for each t. A rejection of this null hypothesis indicates spillover effects.

To estimate post-treatment average effects, we estimate:

$$Y_{ij} = \phi S_{d,ij} + \gamma none_{d,ij} + \beta_t Y_{ij0} + \mathbf{X'_{ij0}}\theta + \sum \lambda_b + \varepsilon_{ijt}. \qquad (1.12)$$

We test the hypothesis that $\phi = 0$. If evidence of spillovers is detected, S_d and $none_d$, and their interactions with an indicator for assignment to the control group, will be included in equations 1.1, 1.2, 1.4, and 1.5 estimating single-period and average post-intervention treatment effects, with radius or radii to be selected based on spillover results.

1.9 Demand for Treatment

During the last round of the producer survey, we conclude by offering to train all previously untreated producers on aflatoxin safety for kulikuli production. This training will be given to the producer individually and cover aflatoxin and associated health risks, good groundnut purchasing practices, how to identify risky nuts, and hands-on nut sorting training.[3] The script and protocol will be similar to the one used in the group setting previously.

At the conclusion of the training, the enumerator explained the testing and rating system to the producer and showed her the sign she would receive as part of the testing and rating system. The enumerator then offered the producer the choice between two options. To receive GHC 100 and not participate in the testing and rating system or to receive a random amount of money (10, 20, 30, 40, 50, 60, 70, 80, or 90 GHC) and participate in the testing and rating system.[4] Producers were told that money will be delivered via the Momo mobile money system within two weeks, to coincide with the delivery of signs and collection of samples. [5] The randomization of cash offerings was done through Qualtrix's uniform randomization algorithm and neither the producer nor the enumerator was aware of the cash offering before beginning the survey or the training. This prevented enumerators from over-selecting higher prices to benefit producers or any issues of self-selection that may impact our demand calculations. If the producer chooses testing and rating, she will be told that the team will return in 1-2 weeks to collect a sample and deliver a sign like the one previously trained producers received.

We have decided to offer training for free for three reasons. First, aflatoxin is a public health issue that we feel all producers in the sample should be

[3] In the previous training several producers said they would prefer individual to group training.

[4] An alternative would be to offer a choice between training and some randomly selected amount of money. We prefer our approach because it holds income constant while allowing price to vary instead of allowing both income and price to vary.

[5] We do not pay immediately to avoid a situation where the producer chooses between 100 GHC immediately and with certainty and some smaller amount of money immediately and with certainty and participation in a future program they may view as uncertain.

aware of. Second, it is unlikely any government or NGO program would charge producers to receive food safety information. Because of the cost associated with a testing and rating system it is more likely that producers would need to pay for this. Third, we want to isolate willingness to pay for testing and rating because this is most interesting from a research point of view.

After the producer makes their choice, data collection will be over, but we will continue to run the rating program for one or two more tests per enrolled producer (supplies permitting). Ratings will be based on the distribution of aflatoxin test results in the untreated population at endline. As before, if a producer does not receive a green rating the first time they have their production tested we will conduct a second test within one or two weeks. If the producer receives a green rating they may or may not undergo additional testing.

To derive a demand curve for grading, we regress a binary variable for whether a producer enrolls in training (Y_{ij}) on the opportunity cost of doing so. The opportunity cost (beyond the producer's time) will be a randomly determined cash payment that a producer can elect to receive instead of training and certification. To allow for non-linearity, we will use a vector of price dummy variables ($\mathbf{P_{ij}}$). Initially, we control for market cluster treatment status (T_j). We also include time-invariant controls and market cluster strata bin dummies. The model is specified as:

$$Y_{ij} = \mathbf{P'_{ij}}\beta_{\mathbf{P}} + \beta_2 T_j + \mathbf{X'_{ij}}\theta + \sum \lambda_b + \varepsilon_{ijt}. \tag{1.13}$$

We then interact P_{ij} and T_j to determine if demand is different for those with certified producers already in their market cluster and those without:

$$Y_{ij} = P'_{ij}\beta_P + \beta_2 T_j + (T_j \times \mathbf{P_{ij}})'\beta_{\mathbf{PT}} + \mathbf{X'_{ij}}\theta + \sum \lambda_b + \varepsilon_{ijt}. \tag{1.14}$$

1.10 Discussion

1.11 Appendix

1.11.1 Consumer Results

Table 1.1: Consumer Effects Round 1

First-Round Post-Intervention Treatment Effects

Dependent Variables	Treatment Effect	Observations
Frequency of Kulikuli Purchases	-0.027	810
	(0.106)	
Quantity of Kulikuli Purchased	0.689	806
	(0.503)	
Age of Youngest Consumer	-1.210	793
	(0.979)	
Knowledge of Health Risks from Consuming Kulikuli	0.096	810
	(0.094)	
Knowledge of Aflatoxins	0.162**	810
	(0.072)	
Aware of Aflatoxins	0.029*	810
	(0.015)	
Aware of Health Risks from Consuming Kulikuli	0.049	810
	(0.051)	
Price of Kulikuli	0.227	806
	(0.156)	
Quality Difference in Kulikuli Among Producers	0.065	707
	(0.073)	
Chose Kulikuli Producer for Safety or Quality	0.135**	810
	(0.068)	

Table 1.2: Consumer Effects Round 2

Second-Round Post-Intervention Treatment Effects		
Dependent Variables	Treatment Effect	Observations
Frequency of Kulikuli Purchases	0.039	802
	(0.105)	
Quantity of Kulikuli Purchased	0.052	798
	(0.661)	
Age of Youngest Consumer	-0.219	799
	(1.144)	
Knowledge of Health Risks from Consuming Kulikuli	-0.021	802
	(0.107)	
Knowledge of Aflatoxins	-0.120	802
	(0.079)	
Aware of Aflatoxins	-0.017	802
	(0.012)	
Aware of Health Risks from Consuming Kulikuli	0.001	802
	(0.064)	
Price of Kulikuli	-0.333*	795
	(0.199)	
Quality Difference in Kulikuli Among Producers	0.147	670
	(0.094)	
Chose Kulikuli Producer for Safety or Quality	0.010	802
	(0.078)	

1.11.2 Consumer Effects Across Rounds

Table 1.3: Treated Consumers

	Baseline	First Round	Second Round	Baseline - First Round	Baseline - Second Round	First Round - Second Round
				(1)-(2)	(1)-(3)	(2)-(3)
Purchased Kulikuli for Food Safety	0.05	0.41	0.35	-0.37***	-0.30***	0.07*
	(0.21)	(0.52)	(0.48)	(0.03)	(0.03)	(0.03)
Perceives Quality Difference Across Producer	1.21	1.74	1.66	-0.53***	-0.46***	0.08**
	(0.74)	(0.48)	(0.56)	(0.04)	(0.04)	(0.04)
Total Price Paid for Kulikuli	1.87	2.40	2.51	-0.52***	-0.64***	-0.12
	(1.73)	(2.00)	(1.86)	(0.13)	(0.12)	(0.13)
Aware of Food Safety Issues	0.20	0.22	0.23	-0.02	-0.03	-0.01
	(0.40)	(0.42)	(0.42)	(0.03)	(0.03)	(0.03)
Aware of Aflatoxin	0.02	0.05	0.01	-0.02**	0.01	0.04***
	(0.15)	(0.21)	(0.10)	(0.01)	(0.01)	(0.01)
Knowledge of Aflatoxin Health Issues	0.03	0.08	-0.05	-0.05	0.08	0.13*
	(1.19)	(1.34)	(0.50)	(0.08)	(0.06)	(0.07)
Knowledge of Health Issues from Kulikuli	-0.06	0.04	-0.01	-0.10	-0.06	0.04
	(0.95)	(1.24)	(0.86)	(0.07)	(0.06)	(0.07)
Youngest Consumer of Kulikuli in the House	31.02	9.89	6.65	21.13***	24.37***	3.24***
	(13.93)	(11.58)	(8.18)	(0.85)	(0.75)	(0.70)
Rings of Kulikuli Purchased	7.97	7.64	7.47	0.33	0.50	0.18
	(9.68)	(6.28)	(7.31)	(0.53)	(0.56)	(0.47)
Frequency of Kulikuli Purchases	2.54	2.12	2.12	0.42**	0.42**	-0.00
	(4.37)	(0.92)	(0.86)	(0.20)	(0.20)	(0.06)
Observations	505	412	421	917	926	833

Table 1.5: Control Consumers Across Rounds

Outcomes	Baseline	First Round	Second Round	Baseline - First Round	Baseline - Second Round	First Round - Second Round
				(1)-(2)	(1)-(3)	(2)-(3)
Purchased Kulikuli for Food Safety	0.09	0.33	0.39	-0.24***	-0.30***	-0.06*
	(0.29)	(0.48)	(0.49)	(0.03)	(0.03)	(0.03)
Perceives Quality Difference Across Producer	1.34	1.64	1.56	-0.31***	-0.22***	0.08*
	(0.77)	(0.55)	(0.63)	(0.05)	(0.05)	(0.05)
Total Price Paid for Kulikuli	1.78	2.15	2.83	-0.37***	-1.04***	-0.67***
	(0.99)	(1.26)	(1.74)	(0.08)	(0.10)	(0.11)
Aware of Food Safety Issues	0.27	0.18	0.24	0.09***	0.03	-0.06*
	(0.44)	(0.39)	(0.43)	(0.03)	(0.03)	(0.03)
Aware of Aflatoxin	0.02	0.02	0.03	0.00	-0.01	-0.01
	(0.14)	(0.13)	(0.16)	(0.01)	(0.01)	(0.01)
Knowledge of Aflatoxin Health Issues	-0.04	-0.08	0.06	0.05	-0.09	-0.14**
	(0.72)	(0.40)	(1.35)	(0.04)	(0.08)	(0.07)
Knowledge of Health Issues from Kulikuli	0.07	-0.04	0.01	0.11*	0.07	-0.05
	(1.05)	(0.67)	(1.13)	(0.06)	(0.08)	(0.07)
Youngest Consumer of Kulikuli in the House	31.99	10.65	6.65	21.34***	25.34***	4.00***
	(14.18)	(13.04)	(9.53)	(0.95)	(0.85)	(0.82)
Rings of Kulikuli Purchased	7.60	7.04	7.54	0.57**	0.07	-0.50*
	(4.27)	(3.85)	(4.45)	(0.28)	(0.31)	(0.30)
Frequency of Kulikuli Purchases	2.24	2.14	2.04	0.10*	0.20***	0.10
	(0.85)	(0.88)	(0.81)	(0.06)	(0.06)	(0.06)
Observations	431	398	381	829	812	779

Table 1.6: Treated vs. Control

Dependent Variables	First Round	Control Mean	Observations	Second Round	Control Mean	Observations	Third Round	Control Mean	Observations	Average	Observations	
Aware of Aflatoxins in Kulikuli	**	0.02			0.02		0.08	0.02	572.00	0.08	0.02	572.00
							(0.03)			(0.03)		
Different Vendor than Baseline	0.11***	0.37	536.00	0.11	0.37	533.00	0.00	0.37	546.00	0.09	0.37	546.00
	(0.04)			(0.04)			(0.00)			(0.03)		
Aflatoxin Levels (IHS)	-0.21**	4.79	362.00	-0.21	4.79	362.00	-0.32	4.79	233.00	-0.28	4.79	233.00
	(0.14)			(0.14)			(0.15)			(0.11)		
Knowledge of Health Risks Associated with Aflatoxins	***	-0.35			-0.35		1.18	-0.35	572.00	1.18	-0.35	572.00
							(0.16)			(0.16)		
Price per Gram	0.00	0.01	354.00		0.01		-0.00	0.01	245.00	0.00	0.01	245.00
	(0.00)						(0.00)			(0.00)		
Aflatoxin Below 10PPB	0.07**	0.04	362.00	0.00	0.04	626.00	0.08	0.04	246.00	0.03	0.04	246.00
	(0.04)			(0.00)			(0.05)			(0.01)		
Mean Daily Consumption	-0.08*	-0.01	324.00	0.06	-0.01	362.00	-0.14	-0.01	564.00	-0.19	-0.01	564.00
	(0.20)			(0.21)			(0.12)			(0.11)		
Compared Multiple Vendors	0.06**	0.72	550.00	0.17	0.72	555.00	0.18	0.72	572.00	0.13	0.72	572.00
	(0.07)			(0.07)			(0.07)			(0.05)		
Consumes Outsorts	-0.45***	0.89	560.00	-0.47	0.89	560.00	-0.37	0.89	572.00	-0.42	0.89	572.00
	(0.06)			(0.06)			(0.06)			(0.05)		
Discards Outsorts	0.17***	0.04	560.00	0.08	0.04	560.00	0.15	0.04	572.00	0.12	0.04	572.00
	(0.06)			(0.05)			(0.05)			(0.04)		
Displays Rating Sign	0.70***		330.00	0.61		284.00	0.63		572.00	0.65	0.00	572.00
	(0.07)			(0.08)			(0.07)			(0.05)		
Price of Output	0.08	0.37	557.00	0.06	0.37	557.00	0.01	0.37	568.00	0.04	0.37	568.00
	(0.04)			(0.06)			(0.02)			(0.04)		
Mentions Food Safety as Goal	0.28***	0.12	561.00	0.27	0.12	560.00	0.22	0.12	572.00	0.25	0.12	572.00
	(0.08)			(0.08)			(0.06)			(0.05)		
Mean Daily Production	-0.04	2.59	337.00	0.23	2.59	376.00	-0.25	2.59	569.00	-0.18	2.59	569.00
	(0.18)			(0.20)			(0.12)			(0.13)		
Vendor-Assessed Output Quality	0.05*	1.18	561.00	0.01	1.18	560.00	0.19	1.18	520.00	0.12	1.18	520.00
	(0.06)			(0.08)			(0.17)			(0.07)		
Chose Vendor for Quality	-0.09	0.58	550.00	-0.03	0.58	555.00	0.00	0.58	572.00	-0.05	0.58	572.00
	(0.06)			(0.05)			(0.02)			(0.04)		
Enumerator-Assessed Input Quality	-0.17	1.47	561.00	-0.14	1.47	557.00	0.07	1.47	572.00	-0.09	1.48	572.00
	(0.08)			(0.09)			(0.11)			(0.06)		
Mean Daily Sales	-0.08	2.36	335.00	0.27	2.36	367.00	-0.27	2.36	568.00	-0.21	2.36	568.00
	(0.20)			(0.21)			(0.14)			(0.14)		
Purchases Nuts out of Shell	0.11**	0.85	561.00	0.12	0.85	560.00	0.12	0.85	572.00	0.11	0.85	572.00
	(0.05)			(0.05)			(0.07)			(0.05)		
Correctly Identifies At Risk Nut Characteristics	0.58***	-0.11	561.00	0.02	-0.11	557.00	0.23	-0.11	566.00	0.28	-0.10	566.00
	(0.12)			(0.16)			(0.17)			(0.11)		
% Groundnuts Sorted Out	0.05	0.10	488.00	-0.01	0.10	409.00	0.00	0.10	566.00	0.01	0.10	566.00
	(0.02)			(0.02)			(0.00)			(0.01)		
Currently Selling Kulikuli	-0.07	0.88	562.00	-0.02	0.88	476.00	0.00	0.88	572.00	-0.02	0.88	572.00
	(0.05)			(0.06)			(0.00)			(0.03)		
Price of Groundnut Stock(GhC)	0.43	41.99	559.00	0.47	41.99	552.00	-0.32	41.99	572.00	0.25	42.01	572.00
	(0.41)			(0.48)			(0.78)			(0.43)		
Time Spent Sorting(Hrs)	0.14	2.40	544.00	0.33	2.40	553.00	-0.29	2.40	566.00	0.05	2.40	566.00
	(0.36)			(0.43)			(0.40)			(0.25)		
Purchases Unbroken Nuts	0.17***	0.75	537.00	0.15	0.75	536.00	0.16	0.75	548.00	0.15	0.75	548.00
	(0.07)			(0.06)			(0.07)			(0.05)		
Visually Sorted Nuts=1	0.00	0.99	561.00	0.00	0.99	560.00	0.01	0.99	572.00	0.00	1.00	572.00
	(0.00)			(0.00)			(0.01)			(0.00)		
Weight per Unit(Grams)	1.38	57.06	362.00	1.38	57.06	362.00	0.48	57.06	233.00	1.85	57.07	233.00
	(1.69)			(1.69)			(3.04)			(2.18)		

Table 1.7: Treated vs. Untreated

Dependent Variables	First Round	Control Mean	Observations	Second Round	Control Mean	Observations	Third Round	Control Mean	Observations	Average	Observations	
Aware of Aflatoxins in Kulikuli		0.02			0.02		0.10***	0.02	370.00	0.10***	0.02	370.00
							(0.02)			(0.02)		
Different Vendor than Baseline	0.03	0.37	336.00	0.06	0.37	333.00	0.00**	0.37	343.00	0.05**	0.37	343.00
	(0.04)			(0.04)			(0.00)			(0.02)		
Aflatoxin Levels (IHS)	-0.32**	4.79	231.00		4.79		-0.26*	4.79	142.00	-0.31**	4.79	142.00
	(0.13)						(0.20)			(0.13)		
Knowledge of Health Risks Associated with Aflatoxins		-0.35			-0.35		1.16***	-0.35	370.00	1.16***	-0.35	370.00
							(0.08)			(0.08)		
Price per Gram	-0.00	0.01	222.00		0.01		-0.00	0.01	143.00	-0.00	0.01	143.00
	(0.00)						(0.00)			(0.00)		
Aflatoxin Below 10PPB	0.07	0.04	231.00		0.04		0.05	0.04	145.00	0.03*	0.04	145.00
	(0.04)						(0.06)			(0.01)		
Mean Daily Consumption	0.17	-0.01	172.00	0.08	-0.01	208.00	0.11	-0.01	364.00	0.09	-0.01	364.00
	(0.14)			(0.15)			(0.11)			(0.10)		
Compared multiple vendors	-0.02	0.72	356.00	-0.05*	0.72	351.00	0.05*	0.72	370.00	-0.00	0.72	370.00
	(0.03)			(0.04)			(0.04)			(0.02)		
Consumes Outsorts	-0.38***	0.89	359.00	-0.36***	0.89	356.00	-0.32***	0.89	370.00	-0.34***	0.89	370.00
	(0.07)			(0.06)			(0.04)			(0.03)		
Discards Outsorts	0.11**	0.04	359.00	0.01	0.04	356.00	0.11***	0.04	370.00	0.08***	0.04	370.00
	(0.05)			(0.03)			(0.03)			(0.02)		
Displays Rating Sign	0.63***		211.00	0.55***		250.00	0.64***		370.00	0.65***	0.00	370.00
	(0.09)			(0.09)			(0.03)			(0.03)		
Price of Output	0.01	0.37	357.00	0.02*	0.37	355.00	0.00	0.37	368.00	0.01	0.37	368.00
	(0.01)			(0.02)			(0.01)			(0.01)		
Mentions Food Safety as Goal	0.12**	0.12	360.00	0.12*	0.12	357.00	0.09*	0.12	370.00	0.10***	0.12	370.00
	(0.06)			(0.06)			(0.04)			(0.03)		
Mean Daily Production	0.05	2.59	177.00	0.30	2.59	214.00	0.08	2.59	365.00	0.10	2.59	365.00
	(0.18)			(0.16)			(0.10)			(0.10)		
Vendor-Assessed Output Quality	0.07	1.18	360.00	0.04	1.18	357.00	0.24*	1.18	332.00	0.15***	1.18	332.00
	(0.05)			(0.03)			(0.13)			(0.06)		
Chose Vendor for Quality	-0.02	0.58	356.00	0.00	0.58	351.00	0.01	0.58	370.00	-0.01	0.58	370.00
	(0.03)			(0.03)			(0.02)			(0.02)		
Enumerator-Assessed Input Quality	-0.02	1.47	358.00	0.04	1.47	356.00	0.02	1.47	370.00	0.01	1.47	370.00
	(0.03)			(0.02)			(0.05)			(0.03)		
Mean Daily Sales	0.10	2.36	175.00	0.32**	2.36	211.00	0.07	2.36	365.00	0.11	2.36	365.00
	(0.19)			(0.16)			(0.11)			(0.11)		
Purchased Nuts out of Shell	-0.01	0.85	358.00	-0.01	0.85	357.00	0.03*	0.85	370.00	0.00	0.85	370.00
	(0.01)			(0.01)			(0.03)			(0.01)		
Correctly Identifies At Risk Nut Characteristics	0.38***	-0.11	357.00	0.14	-0.11	354.00	0.19*	-0.11	367.00	0.26***	-0.11	367.00
	(0.10)			(0.11)			(0.11)			(0.07)		
% Groundnuts Sorted Out	0.01	0.10	294.00	-0.00	0.10	263.00	-0.00	0.10	366.00	-0.00	0.10	366.00
	(0.01)			(0.01)			(0.00)			(0.01)		
Currently Selling Kulikuli	0.08	0.88	348.00	0.07	0.88	292.00	0.00**	0.88	370.00	0.05*	0.88	370.00
	(0.05)			(0.04)			(0.00)			(0.03)		
Price of Groundnut Stock(GhC)	0.27	41.99	365.00	0.07	41.99	357.00	0.33	41.99	370.00	0.24	41.99	370.00
	(0.34)			(0.26)			(0.65)			(0.32)		
Time Spent Sorting(Hrs)	0.08	2.40	345.00	-0.16	2.40	350.00	0.00	2.40	367.00	-0.00	2.40	367.00
	(0.23)			(0.17)			(0.18)			(0.15)		
Purchases Unbroken Nuts	-0.02	0.75	337.00	-0.01	0.75	337.00	0.04	0.75	344.00	0.00	0.75	344.00
	(0.03)			(0.02)			(0.03)			(0.02)		
Visually Sorted Nuts=1	0.00***	0.99	360.00	0.00***	0.99	357.00	0.01*	0.99	370.00	0.00	0.99	370.00
	(0.00)			(0.00)			(0.01)			(0.00)		
Weight per Unit(Grams)	1.03	57.06	231.00		57.06		3.15*	57.06	142.00	4.22**	57.06	142.00
	(1.57)						(2.62)			(1.85)		

Table 1.8: Untreated vs. Control

Dependent Variables	First Round	Control Mean	Observations	Second Round	Control Mean	Observations	Third Round	Control Mean	Observations	Average	Observations	
Aware of Aflatoxins in Kulikuli		0.02			0.02		-0.01	0.02*	556.00	-0.01	0.02	556.00
							(0.02)			(0.02)		
Different Vendor than Baseline	0.08*	0.37	522.00	0.06	0.37	526.00	0.00	0.37**	527.00	0.04	0.37	527.00
	(0.05)			(0.04)			(0.00)			(0.03)		
Aflatoxin Levels (IHS)	0.04	4.79	357.00		4.79		-0.09	4.79	221.00	-0.00	4.79	221.00
	(0.12)						(0.17)			(0.11)		
Knowledge of Health Risks Associated with Aflatoxins		-0.35			-0.35		0.02	-0.35*	556.00	0.02	-0.35	556.00
							(0.02)			(0.02)		
Price per Gram	0.00	0.01	342.00		0.01		0.00	0.01	232.00	0.00	0.01	232.00
	(0.00)						(0.00)			(0.00)		
Aflatoxin Below 10PPB	0.02	0.04	357.00		0.04		0.03	0.04	235.00	0.01	0.04	235.00
	(0.03)						(0.05)			(0.01)		
Mean Daily Consumption	-0.21	-0.01	304.00	-0.01	-0.01	346.00	-0.25	-0.01*	544.00	-0.29	-0.01	544.00
	(0.22)			(0.24)			(0.13)			(0.13)	**	
Compared multiple vendors	0.08	0.72	538.00	0.23	0.72	546.00	0.14	0.72*	556.00	0.14	0.72	556.00
	(0.07)			(0.06)***			(0.08)			(0.06)	**	
Consumes Outsorts	-0.08	0.89	545.00	-0.11	0.89	552.00	-0.04	0.89	556.00	-0.07	0.89	556.00
	(0.05)			(0.05)**			(0.04)			(0.04)	*	
Discards Outsorts	0.04	0.04	545.00	0.06	0.04	552.00	0.04	0.04	556.00	0.04	0.04	556.00
	(0.03)			(0.04)*			(0.02)			(0.03)		
Displays Rating Sign											0.00	
										(0.00)		
Price of Output	0.07	0.37	540.00	0.04	0.37	548.00	0.01	0.37	552.00	0.03	0.37	552.00
	(0.04)			(0.05)			(0.02)			(0.03)		
Mentions Food Safety as Goal	0.17**	0.12	547.00	0.14	0.12	553.00	0.13	0.12**	556.00	0.15	0.12	556.00
	(0.07)			(0.07)**			(0.06)			(0.04)	***	
Mean Daily Production	-0.07	2.59	316.00	-0.04	2.59	364.00	-0.33	2.59**	550.00	-0.29	2.59	550.00
	(0.21)			(0.24)			(0.12)			(0.14)	**	
Vendor-Assessed Output Quality	-0.01	1.18	547.00	-0.02	1.18	553.00	-0.06	1.18	496.00	-0.02	1.18	496.00
	(0.06)			(0.08)			(0.17)			(0.08)		
Chose Vendor for Quality	-0.07	0.58	538.00	-0.02	0.58	546.00	-0.01	0.58	556.00	-0.04	0.58	556.00
	(0.06)			(0.05)			(0.01)			(0.04)		
Enumerator-Assessed Input Quality	-0.17*	1.47	545.00	-0.19	1.47	551.00	0.04	1.47	556.00	-0.10	1.48	556.00
	(0.09)			(0.08)**			(0.10)			(0.06)	*	
Mean Daily Sales	-0.17	2.36	314.00	-0.04	2.36	354.00	-0.38	2.36*	549.00	-0.37	2.36	549.00
	(0.24)			(0.24)			(0.16)			(0.15)	**	
Purchased Nuts out of Shell	0.13**	0.85	545.00	0.14	0.85	553.00	0.09	0.85*	556.00	0.11	0.85	556.00
	(0.05)			(0.05)**			(0.08)			(0.05)	**	
Correctly Identifies At Risk Nut Characteristics	0.18	-0.11	544.00	-0.10	-0.11	551.00	0.01	-0.11	549.00	0.01	-0.10	549.00
	(0.14)			(0.15)			(0.16)			(0.11)		
% Groundnuts Sorted Out	0.04***	0.10	474.00	-0.01	0.10	400.00	0.00	0.10	548.00	0.01	0.10	548.00
	(0.02)			(0.02)			(0.00)			(0.01)		
Currently Selling Kulikuli	-0.14**	0.88	552.00	-0.10	0.88	476.00	0.00	0.88**	556.00	-0.06	0.88	556.00
	(0.05)			(0.06)*			(0.00)			(0.03)	*	
Price of Groundnut Stock(GhC)	0.16	41.99	544.00	0.42	41.99	533.00	-0.71	41.99	556.00	-0.01	42.01	556.00
	(0.50)			(0.47)			(0.70)			(0.39)		
Time Spent Sorting(Hrs)	0.13	2.40	533.00	0.51	2.40	545.00	-0.23	2.40	549.00	0.12	2.40	549.00
	(0.34)			(0.45)			(0.43)			(0.26)		
Purchases Unbroken Nuts	0.20***	0.75	522.00	0.16	0.75	529.00	0.12	0.75*	530.00	0.15	0.75	530.00
	(0.06)			(0.06)**			(0.08)			(0.05)	***	
Visually Sorts Nuts	0.00***	0.99	547.00	0.00	0.99	553.00	0.00	0.99*	556.00	0.00	1.00	556.00
	(0.00)			(0.00)***			(0.01)			(0.00)		
Weight per Unit(Grams)	0.82	57.06	357.00		57.06		-4.42	57.06*	221.00	-1.65	57.07	221.00
	(1.76)						(2.68)			(2.16)		

Table 1.9: Average Effects

Dependent Variables	Treated vs. Control	Control Mean	Observations	Treated vs. Untreated	Untreated Mean	Observations	Untreated vs. Control	Control Mean	Observations
Aware of Aflatoxins in Kulikuli	0.10^{***}	0.02	572	0.10^{***}	0.02	370	-0.01	0.02	556
	(0.03)			(0.02)			(0.01)		
Different Vendor than Baseline	0.07^{***}	0.37	561	0.05^{**}	0.37	353	0.03	0.37	548
	(0.02)			(0.02)			(0.02)		
Aflatoxin Levels (IHS)	-0.34^{***}	4.79	407	-0.31^{**}	4.79	259	-0.04	4.79	397
	(0.11)			(0.13)			(0.12)		
Knowledge of Health Risks Associated with Aflatoxins	1.38^{***}	-0.35	572	1.16^{***}	-0.35	370	0.01	-0.35	556
	(0.17)			(0.08)			(0.02)		
Price per Weight (Pesewas per Gram)	-0.06	7.40	404	-0.00	7.34	254	0.06	7.40	386
	(0.06)			(0.00)			(0.08)		
Aflatoxin Below 10PPB	0.03^{**}	0.04	626	0.03^{*}	0.04	390	0.01	0.04	622
	(0.01)			(0.01)			(0.01)		
Mean Daily Consumption	-0.21^{**}	-0.01	579	0.09	-0.01	371	-0.29^{***}	-0.01	564
	(0.11)			(0.10)			(0.11)		
Compared multiple vendors	0.13^{**}	0.72	593	-0.00	0.72	381	0.13^{**}	0.72	584
	(0.06)			(0.02)			(0.05)		
Consumes Outsorts	-0.45^{***}	0.89	593	-0.34^{***}	0.89	381	-0.09^{***}	0.89	584
	(0.04)			(0.03)			(0.03)		
Discards Outsorts	0.16^{***}	0.04	593	0.08^{***}	0.04	381	0.06^{***}	0.04	584
	(0.03)			(0.02)			(0.02)		
Displays Rating Sign	0.64^{***}		580	0.65^{***}		375	0.00^{***}		567
	(0.05)			(0.03)			(0.00)		
Price of Output	0.03	0.37	592	0.01	0.37	380	0.02	0.37	584
	(0.03)			(0.01)			(0.03)		
Mentions Food Safety as Goal	0.25^{***}	0.12	593	0.10^{***}	0.12	381	0.13^{***}	0.12	584
	(0.06)			(0.03)			(0.05)		
Mean Daily Production	-0.18	2.59	581	0.10	2.59	371	-0.30^{**}	2.59	566
	(0.12)			(0.10)			(0.13)		
Vendor-Assessed Output Quality	0.15^{**}	1.18	591	0.15^{***}	1.18	380	0.00	1.18	581
	(0.08)			(0.06)			(0.08)		
Chose Vendor for Quality	-0.07	0.58	593	-0.01	0.58	381	-0.06	0.58	584
	(0.04)			(0.02)			(0.04)		
Enumerator-Assessed Input Quality	-0.09	1.48	593	0.01	1.47	381	-0.11^{*}	1.48	584
	(0.06)			(0.03)			(0.06)		
Mean Daily Sales	-0.21	2.36	580	0.11	2.36	371	-0.36^{**}	2.36	565
	(0.13)			(0.11)			(0.15)		
Purchased Nuts out of Shell	0.11^{**}	0.85	593	0.00	0.85	381	0.11^{**}	0.85	584
	(0.05)			(0.01)			(0.05)		
Correctly Identifies At Risk Nut Characteristics	0.33^{***}	-0.10	593	0.26^{***}	-0.11	381	0.03	-0.10	584
	(0.12)			(0.07)			(0.11)		
% Groundnuts Sorted Out	0.01	0.10	589	-0.00	0.10	381	0.01	0.10	580
	(0.01)			(0.01)			(0.01)		
Currently Selling Kulikuli	-0.02	0.88	595	0.05^{*}	0.88	384	-0.07^{**}	0.88	587
	(0.03)			(0.03)			(0.03)		
Price of Groundnut Stock(GhC)	-0.13	42.01	572	0.24	41.99	370	-0.45	42.01	556
	(0.73)			(0.32)			(0.67)		
Time Spent Sorting(Hrs)	-0.12	2.40	592	-0.00	2.40	380	-0.09	2.40	584
	(0.28)			(0.15)			(0.29)		
Purchases Unbroken Nuts	0.15^{***}	0.75	593	0.00	0.75	354	0.15^{***}	0.75	584
	(0.06)			(0.02)			(0.05)		
Visually Sorts Nuts	0.00	1.00	593	0.00	0.99	381	-0.00	1.00	584
	(0.00)			(0.00)			(0.00)		
Weight per Unit(Grams)	2.27	57.07	407	4.22^{**}	57.00	259	-1.65	57.07	397
	(2.05)			(1.85)			(2.60)		

Figure 1.2: Treatment Effects

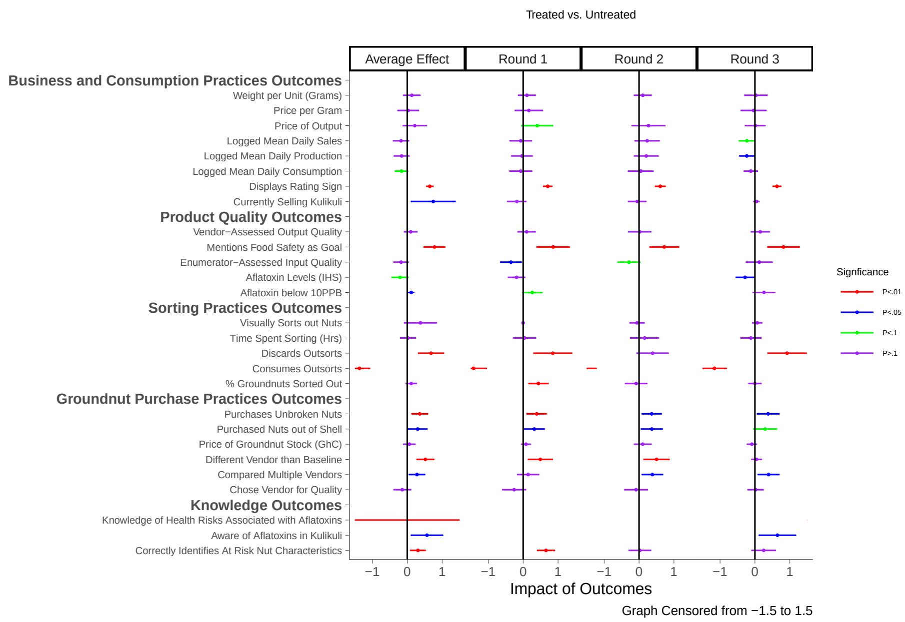


Figure 1.3: Treatment within Treated Cluster Effects

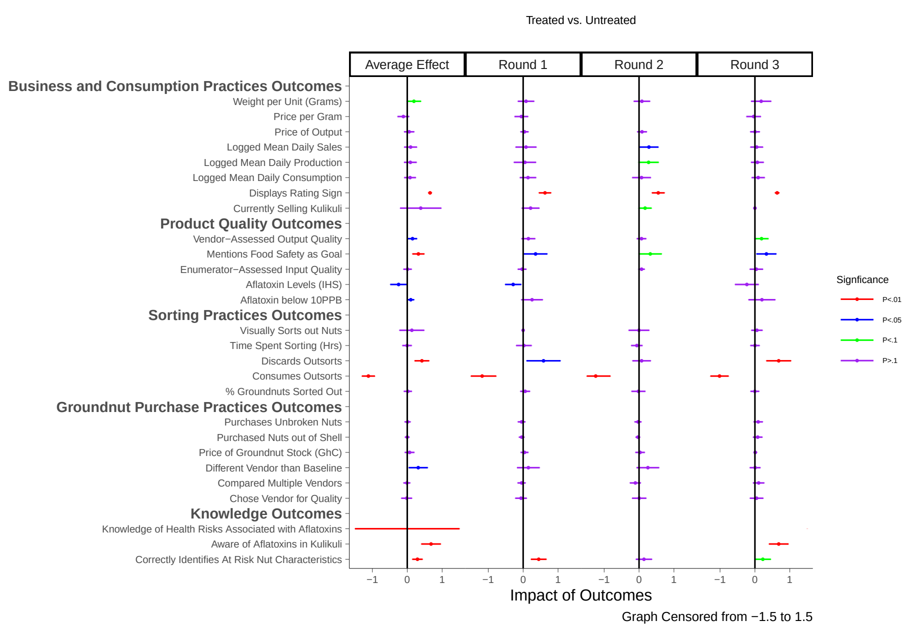
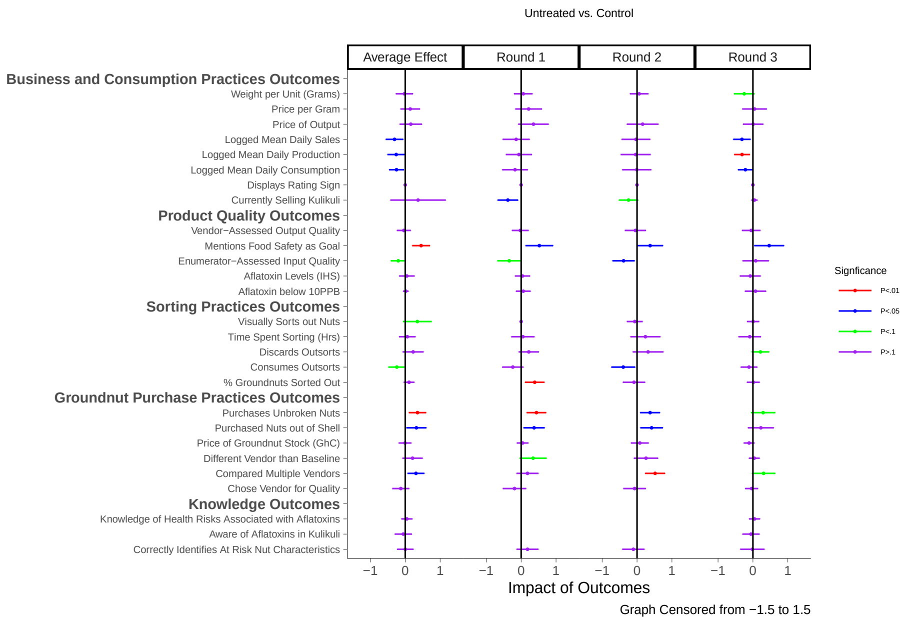


Figure 1.4: Treatment within Treated Cluster Effects



1.11.3 Treatment Intensity

Figure 1.5: Treatment Intensity on Treated

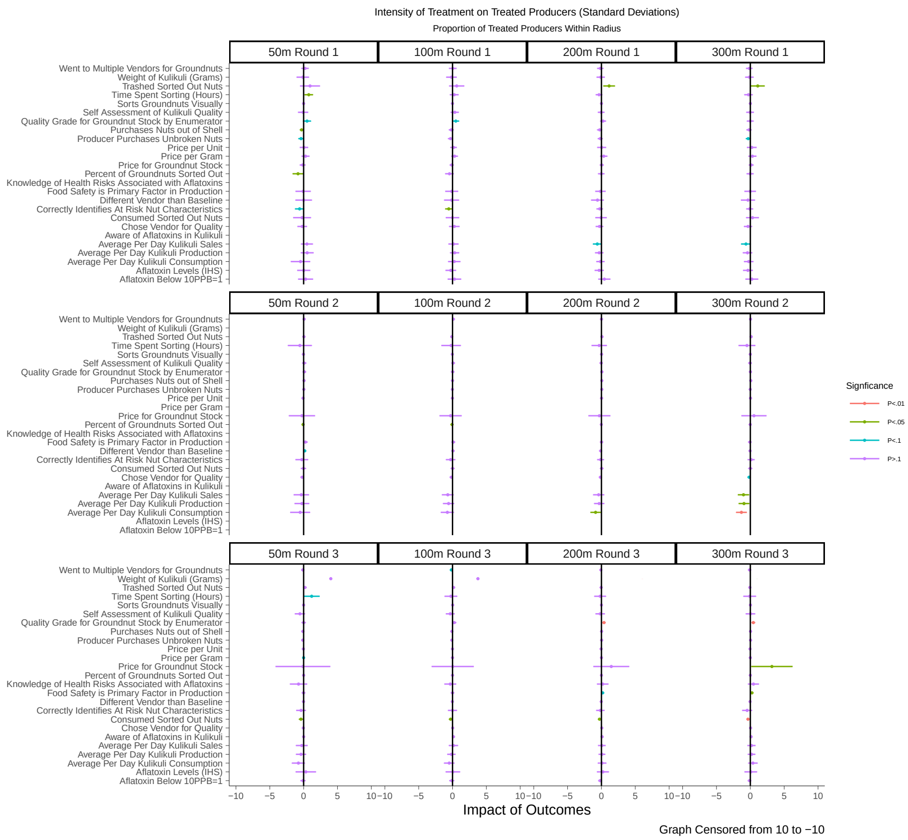


Figure 1.6: Treatment Intensity on Untreated

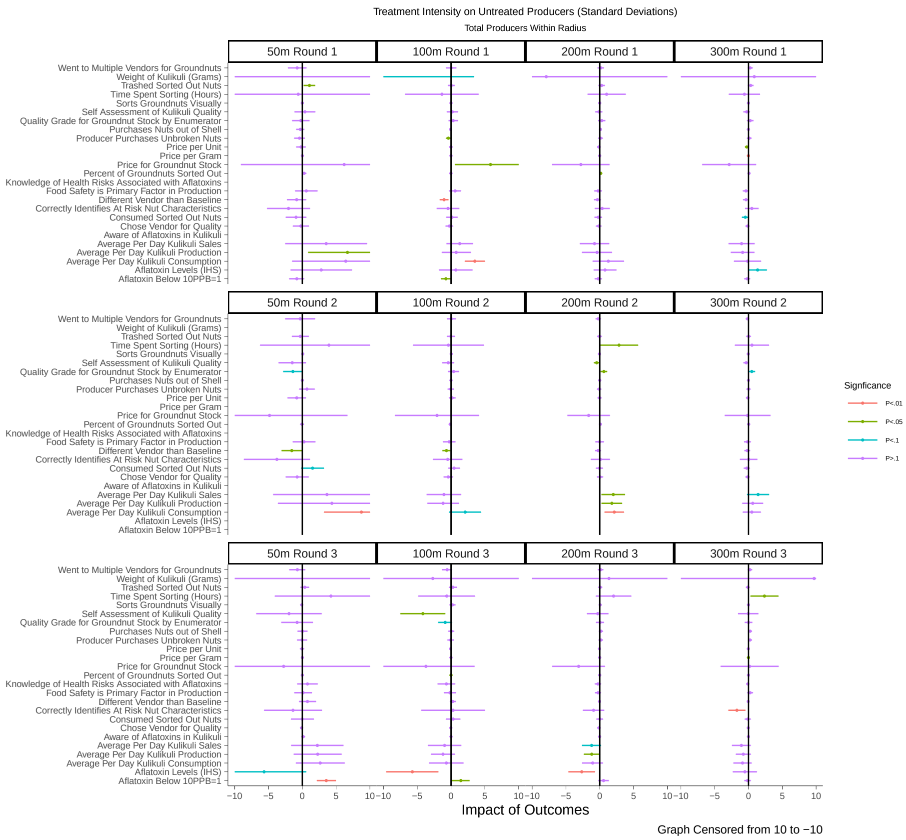
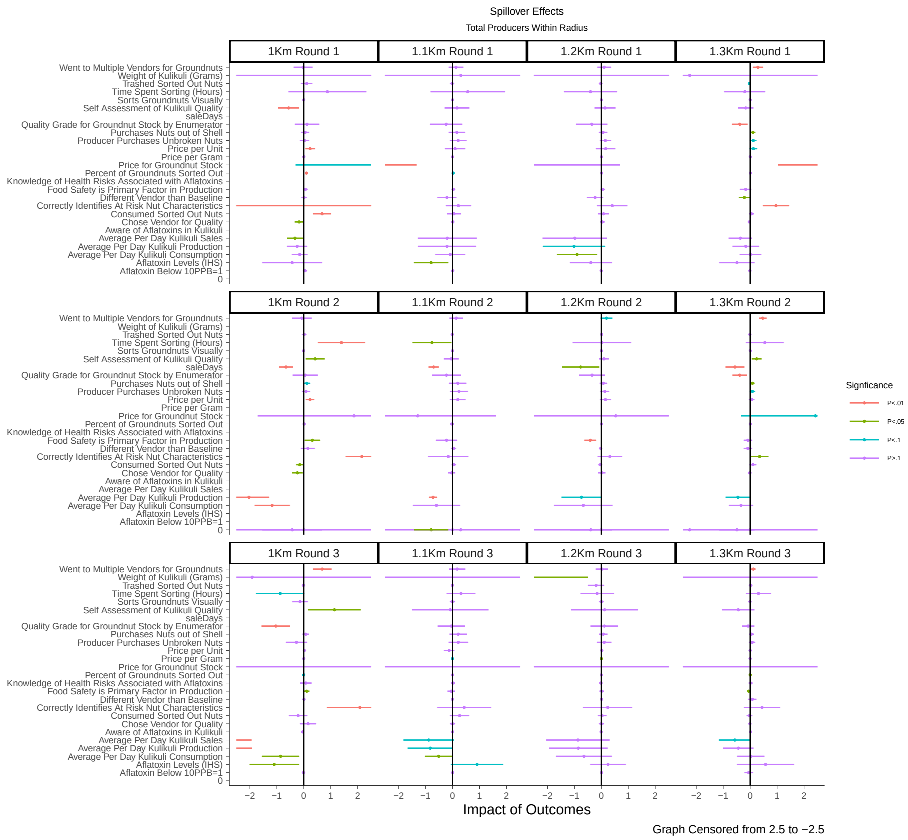


Figure 1.7: Spill Over Effects



1.11.4 Consumer Intensity Treatment

Figure 1.8: Treatment Intensity on Treated Consumers

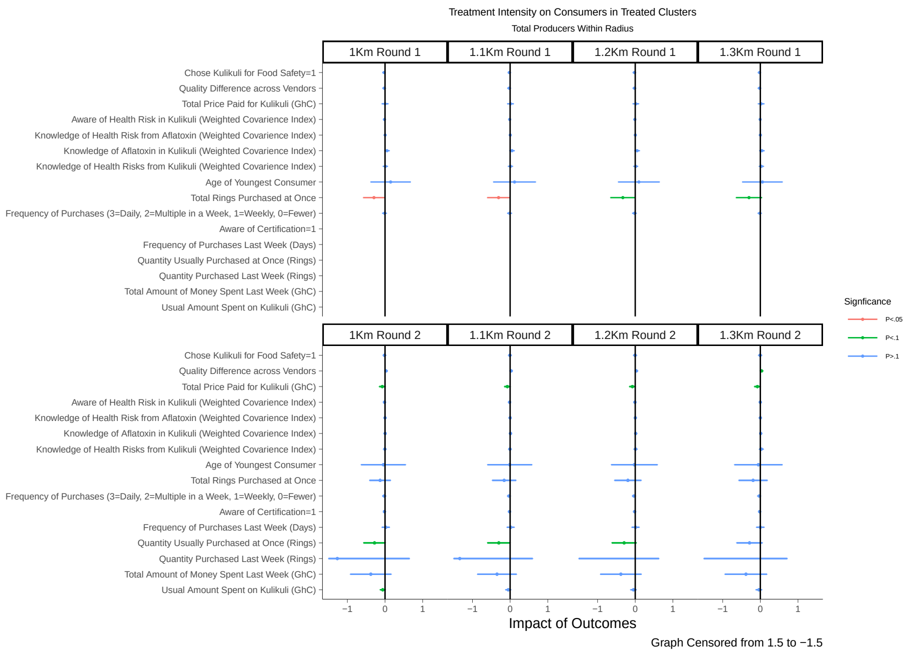
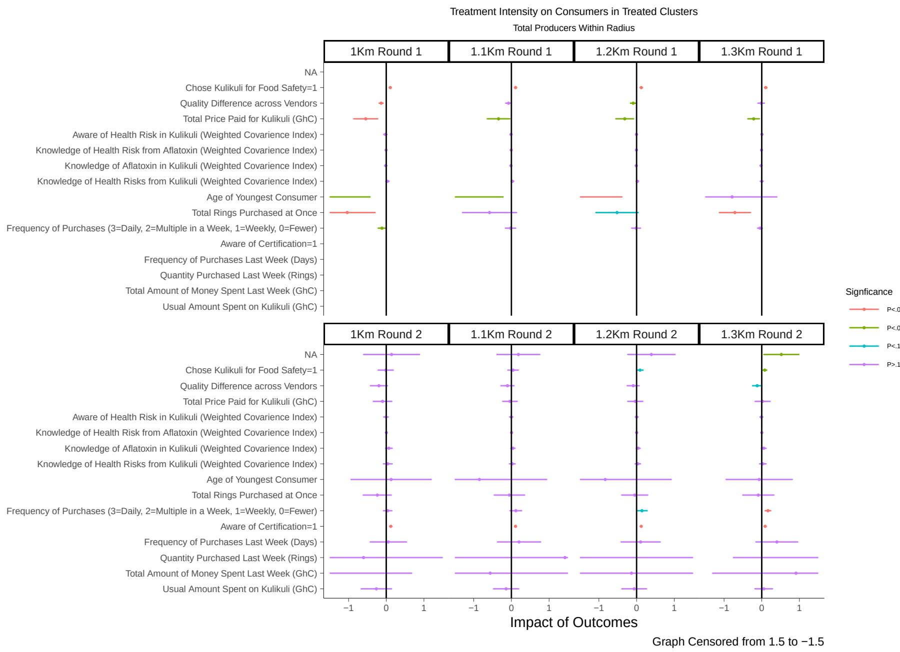
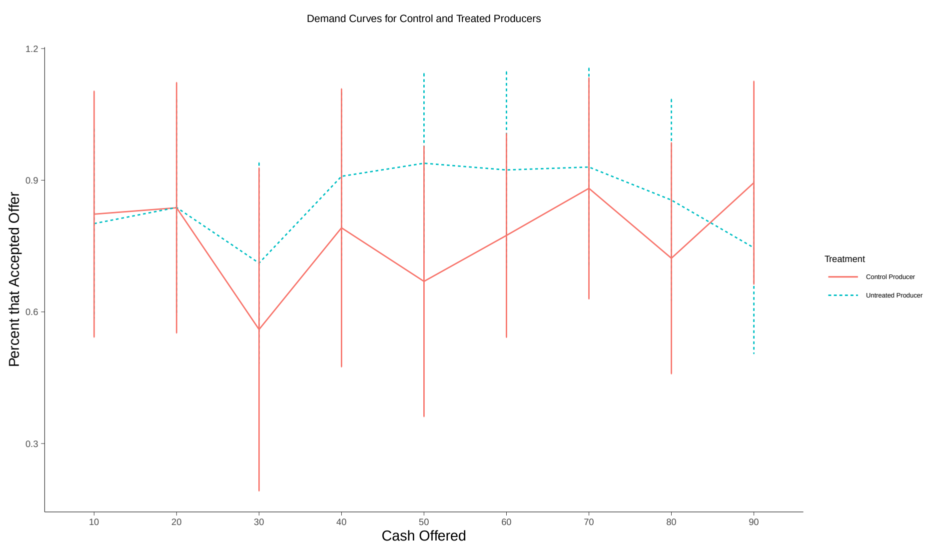


Figure 1.9: Treatment Intensity on Control Consumers



1.11.5 Demand for Certification

Figure 1.10: Demand for Certification by Treatment



1.11.6 Attrition.

Table 1.10: Attrition Drivers Treated v. Control

Baseline Dependent Variables	Any Follow Up Survey	Observations	Any Follow Up Input	Observations	Any Follow up Sample	Observations
Aflatoxin Levels (IHS)	-0.00	626	-0.02	626	-0.01	626
	(0.00)		(0.02)		(0.03)	
Aflatoxin Levels (IHS)*Treated	0.00	626	0.02	626	-0.10*	626
	(0.00)		(0.03)		(0.05)	
Treated Producer (Omitted)	1.33	626	6.41	626	-19.93	626
	(0.00)		(7.35)		(14.79)	
Aflatoxin Below 10PPB	0.03	626	-0.09	626	-0.02	626
	(0.00)		(0.07)		(0.14)	
Aflatoxin Below 10PPB*Treated	-0.03	626	0.20	626	-0.32	626
	(0.00)		(0.13)		(0.24)	
Knowledge of Health Risks Associated with Aflatoxins	-0.00	626	0.00	626	-0.02	626
	(0.00)		(0.02)		(0.03)	
Knowledge of Health Risks Associated with Aflatoxins*Treated	0.00	626	0.00	626	0.08	626
	(0.00)		(0.02)		(0.06)	
Aware of Aflatoxins	0.02	626	-0.05	626	0.40***	626
	(0.00)		(0.04)		(0.10)	
Aware of Aflatoxins*Treated	-0.05	626	0.22***	626	-0.18	626
	(0.00)		(0.08)		(0.14)	
Mean Daily Consumption	-0.00	626	-0.00	626	-0.00*	626
	(0.00)		(0.00)		(0.00)	
Mean Daily Consumption*Treated	0.00	626	0.00	626	-0.00	626
	(0.00)		(0.00)		(0.00)	
Compared multiple vendors	0.00	626	-0.03	626	0.07	626
	(0.00)		(0.04)		(0.08)	
Compared multiple vendors*Treated	-0.00	626	0.05	626	0.06	626
	(0.00)		(0.07)		(0.12)	
Consumes Outsorts	0.02	626	-0.01	626	-0.07	626
	(0.00)		(0.04)		(0.08)	
Consumes Outsorts*Treated	-0.02	626	0.10	626	0.14	626
	(0.00)		(0.10)		(0.16)	
Discards Outsorts	0.05*	626	0.09	626	0.08	626
	(1.00)		(0.07)		(0.12)	
Discards Outsorts*Treated	-0.11**	626	-0.08	626	0.06	626
	(2.00)		(0.16)		(0.20)	
Price per Weight (Pesewas per Gram)	0.15	626	0.25	626	0.21	626
	(0.00)		(0.16)		(0.25)	
Price per Weight (Pesewas per Gram)*Treated	-0.14	626	-0.02	626	-0.55	626
	(0.00)		(0.27)		(0.42)	
Price of Output	0.01	626	-0.56	626	-0.72	626
	(0.00)		(0.41)		(0.65)	
Price of Output*Treated	-0.04	626	0.07	626	1.17	626
	(0.00)		(0.57)		(1.05)	
Mentions Food Safety as Goal	0.06*	626	0.07	626	0.18**	626
	(1.00)		(0.08)		(0.07)	
Mentions Food Safety as Goal*Treated	-0.10**	626	0.04	626	0.05	626
	(2.00)		(0.10)		(0.15)	
Mean Daily Production	0.00	626	0.00	626	-0.00	626
	(0.00)		(0.00)		(0.00)	
Mean Daily Production*Treated	-0.00	626	-0.00*	626	0.00	626
	(0.00)		(0.00)		(0.00)	
Vendor-Assessed Output Quality	0.00	626	-0.00	626	0.02	626
	(0.00)		(0.03)		(0.04)	
Vendor-Assessed Output Quality*Treated	0.01	626	0.01	626	-0.08	626
	(0.00)		(0.06)		(0.08)	
Chose Vendor for Quality	-0.02	626	0.01	626	0.02	626
	(0.00)		(0.05)		(0.07)	
Chose Vendor for Quality*Treated	0.02	626	-0.05	626	-0.08	626
	(0.00)		(0.07)		(0.13)	
Enumerator-Assessed Input Quality	0.01	626	-0.08**	626	0.01	626
	(0.00)		(0.03)		(0.07)	
Enumerator-Assessed Input Quality*Treated	-0.00	626	0.07	626	-0.17*	626
	(0.00)		(0.05)		(0.10)	
Purchased Nuts out of Shell	-0.00	626	-0.00	626	0.00	626
	(0.00)		(0.00)		(0.00)	
Purchased Nuts out of Shell*Treated	0.00	626	0.00*	626	0.00	626
	(0.00)		(0.00)		(0.00)	
Mean Daily Sales	-0.06	626	0.12*	626	0.10	626
	(0.00)		(0.07)		(0.15)	
Mean Daily Sales*Treated	0.09	626	0.08	626	0.35*	626
	(0.00)		(0.10)		(0.21)	
Correctly Identifies At Risk Nut Characteristics	-0.01	626	0.04*	626	-0.06***	626
	(0.00)		(0.02)		(0.02)	
Correctly Identifies At Risk Nut Characteristics*Treated	-0.00	626	-0.06*	626	0.09*	626
	(0.00)		(0.03)		(0.05)	
% Groundnuts Sorted Out	0.04	626	-0.37	626	0.17	626
	(0.00)		(0.27)		(0.38)	
% Groundnuts Sorted Out*Treated	0.15	626	0.43	626	-0.52	626
	(0.00)		(0.35)		(0.54)	
Currently Selling Kulikuli	-0.00	626	0.06	626	0.01	626
	(0.00)		(0.04)		(0.06)	
Currently Selling Kulikuli*Treated	0.01	626	-0.05	626	-0.15	626
	(0.00)		(0.06)		(0.12)	
Price of Groundnut Stock(GhC)	-0.00	626	-0.00	626	0.00	626
	(0.00)		(0.00)		(0.00)	
Price of Groundnut Stock(GhC)*Treated	-0.00	626	0.01	626	0.01**	626
	(0.00)		(0.01)		(0.01)	
Time Spent Sorting(Hrs)	0.00	626	0.00	626	0.01	626
	(0.00)		(0.01)		(0.01)	
Time Spent Sorting(Hrs)*Treated	-0.01*	626	-0.01	626	0.02	626
	(1.00)		(0.01)		(0.01)	
Purchases Unbroken Nuts (Omitted)	-0.01	626	-0.11	626	-0.15	626
	(0.00)		(0.07)		(0.10)	
Purchases Unbroken Nuts*Treated	-0.02	626	0.08	626	-0.18	626
	(0.00)		(0.10)		(0.14)	
Visually Sorts Nuts	-0.02	626	-0.25**	626	-0.56***	626
	(0.00)		(0.11)		(0.10)	
Visually Sorts Nuts*Treated	-1.25	626	-7.16	626	20.49	626
	(0.00)		(7.48)		(14.85)	
Weight per Unit(Grams)	0.00	626	0.00	626	0.00	626
	(0.00)		(0.00)		(0.00)	
Weight per Unit(Grams)*Treated	-0.00	626	-0.00	626	-0.00	626
	(0.00)		(0.00)		(0.00)	

Table 1.11: Attrition Drivers Untreated v. Control

Baseline Dependent Variables	Any Follow Up Survey	Observations	Any Follow Up Input	Observations	Any Follow up Sample	Observations
Untreated	0.15	622	0.01	622	-0.46	622
	(0.00)		(0.34)		(0.51)	
Aflatoxin Levels (IHS)	-0.00	622	-0.02	622	-0.01	622
	(0.00)		(0.02)		(0.03)	
Aflatoxin Levels (IHS)*Untreated	-0.00	622	0.04	622	-0.02	622
	(0.00)		(0.03)		(0.05)	
Aflatoxin Below 10PPB	0.03	622	-0.09	622	-0.02	622
	(0.00)		(0.07)		(0.14)	
Aflatoxin Below 10PPB*Untreated	-0.05	622	0.05	622	0.11	622
	(0.00)		(0.13)		(0.22)	
Knowledge of Health Risks Associated with Aflatoxins	-0.00	622	0.00	622	-0.02	622
	(0.00)		(0.02)		(0.03)	
Knowledge of Health Risks Associated with Aflatoxins*Untreated	-0.00	622	0.00	622	-0.01	622
	(0.00)		(0.03)		(0.06)	
Aware of Aflatoxins	0.02	622	-0.05	622	0.40***	622
	(0.00)		(0.04)		(0.10)	
Aware of Aflatoxins*Untreated	-0.01	622	0.01	622	-0.10	622
	(0.00)		(0.09)		(0.21)	
Mean Daily Consumption	-0.00	622	-0.00	622	-0.00*	622
	(0.00)		(0.00)		(0.00)	
Mean Daily Consumption*Untreated	0.00*	622	-0.00	622	0.00	622
	(1.00)		(0.00)		(0.00)	
Compared multiple vendors	0.00	622	-0.03	622	0.07	622
	(0.00)		(0.04)		(0.08)	
Compared multiple vendors*Untreated	0.03	622	0.08	622	-0.08	622
	(0.00)		(0.06)		(0.12)	
Consumes Outsorts	0.00	622	0.00	622	0.00	622
	(0.00)		(0.00)		(0.00)	
Consumes Outsorts*Untreated	0.02	622	-0.01	622	-0.07	622
	(0.00)		(0.04)		(0.08)	
Discards Outsorts	-0.03	622	0.06	622	0.33**	622
	(0.00)		(0.06)		(0.16)	
Discards Outsorts*Untreated	0.05*	622	0.09	622	0.08	622
	(1.00)		(0.07)		(0.12)	
Price per Weight (Pesewas per Gram)	-0.07	622	-0.02	622	-0.01	622
	(0.00)		(0.11)		(0.22)	
Price per Weight (Pesewas per Gram)*Untreated	0.15	622	0.25	622	0.21	622
	(0.00)		(0.16)		(0.25)	
Price of Output	-0.17	622	-0.32	622	-0.14	622
	(0.00)		(0.24)		(0.33)	
Price of Output*Untreated	0.01	622	-0.56	622	-0.72	622
	(0.00)		(0.41)		(0.65)	
Mentions Food Safety as Goal	0.24	622	0.85	622	0.98	622
	(0.00)		(0.55)		(0.76)	
Mentions Food Safety as Goal*Untreated	0.06*	622	0.07	622	0.18**	622
	(1.00)		(0.07)		(0.07)	
Mean Daily Production	-0.04	622	0.10	622	-0.08	622
	(0.00)		(0.11)		(0.12)	
Mean Daily Production*Untreated	0.00	622	0.00	622	-0.00	622
	(0.00)		(0.00)		(0.00)	
Vendor-Assessed Output Quality	-0.00	622	0.00	622	0.00	622
	(0.00)		(0.00)		(0.00)	
Vendor-Assessed Output Quality*Untreated	0.00	622	-0.00	622	0.02	622
	(0.00)		(0.03)		(0.04)	
Chose Vendor for Quality	0.02	622	-0.00	622	-0.08	622
	(0.00)		(0.06)		(0.09)	
Chose Vendor for Quality*Untreated	-0.02	622	0.01	622	0.02	622
	(0.00)		(0.05)		(0.07)	
Enumerator-Assessed Input Quality	-0.02	622	0.03	622	-0.04	622
	(0.00)		(0.07)		(0.12)	
Enumerator-Assessed Input Quality*Untreated	0.01	622	-0.08**	622	0.01	622
	(0.00)		(0.03)		(0.07)	
Purchased Nuts out of Shell	-0.01	622	-0.06	622	0.01	622
	(0.00)		(0.07)		(0.10)	
Purchased Nuts out of Shell*Untreated	-0.00	622	-0.00	622	0.00	622
	(0.00)		(0.00)		(0.00)	
Mean Daily Sales	0.00	622	0.00	622	-0.00	622
	(0.00)		(0.00)		(0.00)	
Mean Daily Sales*Untreated	-0.06	622	0.12*	622	0.10	622
	(0.00)		(0.07)		(0.15)	
Correctly Identifies At Risk Nut Characteristics	0.09	622	-0.12	622	0.15	622
	(0.00)		(0.11)		(0.22)	
Correctly Identifies At Risk Nut Characteristics*Untreated	-0.01	622	0.04*	622	-0.06***	622
	(0.00)		(0.02)		(0.02)	
% Groundnuts Sorted Out	-0.00	622	-0.05	622	0.04	622
	(0.00)		(0.04)		(0.04)	
% Groundnuts Sorted Out*Untreated	0.04	622	-0.37	622	0.17	622
	(0.00)		(0.27)		(0.37)	
Currently Selling Kulikuli	-0.08	622	0.36	622	0.68	622
	(0.00)		(0.40)		(0.55)	
Currently Selling Kulikuli*Untreated	-0.00	622	0.06	622	0.01	622
	(0.00)		(0.04)		(0.06)	
Price of Groundnut Stock(GhC)	-0.01	622	0.09	622	-0.00	622
	(0.00)		(0.10)		(0.14)	
Price of Groundnut Stock(GhC)*Untreated	-0.00	622	-0.00	622	0.00	622
	(0.00)		(0.00)		(0.00)	
Time Spent Sorting(Hrs)	-0.00	622	-0.00	622	0.01	622
	(0.00)		(0.00)		(0.01)	
Time Spent Sorting(Hrs)*Untreated	0.00	622	0.00	622	0.01	622
	(0.00)		(0.01)		(0.01)	
Purchases Unbroken Nuts (Omitted)	-0.00	622	-0.01	622	-0.00	622
	(0.00)		(0.01)		(0.02)	
Purchases Unbroken Nuts*Untreated	-0.01	622	-0.11	622	-0.15	622
	(0.00)		(0.07)		(0.10)	
Visually Sorts Nuts	-0.06	622	0.06	622	-0.18	622
	(0.00)		(0.10)		(0.16)	
Visually Sorts Nuts*Untreated (Omitted)	-0.02	622	-0.25**	622	-0.56***	622
	(0.00)		(0.11)		(0.10)	
Weight per Unit(Grams)	0.00	622	0.00	622	0.00	622
	(0.00)		(0.00)		(0.00)	
Weight per Unit(Grams)*Untreated	-0.00	622	-0.00	622	-0.00	622
	(0.00)		(0.00)		(0.00)	

Table 1.12: Attrition Drivers Treated v. Untreated

Baseline Dependent Variables	Any Follow Up Survey	Observations	Any Follow Up Input	Observations	Any Follow up Sample	Observations
Aflatoxin Levels (IHS)	0.00	390	0.00	390	-0.11***	390
	(0.00)		(0.02)		(0.04)	
Aflatoxin Levels (IHS)*Treated	-0.01	390	0.01	390	0.07	390
	(0.00)		(0.03)		(0.07)	
Treated Producer (Omitted)	2.75	390	20.83	390	5.89	390
	(0.00)		(29.12)		(54.55)	
Aflatoxin Below 10PPB	-0.01	390	0.11	390	-0.34*	390
	(0.00)		(0.10)		(0.18)	
Aflatoxin Below 10PPB*Treated	-0.01	390	-0.15	390	0.43*	390
	(0.00)		(0.13)		(0.25)	
Knowledge of Health Risks Associated with Aflatoxins	0.00	390	0.00	390	0.06	390
	(0.00)		(0.02)		(0.05)	
Knowledge of Health Risks Associated with Aflatoxins*Treated	-0.00	390	0.00	390	-0.09	390
	(0.00)		(0.04)		(0.07)	
Aware of Aflatoxins	-0.03	390	0.17	390	0.21	390
	(0.00)		(0.16)		(0.13)	
Aware of Aflatoxins*Treated	0.04	390	-0.21	390	0.09	390
	(0.00)		(0.19)		(0.22)	
Mean Daily Consumption	-0.00	390	0.00	390	-0.00	390
	(0.00)		(0.00)		(0.00)	
Mean Daily Consumption*Treated	0.00	390	-0.00	390	0.00	390
	(0.00)		(0.00)		(0.00)	
Compared multiple vendors	0.00	390	0.03	390	0.14*	390
	(0.00)		(0.06)		(0.08)	
Compared multiple vendors*Treated	0.04	390	0.03	390	-0.15	390
	(0.00)		(0.08)		(0.12)	
Consumes Outsorts	0.00	390	0.09	390	0.06	390
	(0.00)		(0.09)		(0.15)	
Consumes Outsorts*Treated	-0.02	390	-0.04	390	0.19	390
	(0.00)		(0.10)		(0.20)	
Discards Outsorts	-0.06	390	0.01	390	0.14	390
	(0.00)		(0.13)		(0.22)	
Discards Outsorts*Treated	0.04	390	0.06	390	-0.07	390
	(0.00)		(0.19)		(0.31)	
Price per Weight (Pesewas per Gram)	0.01	390	0.23	390	-0.34	390
	(0.00)		(0.21)		(0.37)	
Price per Weight (Pesewas per Gram)*Treated	-0.03	390	-0.29	390	0.41	390
	(0.00)		(0.28)		(0.49)	
Price of Output	-0.03	390	-0.48	390	0.44	390
	(0.00)		(0.42)		(0.64)	
Price of Output*Treated	0.28*	390	0.77	390	-0.19	390
	(1.00)		(0.56)		(0.92)	
Mentions Food Safety as Goal	-0.04	390	0.11	390	0.23	390
	(0.00)		(0.10)		(0.14)	
Mentions Food Safety as Goal*Treated	0.06	390	0.06	390	-0.14	390
	(0.00)		(0.15)		(0.20)	
Mean Daily Production	0.00	390	-0.00	390	0.00	390
	(0.00)		(0.00)		(0.00)	
Mean Daily Production*Treated	-0.00	390	0.00	390	0.00	390
	(0.00)		(0.00)		(0.00)	
Vendor-Assessed Output Quality	0.01	390	0.01	390	-0.06	390
	(0.00)		(0.04)		(0.07)	
Vendor-Assessed Output Quality*Treated	0.01	390	-0.02	390	0.00	390
	(0.00)		(0.07)		(0.10)	
Chose Vendor for Quality	0.01	390	-0.04	390	-0.06	390
	(0.00)		(0.05)		(0.09)	
Chose Vendor for Quality*Treated	-0.04	390	0.07	390	0.04	390
	(0.00)		(0.07)		(0.12)	
Enumerator-Assessed Input Quality	0.01	390	-0.02	390	-0.17**	390
	(0.00)		(0.05)		(0.08)	
Enumerator-Assessed Input Quality*Treated	-0.00	390	-0.12	390	0.19	390
	(0.00)		(0.08)		(0.12)	
Purchased Nuts out of Shell	0.00	390	0.00	390	0.00	390
	(0.00)		(0.00)		(0.00)	
Purchased Nuts out of Shell*Treated	-0.00	390	-0.00	390	-0.00	390
	(0.00)		(0.00)		(0.00)	
Mean Daily Sales	0.02	390	0.20**	390	0.45**	390
	(0.00)		(0.09)		(0.18)	
Mean Daily Sales*Treated	0.01	390	-0.20	390	-0.20	390
	(0.00)		(0.15)		(0.27)	
Correctly Identifies At Risk Nut Characteristics	-0.01*	390	-0.02	390	0.03	390
	(1.00)		(0.02)		(0.04)	
Correctly Identifies At Risk Nut Characteristics*Treated	-0.00	390	0.01	390	-0.06	390
	(0.00)		(0.04)		(0.06)	
% Groundnuts Sorted Out	0.19*	390	0.07	390	-0.35	390
	(1.00)		(0.23)		(0.40)	
% Groundnuts Sorted Out*Treated	-0.23	390	-0.08	390	1.20**	390
	(0.00)		(0.43)		(0.60)	
Currently Selling Kulikuli	0.00	390	0.01	390	-0.15	390
	(0.00)		(0.05)		(0.11)	
Currently Selling Kulikuli*Treated	-0.02	390	0.14	390	0.15	390
	(0.00)		(0.10)		(0.18)	
Price of Groundnut Stock(GhC)	-0.00	390	0.01	390	0.02***	390
	(0.00)		(0.00)		(0.00)	
Price of Groundnut Stock(GhC)*Treated	-0.00	390	-0.01	390	-0.01	390
	(0.00)		(0.01)		(0.01)	
Time Spent Sorting(Hrs)	-0.00	390	-0.00	390	0.03**	390
	(0.00)		(0.01)		(0.01)	
Time Spent Sorting(Hrs)*Treated	0.01	390	-0.00	390	-0.02	390
	(0.00)		(0.01)		(0.02)	
Purchases Unbroken Nuts (Omitted)	-0.02	390	-0.03	390	-0.33***	390
	(0.00)		(0.07)		(0.11)	
Purchases Unbroken Nuts*Treated	-0.05	390	-0.02	390	0.00	390
	(0.00)		(0.11)		(0.18)	
Visually Sorts Nuts	-5.19	390	9.49	390	20.45	390
	(0.00)		(18.79)		(33.43)	
Visually Sorts Nuts*Treated	2.82	390	21.60	390	4.87	390
	(0.00)		(29.24)		(54.83)	
Weight per Unit(Grams)	0.00	390	0.00	390	-0.00	390
	(0.00)		(0.00)		(0.00)	
Weight per Unit(Grams)*Treated	0.00	390	-0.00	390	0.00	390
	(0.00)		(0.00)		(0.00)	

Table 1.13: Producer Rating Display

	Round 1		Round 2		Round 3	
Rating Card Receives	% Displayed	Total	% Displayed	Total	% Displayed	Total
Green	76%	33	72%	43	62%	65
Yellow	71%	42	63%	58	68%	50
Orange	75%	41	60%	55	69%	58
No Rating Card	38%	21	35%	23	45%	20
Total		137		179		193

Table 1.14: Survey and Samples Taken by Treatment Group

Surveys Taken	Treated (N=197)	Untreated (N=193)	Control (N=429)
Baseline	100%	100%	100%
Any Follow Up Survey	99.0%	96.4%	92.8%
All Follow Up Surveys	90.4%%	82.9%	81.6%
Input Quality Data			
Baseline	100%	100%	100%
Any Follow Up Data	99.0%	96.4%	92.8%
All Follow Up Data	89.8%	82.4%	81.4%
Output Quality Data			
Baseline Samples	76.1%	72.0%	71.3%
Any Follow Up Samples	69.0%	65.3%	63.2%
All Follow Up Samples	30.5%	28.0%	32.9%

Figure 1.11: Kulikuli Ready to be Sold

1.11.7 Appendix Cont.

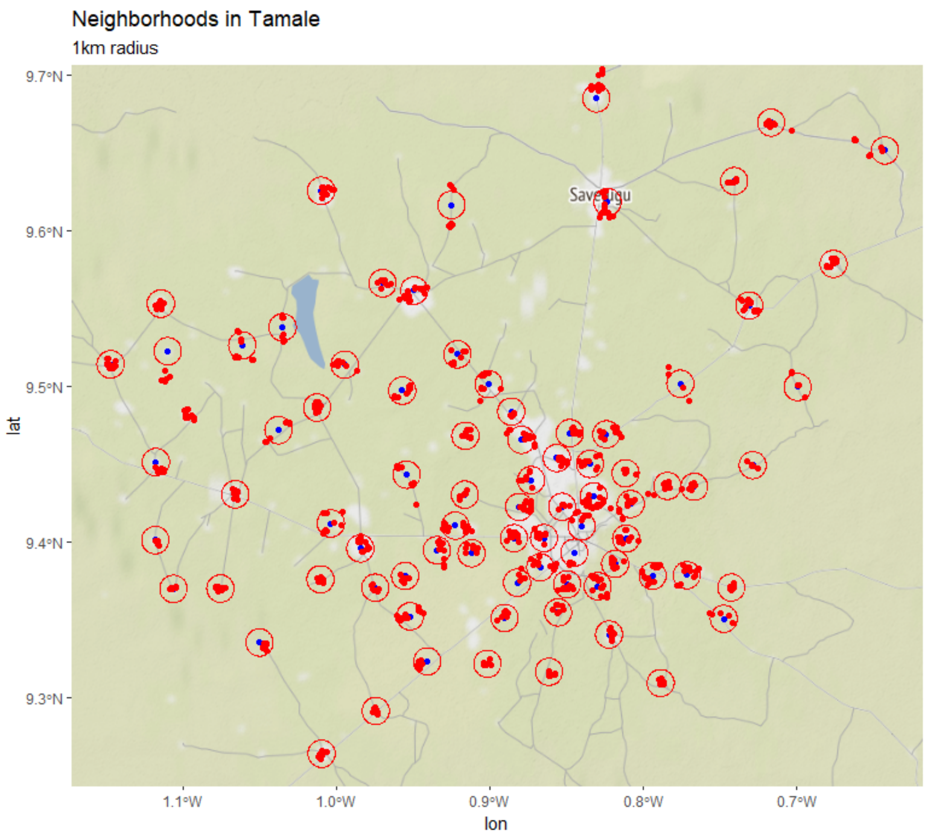
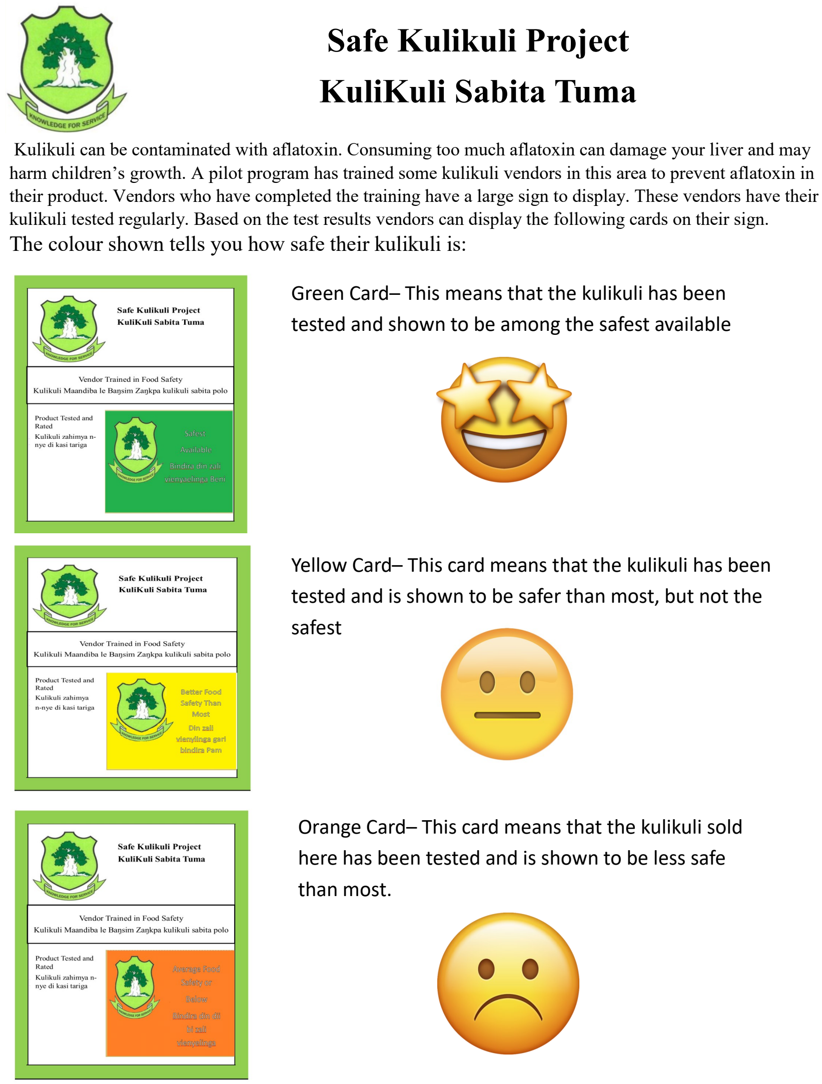


Figure 1.12: Market Clusters



Safe Kulikuli Project
KuliKuli Sabita Tuma

Kulikuli can be contaminated with aflatoxin. Consuming too much aflatoxin can damage your liver and may harm children's growth. A pilot program has trained some kulikuli vendors in this area to prevent aflatoxin in their product. Vendors who have completed the training have a large sign to display. These vendors have their kulikuli tested regularly. Based on the test results vendors can display the following cards on their sign.

The colour shown tells you how safe their kulikuli is:

Green Card– This means that the kulikuli has been tested and shown to be among the safest available

Yellow Card– This card means that the kulikuli has been tested and is shown to be safer than most, but not the safest

Orange Card– This card means that the kulikuli sold here has been tested and is shown to be less safe than most.

Figure 1.13: Consumer Flyer

Figure 1.14: Producer Personal Flyer

Figure 1.15: Producer Poster

Figure 1.16: Grading Cards

1.12 Presentation Tables

1.12.1 OLS Tables

Table 1.15: Knowledge Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Aware of Aflatoxins in Kulikuli	0.10***	572	-0.01	556	0.02
	(0.03)		(0.01)		
Aware of Issues in Kulikuli	0.68***	572	-0.03	556	0.19
	(0.06)		(0.05)		
Knowledge of Health Risks Associated with Aflatoxins	1.38***	572	0.01	556	-0.35
	(0.17)		(0.02)		
Correctly Identifies At Risk Nut Characteristics	0.33***	593	0.03	584	-0.10
	(0.12)		(0.11)		

Table 1.16: Groundnut Purchase Practices Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Different Vendor than Baseline	0.07***	561	0.03	548	0.37
	(0.02)		(0.02)		
Compared Multiple Vendors	0.13**	593	0.13**	584	0.72
	(0.06)		(0.05)		
Purchased Nuts out of Shell	0.11**	593	0.11**	584	0.85
	(0.05)		(0.05)		
Purchased Unbroken Nuts	0.15***	593	0.15***	584	0.75
	(0.06)		(0.05)		
Price of Groundnut Stock (GhC)	-0.13	572	-0.45	556	42.01
	(0.73)		(0.67)		

Table 1.17: Sorting Practices Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
% Groundnuts Sorted Out	0.01	589	0.01	580	0.10
	(0.01)		(0.01)		
Time Spent Sorting (Hrs)	-0.12	592	-0.09	584	2.40
	(0.28)		(0.29)		
Consumes Outsorts	-0.45***	593	-0.09***	584	0.89
	(0.04)		(0.03)		
Discards Outsorts	0.16***	593	0.06***	584	0.04
	(0.03)		(0.02)		

Table 1.18: Product Quality Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Mentions Food Safety as Goal	0.25***	593	0.13***	584	0.12
	(0.06)		(0.05)		
Log of Aflatoxin Level	-0.34***	407	-0.04	397	96.27
	(0.11)		(0.12)		
Aflatoxin Below 10ppb	0.07**	407	0.03	397	0.09
	(0.03)		(0.03)		

Table 1.19: Business Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Currently Selling Kulikuli	0.02	593	-0.04*	584	0.78
	(0.02)		(0.02)		
Log of Mean Daily Sales	-0.21	580	-0.36**	565	2.36
	(0.13)		(0.15)		
Price per Unit Output (GhC)	0.03	592	0.02	584	0.37
	(0.03)		(0.03)		
Weight per Unit (Grams)	2.27	407	-1.65	397	57.07
	(2.05)		(2.60)		

1.12.2 Lasso Tables

Table 1.20: PDSLasso Knowledge Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Aware of Aflatoxins in Kulikuli	0.11***	572	-0.01	556	0.02
	(0.03)		(0.01)		
Aware of Issues in Kulikuli	0.66***	572	-0.07	556	0.19
	(0.06)		(0.05)		
Knowledge of Health Risks Associated with Aflatoxins	1.44***	572	0.02	556	-0.35
	(0.16)		(0.02)		
Correctly Identifies At Risk Nut Characteristics	0.28***	593	0.01	584	-0.10
	(0.10)		(0.11)		

Table 1.21: PDSLasso Groundnut Purchase Practices Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Different Vendor than Baseline	0.06***	561	0.01	548	0.37
	(0.02)		(0.02)		
Compared Multiple Vendors	0.11**	593	0.11**	584	0.72
	(0.05)		(0.04)		
Purchased Nuts out of Shell	0.09***	593	0.09**	584	0.85
	(0.03)		(0.04)		
Purchased Unbroken Nuts	0.11***	593	0.11***	584	0.75
	(0.03)		(0.04)		
Price of Groundnut Stock (GhC)	-0.12	572	-0.16	556	42.01
	(0.72)		(0.61)		

Table 1.22: PDSLasso Sorting Practices Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
% Groundnuts Sorted Out	0.01**	589	0.01	580	0.10
	(0.01)		(0.01)		
Time Spent Sorting (Hrs)	-0.16	592	-0.13	584	2.40
	(0.24)		(0.25)		
Consumes Outsorts	-0.42***	593	-0.07**	584	0.89
	(0.04)		(0.03)		
Discards Outsorts	0.15***	593	0.04**	584	0.04
	(0.03)		(0.02)		

Table 1.23: PDSLasso Business Practices Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Currently Selling Kulikuli	-0.01	593	-0.03	584	0.78
	(0.02)		(0.02)		
Log of Mean Daily Sales	-0.32***	580	-0.40***	565	2.36
	(0.11)		(0.15)		
Price per Unit Output (GhC)	0.01	592	0.01	584	0.37
	(0.03)		(0.03)		
Weight per Unit (Grams)	2.26	407	-2.35	397	57.07
	(2.14)		(2.76)		

Table 1.24: PDSLasso Product Quality Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Mentions Food Safety as Goal	0.24***	593	0.11***	584	0.12
	(0.05)		(0.03)		
Log of Aflatoxin Level	-0.29**	407	-0.04	397	96.27
	(0.11)		(0.12)		
Aflatoxin Below 10ppb	0.07**	407	0.02	397	0.09
	(0.03)		(0.03)		

1.12.3 Full Regression (Full Controls added)

Table 1.25: Knowledge Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Aware of Aflatoxins in Kulikuli	0.11***	572	-0.01	556	0.02
	(0.03)		(0.01)		
Aware of Issues in Kulikuli	0.66***	572	-0.07	556	0.19
	(0.06)		(0.05)		
Knowledge of Health Risks Associated with Aflatoxins	1.44***	572	0.02	556	-0.35
	(0.16)		(0.02)		
Correctly Identifies At Risk Nut Characteristics	0.28***	593	0.01	584	-0.10
	(0.10)		(0.11)		

Table 1.26: Groundnut Purchase Practices Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Different Vendor than Baseline	0.06***	561	0.01	548	0.37
	(0.02)		(0.02)		
Compared Multiple Vendors	0.11**	593	0.11**	584	0.72
	(0.05)		(0.04)		
Purchased Nuts out of Shell	0.09***	593	0.09**	584	0.85
	(0.03)		(0.04)		
Purchased Unbroken Nuts	0.11***	593	0.11***	584	0.75
	(0.03)		(0.04)		
Price of Groundnut Stock (GhC)	-0.12	572	-0.16	556	42.01
	(0.72)		(0.61)		

Table 1.27: Sorting Practices Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
% Groundnuts Sorted Out	0.01**	589	0.01	580	0.10
	(0.01)		(0.01)		
Time Spent Sorting (Hrs)	-0.16	592	-0.13	584	2.40
	(0.24)		(0.25)		
Consumes Outsorts	-0.42***	593	-0.07**	584	0.89
	(0.04)		(0.03)		
Discards Outsorts	0.15***	593	0.04**	584	0.04
	(0.03)		(0.02)		

Table 1.28: Product Quality Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Mentions Food Safety as Goal	0.24***	593	0.11***	584	0.12
	(0.05)		(0.03)		
Log of Aflatoxin Level	-0.29**	407	-0.04	397	96.27
	(0.11)		(0.12)		
Aflatoxin Below 10ppb	0.07**	407	0.02	397	0.09
	(0.03)		(0.03)		

Table 1.29: Business Practices Outcomes

Dependent Variables	Treated vs. Control	Observations	Untreated vs. Control	Observations	Control Mean
Currently Selling Kulikuli	0.01	626	-0.02	622	0.78
	(0.02)		(0.02)		
Log of Mean Daily Sales	-0.32***	580	-0.40***	565	2.36
	(0.11)		(0.15)		
Price per Unit Output (GhC)	0.01	592	0.01	584	0.37
	(0.03)		(0.03)		
Weight per Unit (Grams)	2.26	407	-2.35	397	57.07
	(2.14)		(2.76)		

1.12.4 Balance Tables

Table 1.30: Knowledge Outcomes

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Aware of Aflatoxins in Kulikuli	0.03	0.03	0.01	0.03	626	-0.01	390	0.03	622
				(0.03)		(0.01)		(0.03)	
Aware of Issues in Kulikuli	0.30	0.31	0.39	-0.04	626	0.00	390	-0.05	622
				(0.07)		(0.04)		(0.07)	
Log of Mean Daily Sales	10.02	15.61	14.08	1.49	372	-5.62*	223	3.79	359
				(2.68)		(5.08)		(4.94)	
Correctly Identifies At Risk Nut Characteristics	0.13	0.05	-0.08	0.09	569	0.09	356	0.06	559
				(0.15)		(0.09)		(0.15)	
Total Observations	197	193	429						

Table 1.31: Groundnut Purchase Practices Outcomes

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Compared Multiple Vendors	0.72	0.70	0.79	-0.06	574	0.02	358	-0.08	558
				(0.05)		(0.04)		(0.05)	
Purchases Nuts out of Shell	0.92	0.92	0.98	-0.04	573	-0.01	358	-0.04	561
				(0.03)		(0.03)		(0.03)	
Purchased Unbroken Nuts	0.86	0.88	0.87	0.03	573	-0.02	358	0.04	561
				(0.07)		(0.03)		(0.07)	
Price of Groundnut Stock(GhC)	0.56	0.49	0.66	-0.05	374	0.09	224	-0.13	362
				(0.09)		(0.06)		(0.10)	
Total Observations	197	193	429						

Table 1.32: Sorting Practices Outcomes

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
% Groundnuts Sorted Out	0.17	0.17	0.18	0.02	382	-0.00	232	0.02	368
				(0.02)		(0.01)		(0.02)	
Time Spent Sorting (Hrs)	27.52	26.76	28.66	0.37	567	0.09	368	-0.45	551
				(1.32)		(0.52)		(1.48)	
Consumes Outsorts	0.86	0.89	0.82	0.01	575	-0.03	359	0.07*	562
				(0.04)		(0.04)		(0.04)	
Discards Outsorts	0.05	0.05	0.08	-0.01	575	0.01	359	-0.03	562
				(0.03)		(0.02)		(0.03)	
Total Observations	197	193	429						

Table 1.33: Product Quality Outcomes

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Mentions Food Safety as Goal	0.08	0.07	0.10	-0.03	626	0.02	390	-0.04	622
				(0.04)		(0.03)		(0.04)	
Aflatoxin Level	111.97	113.46	133.56	-23.78**	456	1.66	289	-20.93*	445
				(10.43)		(9.57)		(11.65)	
Aflatoxin Below 10ppb	0.13	0.12	0.08	0.06*	456	0.02	289	0.04	445
				(0.03)		(0.04)		(0.03)	
Total Observations	197	193	429						

Table 1.34: Business Practices Outcomes

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Currently Selling Kulikuli	2.06	2.25	2.54	-0.34	543	-0.19	317	-0.32	524
				(0.36)		(0.26)		(0.36)	
Log of Mean Daily Sales	10.02	15.61	14.08	1.49	372	-5.62^{*}	223	3.79	359
				(2.68)		(5.08)		(4.94)	
Price per Unit Output (GhC)	0.24	0.24	0.23	0.01	570	-0.00	356	0.01	554
				(0.01)		(0.01)		(0.01)	
Weight per Unit (Grams)	62.40	54.54	58.13	3.77	524	7.34^{***}	337	-2.33	495
				(3.35)		(2.42)		(3.94)	
Total Observations	197	193	429						

Table 1.35: Knowledge Outcomes Analysis Sample

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Aware of Aflatoxins in Kulikuli	0.03	0.03	0.01	0.03	572	-0.01	370	0.04	556
				(0.03)		(0.01)		(0.03)	
Aware of Issues in Kulikuli	0.30	0.29	0.35	-0.00	572	0.01	370	-0.03	556
				(0.07)		(0.04)		(0.07)	
Knowledge of Health Risks Associated with Aflatoxins	-0.12	-0.13	0.00	-0.05	572	0.02	370	-0.08	556
				(0.14)		(0.09)		(0.14)	
Correctly Identifies At Risk Nut Characteristics	0.12	0.04	-0.09	0.07	559	0.09	352	0.06	549
				(0.15)		(0.09)		(0.15)	
Total Observations	197	193	429						

Table 1.36: Groundnut Purchase Practices Outcomes Analysis Sample

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Compared Multiple Vendors	0.72	0.69	0.79	-0.06	564	0.02	354	-0.09	548
				(0.05)		(0.04)		(0.05)	
Purchased Nuts out of Shell	0.92	0.92	0.98	-0.04	563	-0.01	354	-0.03	551
				(0.02)		(0.03)		(0.02)	
Purchased Unbroken Nuts	0.86	0.88	0.87	0.04	563	-0.01	354	0.04	551
				(0.08)		(0.03)		(0.07)	
Price of Groundnut Stock (GhC)	0.83	0.89	0.90	-0.09^{**}	370	-0.06	221	-0.04	357
				(0.04)		(0.04)		(0.05)	
Total Observations	197	193	429						

Table 1.37: Sorting Practices Outcomes Analysis Sample

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
% Groundnuts Sorted Out	0.17	0.17	0.18	0.02	373	-0.00	228	0.01	359
				(0.02)		(0.01)		(0.02)	
Time Spent Sorting (Hrs)	27.52	26.76	28.66	0.37	567	0.09	368	-0.45	551
				(1.32)		(0.52)		(1.48)	
Consumes Outsorts	0.86	0.89	0.82	0.02	565	-0.02	355	0.07	552
				(0.04)		(0.04)		(0.04)	
Discards Outsorts	0.05	0.05	0.09	-0.02	565	-0.00	355	-0.03	552
				(0.03)		(0.02)		(0.03)	
Total Observations	197	193	429						

Table 1.38: Product Quality Outcomes Analysis Sample

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Mentions Food Safety as Goal	0.08	0.07	0.11	-0.04	593	0.01	381	-0.05	584
				(0.04)		(0.03)		(0.05)	
Aflatoxin Level	84.07	85.56	87.87	0.56	407	-1.49	262	5.24	397
				(14.15)		(13.98)		(15.65)	
Aflatoxin Below 10ppb	0.12	0.12	0.09	0.04	337	0.01	222	0.04	333
				(0.03)		(0.04)		(0.03)	
Total Observations	197	193	429						

Table 1.39: Business Practices Outcomes of Analysis Sample

Dependent Variables	Treated	Control	Untreated	Treated vs. Control	Observations	Untreated vs. Control	Observations	Treated vs. Untreated	Observations
Currently Selling Kulikuli	2.07	2.27	2.55	-0.35	532	-0.21	312	-0.35	514
				(0.38)		(0.26)		(0.37)	
Log of Mean Daily Sales	10.19	16.14	14.25	1.84	364	-5.96*	216	4.52*	348
				(2.73)		(5.23)		(5.11)	
Price per Unit Output (GhC)	0.24	0.24	0.23	0.01	559	-0.00	351	0.01	544
				(0.01)		(0.01)		(0.01)	
Weight per Unit (Grams)	61.85	55.34	59.54	1.36	394	5.22	259	-2.66	383
				(3.18)		(2.74)		(4.20)	
Total Observations	197	193	429						

1.12.5 Difference in Differences Analysis

Table 1.40: Knowledge Outcomes

Dependent Variables	Treated vs. Control	Control Mean	Observations	Untreated vs. Control	Control Mean
Aware of Aflatoxins in Kulikuli	0.08**	572	-0.04	556	0.02
	(0.03)		(0.03)		
Aware of Issues in Kulikuli	0.69***	572	0.01	556	0.19
	(0.09)		(0.09)		
Knowledge of Health Risks Associated with Aflatoxins	1.44***	572	0.10	556	-0.35
	(0.24)		(0.15)		
Correctly Identifies At Risk Nut Characteristics	0.26*	559	-0.02	549	-0.10
	(0.14)		(0.13)		

Table 1.41: Groundnut Purchase Practices Outcomes

Dependent Variables	Treated vs. Control	Control Mean	Observations	Untreated vs. Control	Control Mean
Different Vendor than Baseline	0.07***	561	0.03	548	0.37
	(0.02)		(0.02)		
Compared Multiple Vendors	0.18***	564	0.19***	548	0.72
	(0.06)		(0.06)		
Purchased Nuts out of Shell	0.14**	563	0.13**	551	0.85
	(0.06)		(0.06)		
Purchased Unbroken Nuts	0.12*	563	0.11*	551	0.75
	(0.06)		(0.06)		
Price of Groundnut Stock (GhC)	-0.33	567	0.13	551	42.01
	(1.57)		(1.63)		

Table 1.42: Sorting Practices Outcomes

Dependent Variables	Treated vs. Control	Control Mean	Observations	Untreated vs. Control	Control Mean
% Groundnuts Sorted Out	0.01	589	0.06	580	0.10
	(0.11)		(0.10)		
Time Spent Sorting (Hrs)	0.21	532	0.25	514	2.40
	(0.47)		(0.46)		
Consumes Outsorts	-0.46***	565	-0.16***	552	0.89
	(0.06)		(0.04)		
Discards Outsorts	0.17***	565	0.09***	552	0.04
	(0.04)		(0.03)		

Table 1.43: Product Quality Outcomes

Dependent Variables	Treated vs. Control	Control Mean	Observations	Untreated vs. Control	Control Mean
Mentions Food Safety as Goal	0.27***	593.00	0.17***	584.00	0.12
	(0.06)		(0.05)		
Log of Aflatoxin Level	-0.14	337.00	0.09	333.00	96.27
	(0.16)		(0.18)		
Aflatoxin Below 10ppb	0.04	337.00	-0.00	333.00	0.09
	(0.04)		(0.05)		

Table 1.44: Business Practices Outcomes

Dependent Variables	Treated vs. Control	Control Mean	Observations	Untreated vs. Control	Control Mean
Currently Selling Kulikuli	0.11***	370	0.01	357	0.78
	(0.03)		(0.05)		
Log of Mean Daily Sales	-55.36	365	-152.52	350	2.36
	(91.00)		(165.72)		
Price per Unit Output (GhC)	0.02	559	0.01	544	0.37
	(0.03)		(0.03)		
Weight per Unit (Grams)	0.92	394	1.28	383	57.07
	(3.20)		(4.25)		

1.12.6 Consumer Attrition Table

Table 1.45: Consumer Survey Rate

Surveys Taken	Treated (N=505)	Control (N=431)
Baseline	100%	100%
Any Follow Up Survey	94.1%	98.4%
All Follow Up Surveys	79.4%	92.1%

1.12.7 Consumer Balance Table

Table 1.46: Balance Table

Aware of Producer Intervention	0.20	0.27	-0.04 (0.06)	936.00
Kulikuli Purchases per Week	2.35	2.25	0.20 (0.15)	936.00
Units of Purchase	8.15	7.65	0.65 (0.71)	918.00
Quality Varies by Producer	1.26	1.39	-0.12 (0.11)	936.00
Knowledge of Food Safety Issues in Kulikuli	-0.07	0.08	-0.14 (0.10)	935.00
Chose Kulikuli Vendor for Safe/Clean Product	0.03	0.09	-0.04 (0.04)	936.00
Age of Youngest Consumer	31.00	32.19	-1.62 (1.66)	897.00
Total Observations	505.00	431.00		

Table 1.47: Balance Table of Analysis Sample

Dependent Variables	Treated	Control	Treated vs. Control	Observations
Aware of Producer Intervention	0.20	0.27	-0.04	855
			(0.06)	
Kulikuli Purchases per Week	2.35	2.25	0.07	855
			(0.09)	
Units of Purchase	8.15	7.65	0.79	838
			(0.78)	
Quality Varies by Producer	1.26	1.39	-0.14	804
			(0.11)	
Knowledge of Food Safety Issues in Kulikuli	-0.07	0.08	-0.14	854
			(0.10)	
Chose Kulikuli Vendor for Safe/Clean Product	0.03	0.09	-0.04	855
			(0.04)	
Age of Youngest Consumer	31	32.19	-1.61	821
			(1.64)	
Total Observations	505	431		

1.12.8 Consumer Lasso Table

Table 1.48: Consumer Treatment Effect

Dependent Variables	Treatment Effect	Control Mean	Observati
Aware of Producer Intervention	0.14***	0.02	817.0
	(0.03)		
Kulikuli Purchases per Week	-0.02	1.85	855.0
	(0.10)		
Units per Purchase	1.06*	6.44	853.0
	(0.64)		
Quality Varies by Producer	0.11*	1.81	804.0
	(0.06)		
Knowledge of Food Safety Issues in Kulikuli	0.07	-0.25	855.0
	(0.07)		
Chose Kulikuli Vendor for Safe/Clean Product	0.07	0.38	855.0
	(0.06)		
Age of Youngest Consumer	-0.89	4.46	855.0
	(0.91)		

Chapter 2

Challenges to Establishing Premium Groundnut Value Chains: Lessons from an (Attempted) Field Experiment in Ghana

2.1 Introduction

Agricultural value chain development is a priority for many governments, non-government organizations (NGOs), and private actors for its potential to increase farmer incomes and improve food quality. In many developing countries agricultural value chains have undergone rapid transformation in the past few decades, in large part due to the expansion of supermarkets (Reardon et al., 2003; Weatherspoon & Reardon, 2003). Reardon et al. (2009) describe a set of conditions necessary for value chain development including products that can be differentiated by quality, downstream buyers able to pay above market rates, cost-effective aggregation, and manageable risk of shortages and contract violations. In our attempts to establish a value chain for high-quality groundnuts in Ghana as part of a field experiment, we encountered several challenges to these conditions that we believe are characteristic of the groundnut value chain in Ghana, and more broadly throughout the developing world: uncertainty, cash flow constraints, and lack of trust. The goal of this paper is to share our experience, highlighting how these overarching issues prevent value chain development that should benefit both producers and consumers.

Aflatoxin contamination of staple crops such as maize, rice, and groundnuts presents a unique challenge to groundnut value chain development. In West Africa, where groundnut production is a major source of income, nutrition, and employment (Ntare et al., 2005), the risk of aflatoxin contamination is high. This is primarily due to the hot, dry climate, combined with low irrigation rates, which create an ideal environment for the growth of *Aspergillus flavus*, the fungus that produces aflatoxin (Florkowski & Kolavalli, 2014). Aflatoxin is invisible and tasteless, and chronic exposure to aflatoxin is linked to liver disease (IARC, 1993; Williams et al., 2004; Liu & Wu, 2010; Liu et al., 2012) and stunting among children (Hoffmann et al., 2018; Gong et al., 2004). It cannot be eliminated through processing or cooking. Attempts to incentivize groundnut farmers to adopt aflatoxin control technologies have seen mixed results. Deutschmann et al. (2020) finds that food safety incentivized contract farming in Senegal greatly increases the adoption of AflaSafe, a soil additive containing atoxigenic strains of *Aspergillus flavus* that out-compete toxigenic strains resulting in reduced aflatoxin production. In Ghana, Magnan et al. (2021) find that introducing a new buyer offering a premium for low aflatoxin groundnuts did not increase the adoption of drying tarpaulins, which requires a cash investment, but did increase other aflatoxin-mitigating post-harvest practices that do not. Unlike their counterparts in Senegal, the Ghanaian farmers were not involved in contract farming, nor were they offered inputs on credit.

The overarching goal of our research project was to develop a value chain linking smallholders to a premium processor through aggregators. This value chain would benefit farmers, who would receive higher prices, and processors, who would receive produce of known and high quality. Unlike other research in this field, we attempted to create this value chain within a highly disorganized and disaggregated market environment, which proved to be an immense challenge.

The rest of this paper proceeds as follows. In Section 2.2 we briefly discuss the current state of the groundnut value chain in Northern Ghana and outline three main challenges to its development. In Section 2.3 we describe our proposed research project and our experiences working with groundnut value chain actors. In Section 2.4 we offer some potential solutions to the problems we encountered. In Section 2.5 we conclude.

2.2 The Groundnut Value Chain in Ghana

The groundnut value chain in Ghana consists of many fragmented smallholder farmers, aggregators, processors, and retailers. Downstream actors have little to no information about the conditions under which groundnuts are grown, dried, and stored. Consumers cannot identify safe groundnuts and groundnut products in this market environment, as aflatoxin is invisible, odorless, and tasteless. Because acute toxicosis from aflatoxin consumption is rare and the diseases linked to aflatoxin occur over long periods of exposure, aflatoxin safety can be considered a credence good; quality is unknown by the consumer even after purchasing it. For these reasons, it is very difficult to establish quality premiums to incentivize farmers, leaving markets full of unsafe groundnuts.

Figure 1 shows the many actors in the Ghanaian groundnut value chain, highlighting its fragmented and non-linear nature. Aggregators play a central role. These aggregators typically purchase groundnuts from farmers or farmer groups in order to resell them on the spot market to larger downstream aggregators or to wholesalers. Alternatively, aggregators can purchase groundnuts from farmers to fulfill a purchase agreement with processors. Oftentimes, an aggregator will provide farmers with inputs on credit and collect payment in groundnuts at harvest.

The aggregator model is full of challenges, especially when it comes to supplying premium groundnut processors. First, farmers may decide to side sell to a different buyer after agreeing to sell to an aggregator. Processors may receive lower quantity and quality deliveries from aggregators than expected. Delays in aggregation and deliveries can lead to broken purchase agreements. As a result, domestic firms that require low aflatoxin groundnuts often resort to importing rather than sourcing locally, despite Ghana being the tenth largest groundnut producing country in the world (FAOSTAT, 2016). In our efforts to connect smallholders to premium processors through a more direct and linear value chain, we interacted with many value chain actors including farmers, out-growers, aggregators, processors, and NGOs. In the remainder of this section, we will discuss the three main challenges inhibiting groundnut value chain development: uncertainty, cash flow constraints, and a lack of trust.

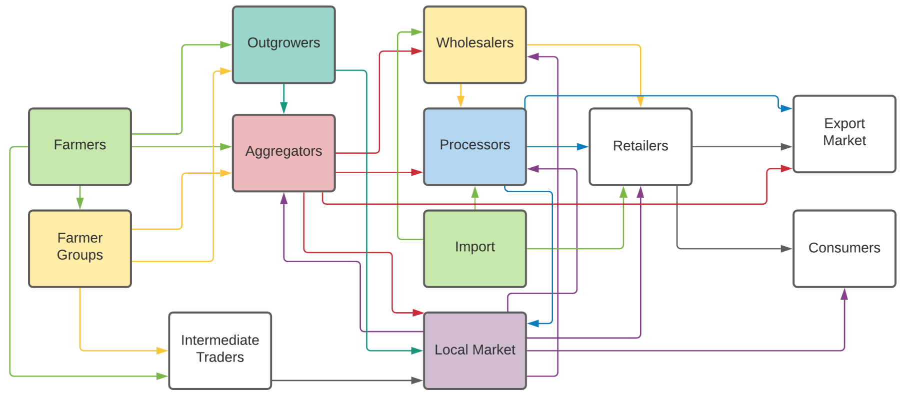


Figure 2.1: Groundnut Value Chain

2.2.1 Uncertainty

The first overarching issue inhibiting groundnut value chain development is uncertainty. Uncertainty exists for both price and quality. Price uncertainty prevents actors in the value chain (processors, aggregators, and farmers) from setting a price before harvest. The graphs in Figure 2 show the monthly prices of staple crops from June 2018 to October 2020 at three regional urban centers: Accra, Kumasi, and Tamale. Groundnut prices are volatile in the Northern region (Tamale), where 94% of all groundnuts in Ghana are produced (Masters et al., 2015). The shaded areas in Figure 2 are the months of September to December of each year when the harvest normally occurs across Northern Ghana.[6] Groundnut prices often increase before harvest and drop shortly after, however the degree to which the prices fluctuate is not similar across the three years.

[6] Discussions with Aggregators from Northern and Upper West, 2021

The price of groundnuts in Tamale is impacted by many factors such as weather, early/late harvest in other groundnut producing regions, and the quantity and quality of groundnut production in neighboring countries, such as Burkina Faso, from where large processors import low aflatoxin groundnuts. Many of the factors impacting groundnut prices are unpredictable, making it risky for aggregators and processors to set a pre-determined purchase price before harvest. If a purchase agreement price is below the eventual market price, aggregators would stand to win and farmers to lose. However, without enforceable contracts, farmers can choose to side sell at a higher price in a local market or to another aggregator. If the purchase agreement price is above the market price, farmers would stand to win and aggregators to lose. However, a processor could choose to terminate the agreement and buy from the local market or attempt to negotiate down the agreed upon price.

After the harvest, farmers are cash constrained and choose to quickly sell at local markets rather than waiting for a specific aggregator. We address farmers' cash constraints in Section 2.2.2. The risk of side selling gives farmers, aggregators, and processors a short window after harvest to establish purchase agreements. In our experience, each actor treats a purchase agreement as a one-off game where the actor attempts to maximize their short term payoff without accounting for possible future interactions with any counter-parties to a transaction. Long-term relationships can insure agents against future price fluctuations, stabilize markets, and provide incentives to invest in production. However, establishing a long-term relationship requires an agent to forego short term gains from a breach of contract.

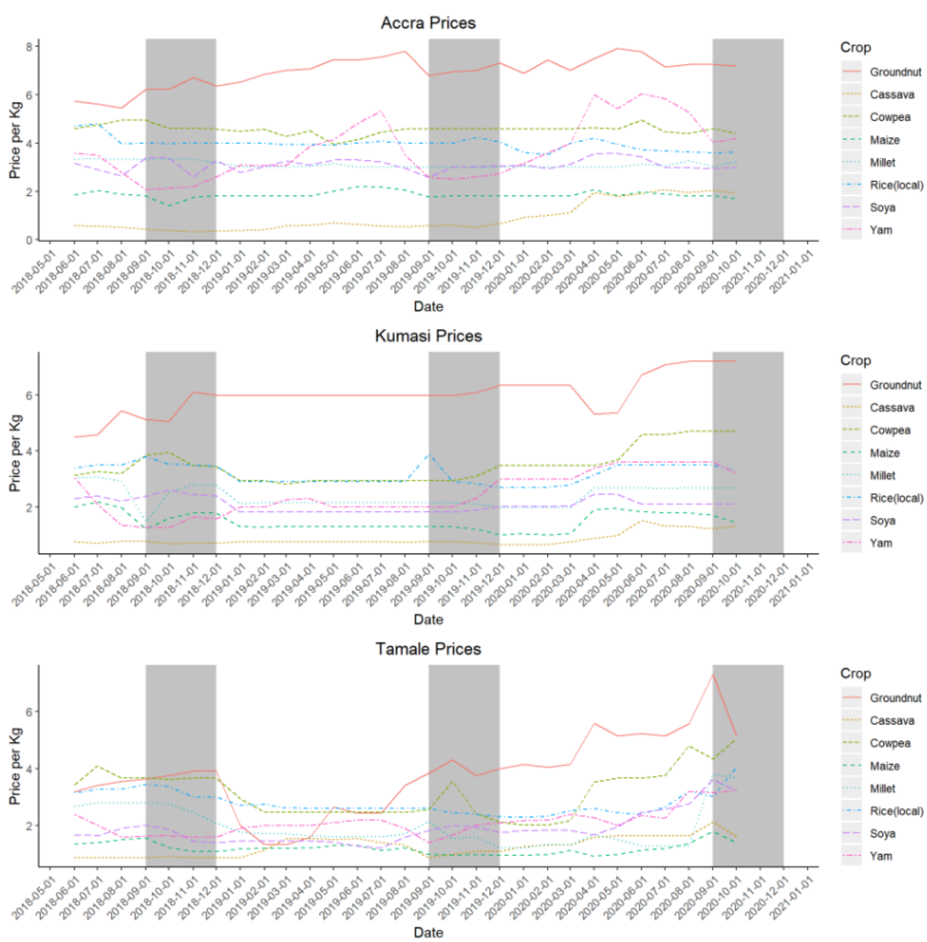


Figure 2.2: Market Prices

In addition to price uncertainty, groundnut value chains are plagued by quality uncertainly. Aflatoxin levels are highly variable from year to year, and even between regions in the same year (Magnan et al. 2021; Hoffmann & Gatobu 2014). This sets up a situation where investments in aflatoxin prevention may or may not lead to higher quality groundnuts than are widely available on the market. Aggregators and farmers face similar risks in forming advance agreements on an agreed quality, just as they do for price. If an aggregator and a farmer agree to a pre-determined price for low aflatoxin groundnuts, but aflatoxin ends up being generally low throughout the region, aggregators can purchase low aflatoxin groundnuts from the market at a lower price, forcing the farmer to lower their price or sell cheaply on the spot market. If aflatoxin levels end up being generally high and the farmer has produced low aflatoxin groundnuts, the farmer can refuse to sell to the aggregator at the agreed upon price and attempt to renegotiate.

Contracts can be used to protect both buyer and seller from price and quantity uncertainty. However, without a legal environment that supports contract enforcement, agents who wish to transact must rely on trust, a topic we will address in Section 2.2.3. If both buyer and seller take a short view of a commercial relationship, they will each try to exploit volatility when it appears to break in their favor, preventing the formation of long-term mutually beneficial relationships.

2.2.2 Cash Flow

The second overarching issue inhibiting the development of premium groundnut value chains is cash flow constraints. Groundnut farmers are exceptionally cash constrained at harvest time, and can ill-afford to wait for payment from aggregators. Even if they do enter an agreement to sell to an aggregator, side selling to meet immediate consumption needs is common. Thus, aggregators need to either provide inputs to farmers, creating an obligation to repay in groundnuts, or to provide cash on the spot when purchasing. While aggregators may not be as cash constrained as farmers, they are not always able to make cash purchases for the quantities necessary to fulfill an agreement with a downstream processor. To make such large purchases the aggregator requires early partial payment from the processor, or for farmers to wait for payment. Both of these scenarios require trust (see Section 2.2.3 below). Without trust, aggregators and processors often resort to smaller transactions drawn out over a longer period of time. This extends the length of time that groundnuts are stored on farms under sub-optimal conditions, which increases the risk of aflatoxin, thus undermining quality objectives, while also increasing the risk that a farmer decides to side sell or an aggregator to default.

Processors can also face cash flow constraints, as they do not receive payment for their groundnut products until they are sold. They are not always in a position to provide cash to aggregators to purchase groundnuts from farmers, or even to pay aggregators upon delivery. Unexpected processor cash flow problems can leave them unable to purchase the groundnuts they agreed to, forcing aggregators to sell on local markets at a lower price. In an environment where cash flow problems are frequent and at times unpredictable, it is difficult for any actor along the value chain to engage in the kind of purchase agreement necessary to get dependable quantities of high quality groundnuts from farmers to processors.

2.2.3 Trust

The final overarching issue preventing groundnut value chain development in Ghana is lack of trust. Without a strong legal environment in which contracts can be enforced, trust must be established over time through reoccurring transactions, often of increasing value. Some long-term relationships do exist in groundnut value chains in Ghana, notably between aggregators and farmers. Some aggregators build relationships with farmers over many years to gain trust and obtain a consistent supply of groundnuts. Generally these relationships are built on input provision. The aggregator provides inputs (often land preparation) on credit to farmers, who pay aggregators back in groundnuts. If farmers successfully pay the Aggregator back, other inputs may be provided on credit (e.g., seed).[7] Farmers have an incentive to pay the Aggregator back in order to receive inputs on credit in the future, reducing the risk of side selling.

[7] Personal communication with farmers and aggregator, January 2020.

Although many farmers and aggregators have long-term relationships, these relationships can be tenuous. Cash flow problems may prevent the aggregator from being able to provide farmers with inputs on credit,[8] and farmers may side sell or default on loans in order to make ends meet, despite having been supplied inputs on credit.[9] Trust can be established between aggregators and processors, but this trust can be dissolved by a single bad transaction, such as an aggregator delivering an especially low quality shipment (e.g., bags of groundnuts full of rocks and debris at the bottom),[10] or a processor not honoring a

[8] Personal communication with farmers, January 2020.

[9] Personal communication with aggregator, October 2019.

[10] Personal communication with processor, January 2020.

contract after the aggregator has purchased groundnuts from farmers, forcing them to sell at a lower price on local markets.[11]

[11] Personal communication with aggregator, January 2020.

Without trust, problems arising from uncertainty and cash flow constraints are exacerbated. Agents along the value chain can mutually insure against price and quality uncertainty, but this requires trust from both parties and repeated transactions. The spectre that one party will exit an agreement to benefit from volatility prevents purchase agreements between farmers and aggregators, and between aggregators and processors, from forming. Trust could help mitigate the effects of cash flow problems on value chain development. For instance, farmers could trust that an aggregator will pay a higher price for groundnuts later than is available on the spot market now, and aggregators could trust that processors will pay them for a large shipment after they have had some time to sell their processed products. Without trust, however, cash on delivery is expected, resulting in delays and inefficiencies that prevent value chain development.

2.3 The Attempted Project

The goal of our project was to estimate the impacts of premium value chain inclusion on smallholder farmer outcomes including production practices, yields, aflatoxin levels, and profits. To do this, we would create a premium value chain in Northern Ghana that would help smallholder farmers mitigate aflatoxin risk and remove uncertainty over aflatoxin levels for aggregators and processors. To causally estimate the impacts of being included in such a value chain, we planned a randomized control trial (RCT) with treatment assigned at the community-level. We would identify groundnut producing communities from the catchment area of the aggregator(s), and assign half of them to be invited to supply low-aflatoxin groundnuts to a premium processor through the aggregator. The other communities would be a control group and produce and market groundnuts as usual. Within each treatment community, the aggregator would work with farmer groups, training them on post-harvest practices and providing them with inputs to increase yields and reduce aflatoxin levels, notably drying tarpaulins. Properly drying groundnuts on tarpaulins and effectively storing them in well aerated areas is a low-cost and effective strategy to reducing aflatoxin levels in groundnuts (Zuza et al., 2018; Strosnider et al., 2006; Turner et al., 2005; Magnan et al., 2021).

To select aggregators for the study, we applied the following criteria: the aggregator must have experience working with groundnut farmers, have adequate cash flow to supply inputs to farmers on credit and purchase large quantities of groundnuts after harvest, be willing to pay farmers a premium for low aflatoxin groundnuts, have a good storage facility, be capable of transporting large quantities of groundnuts, and be willing to enter a purchase agreement with a premium processor. To identify aggregators, we talked with a number of people with experience in the groundnut sector in Northern Ghana, including farmers, aggregators, processors, scholars, consultants, and NGO workers.[12] We questioned 12 different aggregators in person and/or over the phone to identify those who best fit the above criteria.

[12] The Market Development Program for Northern Ghana (https://ghana-made.org) provided the most extensive list of aggregators.

We set out to work with a processor who required low-aflatoxin groundnuts and would be willing to work with an aggregator to directly source groundnuts from farmers rather than purchase them on the wholesale market. Ideally, the processor would be able to provide cash up front to aggregators to facilitate large purchases. We began the project with a certain processor in mind, but also engaged with other processors that produce a variety of groundnut products for the formal market within Ghana and for export.

Before implementing a complex RCT that would entail many transactions between one or more aggregators and hundreds of farmers, and at least one large transaction between an aggregator and a processor, we wanted to pilot a single transaction between an aggregator and processor of low-aflatoxin groundnuts produced by smallholder farmers. Unfortunately, we were not successful. The remainder of this section explains our attempts and how they broke down.

2.3.1 2019 Groundnut Harvest

Our first attempted purchase agreement was between a large agricultural Aggregator based in Accra ("Aggregator 1") and a large groundnut paste processor required to meet high safety standards ("Processor A"). Aggregator 1 mostly aggregates rice, but had aggregated groundnut in the past, including for Processor A. Processor A supplies specialized groundnut paste to the Ghanaian government for school feeding programs and also for export. They therefore must adhere to strict aflatoxin standards. In previous years, they imported groundnuts from the US to ensure low aflatoxin levels. Prior to the study, they transitioned to sourcing domestically and are often required to engage in costly sorting to meet standards.

The first purchase agreement between Aggregator 1 and Processor A was for 20 MT of groundnuts, approximately one-fifth of Processor A's annual requirement. Prior to harvest, the research team worked with Aggregator 1 to identify groundnut producing villages from which they would procure groundnuts, and delivered tarps and provided training on aflatoxin reduction to farmers in these villages. They explained that Aggregator 1 would return to purchase groundnuts at a good price (without specifics) because they would be high quality. The farmers and Aggregator 1 had no prior business interactions.

Uncertainty over the post-harvest market price led to difficulties agreeing on a price before harvest. Aggregator 1 asked the processor to pay 9 GhS/kg, approximately 3 GhS/kg over the expected market price and 1.5 GhS/kg above what Processor A was willing to pay. In order to increase the likelihood of a successful transaction between Aggregator 1 and Processor A, the research team agreed to cover the 1.5 GhS/kg difference. While this action on behalf of the research team calls into question whether future transactions could be made without it, we felt it was necessary to build trust and experience between the two parties. With the help of the research team, Aggregator 1 and Processor A finalized negotiations January of 2020, three months after harvest. Once the terms of the agreement were finalized, Aggregator 1 informed us that they would not have the cash to begin purchasing groundnuts until an unrelated (rice) sale was completed. During this time, Processor A became doubtful of Aggregator 1's ability to fulfill the agreement and began purchasing from local markets at a low price. Aflatoxin risk did not pose a problem to Processor A because overall levels were generally low. At this point, Processor A terminated the purchase agreement with Aggregator 1, stating that they no longer needed groundnuts.

Following the breakdown between Aggregator 1 and Processor A, the research team and Aggregator 1 met with two large processors in Accra to attempt a second purchase agreement for the 2019 harvest, despite it being long after harvest. Both processors, "Processor B" and "Processor C", stated that they imported groundnuts from Burkina Faso because it was cheaper and lower risk than purchasing within Ghana. Surprisingly, Processor B, an exporter of branded groundnut snacks, did not know if they tested for aflatoxin. Their quality concerns were that groundnuts be of uniform size, not shriveled, and white skinned (as opposed to the red skinned groundnuts predominantly grown in Northern Ghana). The lack of concern over aflatoxin and need for white-skinned groundnuts led us to believe Processor B would not be a suitable partner for the project.

Processor C reported sorting out 50 percent of their groundnuts, despite importing them, to meet quality standards. Nevertheless, they said it was less expensive to import groundnuts than to source them domestically. Previous experiences with aggregators made Processor C apprehensive about working with Aggregator 1 without a legally binding purchase agreement. The processor also expressed concern about working with a research team and over whether the working relationship would continue after the study. Aggregator 1 expressed concern over Processor C importing instead of honoring the purchase agreement, and also over the possibility that Processor C would reduce the size of the agreement if consumer demand for their product was low. Ultimately, Processor C declined to enter a purchase agreement because they lacked contracts with retailers that would ensure a need for large quantities of groundnuts.

At this point we turned our attention to smaller processors that do not import. We contacted three such processors who all explained that they cannot engage in the types of large purchase agreements that are advantageous to aggregators. Thus, we went back to Processor A to establish a smaller purchase agreement in the hopes this could lead to larger ones in the future.

In February of 2020, four months after harvest, Aggregator 1 and Processor A established a second purchase agreement for 5 MT at 5.8 GhS/kg, with the research team paying an additional 4.2 GhS/kg to Aggregator 1. A member of the research team accompanied Aggregator 1 to conduct aflatoxin testing with farmers. The groundnuts tested well below the allowable limit and would require little to no sorting. Despite Aggregator 1 having provided training and tarpaulins (or perhaps because of it), the farmers demanded well above the prevailing market price. Furthermore, many farmers had already sold much of their harvest by this time. Because Aggregator 1 did not supply inputs beyond the tarpaulins, the farmers felt no obligation to sell to Aggregator 1, who only managed to purchase 166 kg of groundnuts, forcing them to terminate the purchase agreement with Processor A.

Our attempts to establish a sale from the 2019 groundnut harvest ultimately failed due to a combination of the three factors described above. Price uncertainty led to delays in finalizing a purchase agreement, and lower than expected aflatoxin levels and market prices made the purchase agreement less beneficial for Processor A, making it easy for them to terminate. Aggregator

1's cash constraint prevented them from purchasing groundnuts from farmers in a timely manner. Processor A's cash constraint made them unable to afford the groundnuts at the agreed upon price after the delay in delivery. A lack of trust delayed or prevented the formation of purchase agreements in the first place. Aggregator 1 did not trust that any of the processors would follow through with the purchase agreement, fearing they would instead import or purchase on the spot market. The processors did not trust that Aggregator 1 would deliver the specified quantity and quality of groundnuts. Finally, it also turned out that Aggregator 1 should not have trusted the farmers to sell at a reasonable price after giving them tarpaulins and training.

We should reiterate here that the purchase agreements we attempted to establish were very small. They did not require a massive cash outlay, and were intended to build trust so that larger agreements could be made in the future. The fact that we could not even facilitate a small purchase agreement for premium groundnuts was a cause for concern, but we opted to try again the following season.

2.3.2 2020 Groundnut Harvest

For the 2020 harvest, we identified an aggregator working out of the Upper West region, "Aggregator 2", through an international NGO. At the time, Aggregator 2 was working with the NGO on a project to improve groundnut quality and connect smallholder farmers to markets. Aggregator 2 had longstanding relationships with hundreds of smallholder farmers, had made large sales to processors in the past, had good storage facilities, and importantly, had a line of credit from the NGO to provide inputs to farmers. While credit from NGOs for aggregators is not common, it could be possible for processors to provide credit for this purpose once trust and a trading relationship is established. Importantly, Aggregator 2 had experience with aflatoxin-mitigating technologies. We facilitated a purchase agreement between Aggregator 2 and Processor A, and they settled on a quantity of 100 MT. Consistent with our previous experience, Aggregator 2 and Processor A struggled to agree on price, or even a price premium, before harvest, with Aggregator 2 saying it was too risky to do so before the market price was known.

At the start of the 2020 groundnut season, Aggregator 2 provided seed, land preparation, and fertilizer to farmer groups on credit. The research team purchased tarpaulins and worked with Aggregator 2 to provide training on post-harvest practices to the farmers. After harvest, the research team tested the farmers' groundnuts for aflatoxin, and they were again extremely low. Knowing this, Aggregator 2 set their price at 15 GhS/kg, nearly triple the market price at the time, believing the groundnuts their farmers produced were uniquely low in aflatoxin and claiming to have an exporter that would pay that price if Processor A would not. The high asking price and threat to leave the purchase agreement created considerable tension with Processor A. We discussed the price with Aggregator 2 at length, explaining that Processor A could simply purchase groundnuts on the market and sort if necessary, and managed to reduce his asking price to 9 GhS/kg – still nearly twice the market price. Because of their commitment to the research project, Processor A reluctantly accepted this price. However, they stated they would not work with the Aggregator 2 again.[13] Given that this transaction would not lead to future ones, we encouraged Processor A to terminate the purchase agreement and ended our interactions with Aggregator 2.

[13] In our interactions with Aggregator 2, we found them to frequently exhibit aggressive and bullying behavior to us, to Processor A, and to others.

Having the NGO provide credit to Aggregator 2 resolved the cash flow issue, but price uncertainty and a lack of trust still prevented a sale. After two years of purchase agreements failing due to recurring issues of uncertainty, cash flow constraints, and a lack of trust, we decided it would not be possible to build the necessary relationships to develop a premium groundnut value chain from farmer to aggregator to processor in Northern Ghana within the time horizon of our research project.

2.4 Lessons for Future Value Chain Interventions and Research

The experiences described above indicate that overcoming one or even multiple obstacles to value chain development may not be enough. The research team provided inputs and aflatoxin testing in the field to remove uncertainty over quality and worked with an aggregator who was well financed to prevent cash flow constraints. Furthermore, we subsidized prices to bridge the gap between aggregators and processors. Whether the market price turned out to be high or low, our subsidy would increase the likelihood that processors and aggregators would face an advantageous price, and that the aggregator would be able to pass some of the premium on to farmers. However, several problems remained. In both years, aflatoxin levels in groundnuts available in the market were low enough that processors could easily abandon a purchase agreement, putting the aggregator at risk. Low levels of trust persisted throughout the value chain. Aggregators could not trust farmers, and aggregators and processors could not trust each other. In most cases this lack of trust seems justified, in large part due to uncertainty and cash flow problems beyond the control of any agent.

Here we propose three possible interventions for the development of premium groundnut value chains in Ghana. The first is to use a flexible contract design. Instead of a pre-determined price and quantity (e.g., 7 GhS/kg for 100 MT of groundnuts), the purchase agreement could use a pre-determined premium based on the market price and a quantity range. This would reduce price risk for both aggregators and processors, increase the speed at which purchase agreements are made, and prevent price disagreements. We did suggest this possibility to Aggregator 2, but they wanted to wait until after harvest to make any agreements pertaining to price. Nevertheless, we think these types of agreements merit further exploration. The literature on contracts under price uncertainty focuses on quantity-flexible contracts (Tsay, 1999), options (Cheng et al., 2003), and risk-sharing (Li & Kouvelis, 1999). These studies all involve more developed value chains; there exist little research on contract structure in emerging value chains.

The second intervention is vertical integration. Large processors can invest directly in their own value chain to diminish the role of aggregators. Vertical integration removes problems associated with the lack of trust between aggregators and processors, although trust issues with farmers could remain. Indeed, several processors we spoke with showed interest in directly purchasing from farmers after multiple failed purchase agreements and poor experiences transacting with aggregators.[14] Vertical integration can provide more supply and demand assurance than informal contract arrangements (Macchiavello & Miquel-Florensa, 2017) and allow for quality control. Partial vertical integration in the Ghanaian pineapple industry allowed processors and exporters to maintain strict quality control while spreading exporting risk among multiple smallholder producers (Suzuki et al., 2011).

[14] Personal communication with processor, January 2020.

Although partial vertical integration has seen success in the Ghanaian pineapple sector, there remain several advantages to the aggregator model. While it may be possible for processors to work directly with large farmers, this could exclude smallholders from these value chains, or position large outgrowers as *de facto* aggregators. Aggregators have the advantage of geographical, and in some instances social, proximity to farmers. This could reduce the risk of side selling by farmers. Aggregators also provide local storage and logistics support. With vertical integration, these functions would all fall on the processor, who may not be well positioned to perform them.

The third intervention is a transparent and competitive market for purchase agreements between aggregators and processors. We believe that such a market would speed up purchase agreements, whether they occur before or after harvest. Such a market would also make it easier for processors to engage in multiple purchase agreements to reduce their exposure to contract risk. This would also prevent aggregators from acting as monopolists and renegotiating prices after harvest. Aggregators could also benefit from engaging in several purchase agreements with different processors for the same reason. Aggregators and processors could use this market to experiment with different counterparts and build longer relationships based on their experiences.

While we believe a market for purchase agreements would reduce risk in the groundnut value chain and eventually lead to more trust, intermediaries can act in an anti-competitive manner. Bergquist (2017) finds that intermediaries in Kenya collude, leading to higher profits for traders at the expense of both the producer and the consumer. They find that lowering barriers to entry for traders does not necessarily remedy the problem, as traders were able to maintain their monopolistic pricing even after more traders entered the market. Chau et al. (2016) finds that wholesale wheat traders in Ethiopia can collude to lower the price paid to farmers in small markets, but not large ones, demonstrating the importance of having many aggregators and processors present in the market.

2.5 Conclusion

The groundnut industry in Ghana suffers from significant issues preventing the establishment of premium groundnut value chains. The goal of our project was to overcome what we believed was the primary barrier, uncertainty over quality, by providing aflatoxin-mitigating inputs to farmers and aflatoxin testing to aggregators and processors. However, other issues remained. Price uncertainly, cash flow constraints, and a lack of trust between groundnut value chain actors continued to prevent the creation and execution of purchase agreements between aggregators and processors. Subsidizing transactions to ensure an acceptable price for both parties did not solve the problem, nor did working with an aggregator with adequate cash flow.

In an environment where contracts cannot be legally enforced, other mechanisms are needed to overcome uncertainty and a lack of trust. Possibilities include flexible contracts to reduce the risk of uncertainty in the groundnut market, vertical integration to reduce distrust and potential cash flow problems, and a competitive market for purchase agreements to reduce the risks agents face in transacting with one single counter-party.

Appendix A

Appendix

Figure A.1: Kulikuli Ready to be Sold

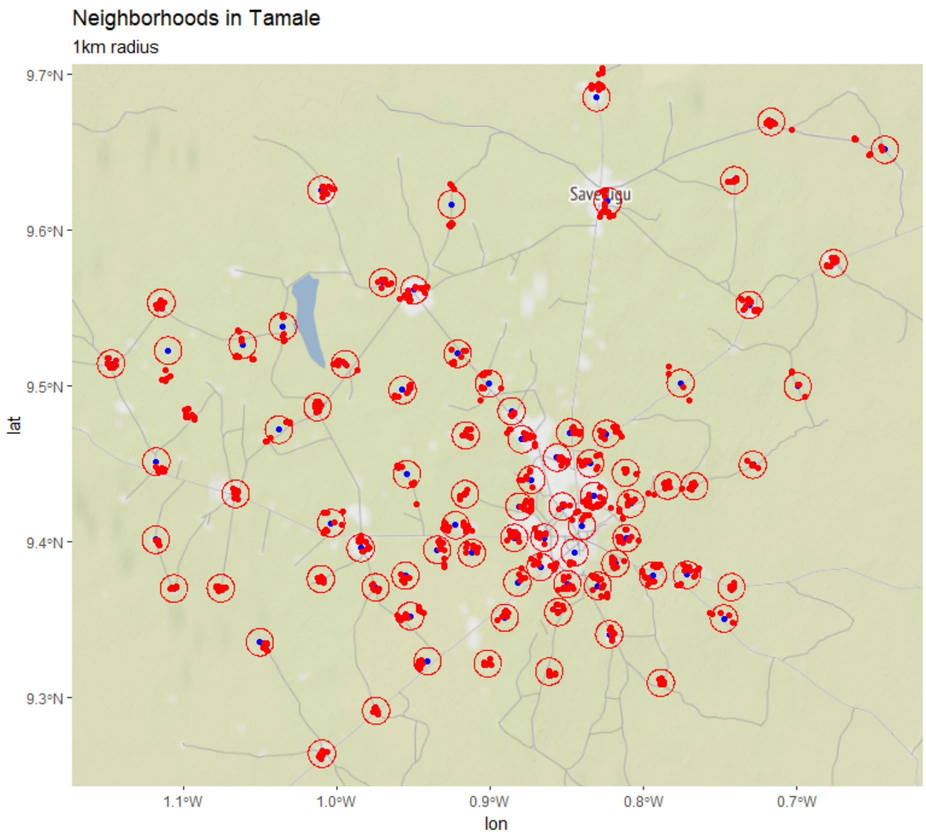


Figure A.2: Market Clusters

Figure A.3: Producer Personal Flyer

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