Do Spouses Share Information?

Exploring Intra-Household Information Sharing and Learning Using a Lab in the Field?

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1 Introduction and Motivation

In many developing countries, information is first introduced to farmers through extension agents, local traders, or marketer. Extension agents rarely meet demand for extension services while subsistence households do not interact frequently with local traders and marketers reducing many farmers access to information. Recent studies on increasing smallholder farmer's access to information focuses 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). Although these studies find higher rates of information sharing and technology adoption, many of these studies find that women had disproportionately lower access to information (Beaman & Dillon 2018, BenYishay et al. 2020). Women often rely on their husband as a primary source for information, however few studies have observed intrahousehold information sharing or potential information barriers women face within their own household. This study uses a laboratory in the field experiment to observe information sharing within the household and whether women or men face barriers to information within their household. This paper contributes to the overall understanding of household behavior and information dissemination as well as exploring the potential limitations of extension training that does not target both spouses in a household.

Although women play a key role in development, technology adoption among women continues to lag behind men. This lag is often attributed to the unique barriers women face such as time constraints, credit constraints, information constraints, and gender norms. These barriers to information are found even within the household where husbands and wives differ in their knowledge and awareness of agricultural technology (Fisher et al., 2019) and credit opportunities (Fletschner & Mesbah, 2011). Studies on information diffusion may overestimate their impact of their intervention by assuming household level access to information or household level knowledge of a new technology. Information diffusion designs, such as peer to peer farmer training, that do not include within household behavior may under perform or lead to larger gender gaps in access to information. Recent work determining spousal roles in adopting technology has found mixed results. For example Gulati et al. (2019) found that women had little influence on the adoption of a labor saving technology. However, Magnan et al. (2020) found that the adoption decision for improved maize varieties were correlated to risk preferences of both the husband's and wives showing that intrahousehold decision making is complicated, heterogeneous, and a crucial component of technology adoption and information dissemination.

Sharing information is not costless and requires time, effort to learn, and effort to train or convey information to others. Incentivizing information sharing has proven to be a useful tool to overcome these costs (BenYishay & Mobarak, 2019). Time burdens fall disproportionately on women who are often responsible for both on farm work and household work such as child rearing. More recent work on information dissemination and gender find that men often discount women's information (BenYishay et al., 2020) and treat information from strangers identical to information from their spouse (Conlon et al., 2021).

Household management schemes and plot management further complicates information sharing by changing how benefits are shared within the household. In Northern Ghana, households have either separate or joint management schemes. Households with separate management schemes produce as two separate farmers, men are the sole manager of their plots and the women are the sole manager of their plots. Households with joint management schemes manage plots jointly and spouses supply inputs jointly often with men supplying their individual plots first and their wife's plots second. The wife rarely has individual marketing decision power, e.g ability to individually sell their own crops on the market, but instead marketing decisions are decided jointly or predominantly by the husband. The management structure of the plot impacts the allocation of resources. Plots that were managed by women were often under supplied inputs, especially labor, and plots deemed to be joint managed mirrored male managed plots which often were over supplied labor (Kang et al. 2020,Udry 1996). These studies focus on physical inputs such as seeds, fertilizer, and labor, but are unable, due to alack of data, to directly observe whether information is shared in the household. Information asymmetry in households in the form of income hiding has been well studied. Castilla & Walker (2012) found that husbands and wives often report different levels of on farm income and that men hide income in the form of gifts to family and friends. Castilla & Walker (2013) find that when giving cash in private to either the husband or the wife increases the likelihood of them hiding income. Ashraf (2009) studied the impact of observability and communication on household decision making. She found when husband's income was private they often deposited money in a private account, when the husband's income was observable the husband increased their personal consumption, and when spouses were able to communicate the husband deposits money in their wife's account. Despite evidence that income hiding is prevalent in households, most theoretical models of household decision making assume that members of the household share information perfectly.

Groundnut production in Ghana presents a unique opportunity to study production and technology awareness knowledge differences between husbands and wives where information would be considered relevant for both. Groundnuts have been traditionally viewed as a "woman's crop" in Ghana and was primarily grown as a food crop to be consumed within the household. In the Northern region as groundnuts have become more marketable, men have begun growing groundnuts as a cash crop, making groundnuts a unique crop where the husband and wife grow groundnuts in the same household on their respective plots. We restrict our sample to only households where both the husband and wife produced groundnuts in the previous growing season. We compare both the information shared in the game and the differences in knowledge and awareness of groundnut technologies between spouses. We attempt to directly connect information sharing in the lab to evidence of information sharing in practice.

It is neither obvious nor theoretically intuitive whether information flows freely or frequently between husbands and wives within households. We use a laboratory experiment in the field to directly observe information sharing within the household using a cognitive puzzle game, the Tower of Hanoi. We asked spouses from groundnut producing households in Northern Ghana to attend two meetings. In the first meeting we train one spouse in each household how to solve a 4-disk version of the Tower of Hanoi. After the training they are asked to complete the puzzle for a cash prize. The untrained spouse is invited the following day and asked to complete the same task for cash. Between meetings, spouses are allowed to discuss the meeting and share information about the game and the prizes. Each household is assigned to a treatment group that decides how payment will be given and which individual from the household will be trained. We use the performance in the game along with two surveys to observe information sharing between spouses and the impact of income control on information sharing. The rest of the paper is organized as follows, section 2 outlines the experimental design, section 3 outlines the theoretical model and our hypotheses, section 4 discusses the data and empirical analysis, section 5 discusses how we plan to deal with multiple hypothesis testing, section 6 is the power calculations, and section 7 is an overview of the budget.

2 Experimental Design

Our study involves 480 households among 12 villages from Northern Ghana, the largest groundnut producing region in Ghana. Groundnuts are produced by both men and women in the household despite being referred to as a "woman's crop". Both the head of household and their spouse produce groundnuts, allowing us to compare information sharing relative to groundnut production. The husband and wife of each household will be interviewed separately. The interview consists of 6 parts: household demographics, information sources, groundnut production, spouse's groundnut production, groundnut technology and disease knowledge, and information sharing within the household.

Each household will be randomly assigned into one of four treatment groups. The treatment groups can be broken down into two categories, spouse and payment. The spouse category consists of two treatments, the husband first treatment (HF) and the wife first treatment (WF). These treatment groups determines which spouse in the household will be trained and which member of the household will rely on their spouse to train them. In the husband (wife) first treatment, the husband (wife) will be trained by the research team on how to solve the puzzle in the minimum number of moves. They will be able to share this information with their spouse after the first meeting.

The payment category consists of the individual payment treatment and the joint payment treatment. All payment will be given at the end of the second meeting. Participants will receive an envelope with their individual identification code. Participants in the individual payment treatment will receive an envelope of cash corresponding to their individual performance in the task. This treatment simulates a management scheme where individuals manage their own plots and have control over the income from those plots. Unlike the individual payment treatment, the joint payment replicates the income ownership of a joint management scheme. Instead of each participant within the household receiving their prize money separately, the household's earnings are combined and split evenly between both spouses. In the first meeting after the husband (wife) finishes the task they will be informed of how much they have earned and informed that they will receive half of the total household's prize money after the second meeting. We will use the household's responses in the survey to identify households as either joint or individual producers and stratify by production scheme into payment treatment For example, if 200 households report having a joint production scheme, we will randomly assign 100 of those households in the joint payment scheme and the other 100 households in the individual production scheme. We will do the same to the households that report an individual production scheme. Figure 1 shows the 2x2 treatment design.

	Individual Payment	Joint Payment
Husband First	HF-I 120 Households	HF-J 120 Household
Wife First	WF-I 120 Households	WF-J 120 Households

Figure 1: Treatment Design

Households will be invited to attend two meetings. Each spouse will be asked to attend one meeting. In the first meeting participants will be asked to complete the 4 disk version of the Tower of Hanoi puzzle, a novel game which requires no experience to play, it is easy to teach with a simple objection and few rules, there is a unique way to solve the game and any information obtained about this game should not hinder a players performance. Figure 1 briefly shows the design and objective of the game. The 4 disk version of the puzzle can be completed in no less than 15 moves. The puzzle is attempted using an android based tablet where the number of moves, time, and each move they make will be recorded. Participants will be between the ages of 18 and 65 years of age. This is for four reasons, that population is more relevant to this topic, farmers 65 and below often adopt technology more frequently (Adesina & Zinnah, 1993), have a higher willingness to pay for extension services (Mwaura et al., 2010), older farmers may be less capable of using a touch screen device causing the data to be misleading, and due to the COVID-19 pandemic, it is deemed safer for participants over the age of 65 to not participate in in-person studies.

The first meeting will consist of 20 participants, each participant will be given two practice rounds where they will be allowed to make as many moves as possible to ensure they understand the game and are comfortable using an Android tablet.

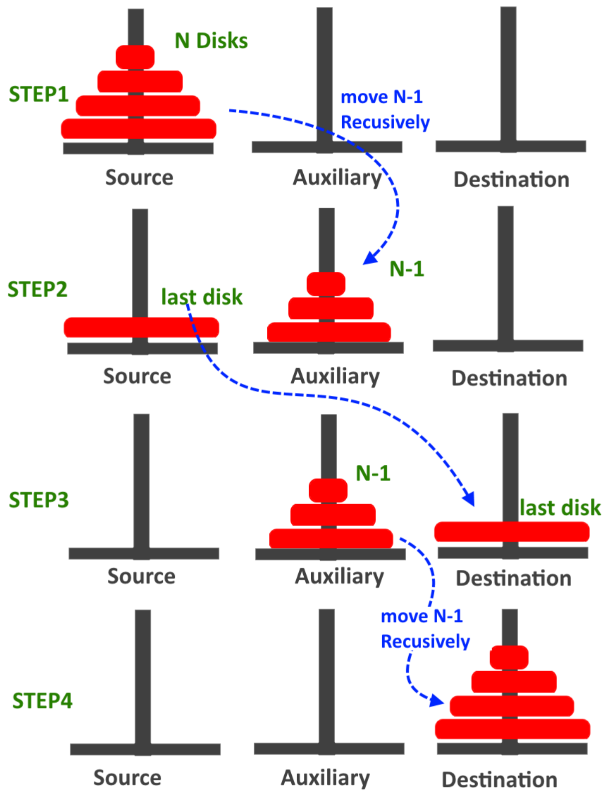

Figure 2: Tower of Hanoi (Source: www.includehelp.com)

Once each participant in the meeting has completed both practice rounds, the participants will break up into groups of 4 where they will be trained to complete the game in only 15 moves. The training will consist of an enumerator slowly showing each move and explaining why that move must be made to complete the game in only 15 moves. The goal of the training is to not only help them memorize the order in which they need to move, but to help them understand why that order is necessary. Finally, after the training, the participants will be asked to complete their third and final round where they will earn a cash prize based on their performance. The cash prizes are shown in Figure 3. To prevent censoring at 75 moves, we offer an additional 1GhC for individuals who complete the task. Any participant who chooses to forfeit a round, the tablet will record this and they will be allowed to move forward on the next round.

The cash prizes are broken down into bins to reduce the complexity of how much money each participant wins and to avoid any confusion by the participant while playing. Traditionally using a non-linear payment system can lead to censoring, players stop after a certain point where they no longer believe they can make it to the next payment system and receive no benefit from moving forward, or strategic playing that may be counter to the researchers intended goals. Neither of these issues are a concern in this experiment. Any player that can strategically make a certain number of moves to maximize their pay to effort level has a dominant strategy to complete the game in 15 moves. We don't expect any outcomes where participants strategically play the game that results in bunching or a result that doesn't align with dominant strategy of the game. A cost per move payment system may be overly confusing to a participant without adding any additional benefits.

Moves	15	≤20	≤25	≤30	≤35	≤40	≤45
Prizes	30GhC	28GhC	26GhC	24GhC	22GhC	20GhC	18GhC
Moves	≤50	≤55	≤60	≤65	≤70	≤75	>75
Prizes	16GhC	14GhC	12GhC	10GhC	8GhC	6GhC	5GhC

Table 1: Cash Prizes

Each meeting is one day apart to allow for information to be shared between spouses, but to minimize information obtained outside the household. At the second meeting, the spouse from each household who has not been trained by the research team will be asked questions to determine if information was shared, how information was shared, and to what extent did the participant from the first meeting train their spouse. After these questions are answered, the meeting will follow directly as the first meeting without the training. After all the participants have finished the task and the interview, they will receive their prize money. If the participant is in the joint payment group they will receive their portion of the household's winning, but if they are in the individual payment group they will only receive their winnings.

3 Theoretical Framework

The theoretical framework for this paper begins with a simplified household model consisting of two individuals $i \in \{1, 2\}$.First we define a simple utility function for individual i in the household. individual i will represent the individual in the household that attends the first meeting. Individual j will represent individual i's spouse. The utility function for individual i is:

$$U_i = \mu Y_i + (1 - \eta)Y_j + \phi((1 - \mu)Y_i + \eta Y_j) \tag{1}$$

Y_i and Y_j are the incomes from individual i and j such that $i \neq j$ in the household respectively. μ is the percent of income individual i keeps from their income and η is the percent of income individual j keeps from their income. ϕ is a scalar that represents the utility that individual i receives from individual j's income. ϕ could represent altruism, or individual j's contribution to household goods. The first assumption we make is $\phi < 1$ or simply individual i receives more utility from their income than from individual j. If this assumption is false, we would expect individual i to give all their income to individual j in the household as their spouse's income brings more utility than their own.

The utility function in equation 1 consists of two parts. The first part is individual i's income, the portion they keep from their own earnings and the portion they take from individual j's earnings. The second part is individual j's income, the portion individual j keeps from their own earnings and the portion they take from individual i's earnings. We can expand the simple utility model of individual i from equation 1 to fit our lab in the field setting. We can rewrite Y_i and Y_j as $Y_i = \alpha P_i(\theta_i) + (1 - \alpha)P_j(\theta_j(\theta_i, \varepsilon))$ and $Y_j = \alpha P_j(\theta_j(\theta_i, \varepsilon)) + (1 - \alpha)P_i(\theta_i)$ where $P_i(\theta_i)$ and $P_j(\theta_j(\theta_i, \varepsilon))$ is the prize money received by individual i and j from their performance. θ_i and θ_j is individual i and j's knowledge about the game. ε is individual i's effort to train their spouse. α is the researchers selected payment scheme, in the joint payment treatment

$\alpha = 0.5$ and in the individual payment treatment $\alpha = 1$. Equation 1 can be rewritten such that

$$U_i = (\mu+\phi(1-\mu))(\alpha P_i(\theta_i)+(1-\alpha)P_j(\theta_j(\theta_i,\varepsilon))+(\phi\eta+(1-\eta))(\alpha P_j(\theta_j(\theta_i,\varepsilon))+(1-\alpha)P_i(\theta_i))-L(\theta_i)-T(\varepsilon) \quad (2)$$

Individual i is the individual within the household that attends the first meeting and is trained by the research team. $L(\theta_i)$ is individual i's cost of learning and $T(\varepsilon)$ is the cost for individual i to train individual j. The prize money is determined by the performance of the individual and the functional form of both P_i and P_j is identical and only varies by θ_i and θ_j. This means that at a given level of knowledge such that $\theta_i = \theta_j$, the prize money awarded are identical, $P_i = P_j$. We can further simplify the model by removing P_i and P_j and having it only represented by θ_i and θ_j. Furthermore we can create λ_i and $_j$ such that $\lambda_i = \mu+\phi(1-\mu)$ and $\lambda_j = \phi\eta+1-\eta$. λ_i is the benefits individual i receives from their own envelope, Y_i. λ_j is the benefits individual i receives from individual j's envelope, Y_j. Therefore we can simplify equation 2 further:

$$U_i = \lambda_i(\alpha\theta_i + (1-\alpha)\theta_j(\theta_i,\varepsilon) + \lambda_j(\alpha\theta_j(\theta_i,\varepsilon)) + (1-\alpha)\theta_i - L(\theta_i)) - T(\varepsilon) \quad (3)$$

Using equation 3 we can no observe how information sharing will theoretically occur in the household. First we compare information sharing and effort under payment regimes.From equation 3, individual i will choose a level of θ_i and ε which solves the following equation:

$$\max_{\theta_i,\varepsilon} \quad \lambda_i(\alpha\theta_i + (1-\alpha)\theta_j(\theta_i,\varepsilon) + \lambda_j(\alpha\theta_j(\theta_i,\varepsilon)) + (1-\alpha)\theta_i - L(\theta_i)) - T(\varepsilon) \quad (4)$$

The first order conditions are:

$$\frac{\partial U_i}{\partial \theta_i} : (\lambda_i(1-\alpha) + \lambda_j\alpha)\frac{\partial \theta_j(\varepsilon)}{\partial \theta_i} + \alpha\lambda_i + (1-\alpha)\lambda_j = \frac{\partial L}{\partial \theta_i} \quad (5)$$

$$\frac{\partial U_i}{\partial \varepsilon} : (\lambda_i(1-\alpha) + \lambda_j\alpha)\frac{\partial \theta_j(\theta_i)}{\partial \varepsilon} = \frac{\partial T}{\partial \varepsilon} \quad (6)$$

We make two further assumptions on this model, first is that $\frac{\partial \theta_j(\varepsilon)}{\partial \theta_i} < 1$ this assumes information transfer is not perfect and as $\varepsilon \to \infty$, $\frac{\partial \theta_j(\varepsilon)}{\partial \theta_i} \to (1-\epsilon)$ where $\epsilon > 0$ but very small. Next we assume that either $\mu = 1$ or $\eta = 1$. This implies once all income sharing has occured within the household one individual in the household will receive at least their own envelope's value.

Using the first order conditions, we compare the optimal levels of θ_i and ε under both payment treatments.

$\alpha = 1$

$$\frac{\partial U_i}{\partial \theta_i} : \lambda_j\frac{\partial \theta_j(\varepsilon)}{\partial \theta_i} + \lambda_i = \frac{\partial L}{\partial \theta_i} \quad (5.1)$$

$$\frac{\partial U_i}{\partial \varepsilon} : \lambda_j\frac{\partial \theta_j(\theta_i)}{\partial \varepsilon} = \frac{\partial T}{\partial \varepsilon} \quad (6.1)$$

$\alpha = 0.5$

$$\frac{\partial U_i}{\partial \theta_i} : \frac{\lambda_i + \lambda_j}{2}(1 + \frac{\partial \theta_j(\varepsilon)}{\partial \theta_i}) = \frac{\partial L}{\partial \theta_i} \quad (5.2)$$

$$\frac{\partial U_i}{\partial \varepsilon} : \frac{\lambda_i + \lambda_j}{2}\frac{\partial \theta_j(\theta_i)}{\partial \varepsilon} = \frac{\partial T}{\partial \varepsilon} \quad (6.2)$$

To observe differences in $\theta_i^{\alpha=1}$ and $\theta_i^{\alpha=0.5}$ we directly compare equation 5.1 to equation 5.2 and differences in $\varepsilon^{\alpha=1}$ and $\varepsilon^{\alpha=0.5}$ by directly comparing equation 6.1 to equation 6.2.

$$\begin{aligned}
&\theta_i^{\alpha=1} > \theta_i^{\alpha=0.5} \\
&\qquad \lambda_i + \lambda_j \frac{\partial \theta_j(\varepsilon)}{\partial \theta_i} > \frac{\lambda_i + \lambda_j}{2}(1 + \frac{\partial \theta_j(\varepsilon)}{\partial \theta_i}) \\
&\qquad \lambda_i + \lambda_j \frac{\partial \theta_j(\varepsilon)}{\partial \theta_i} > \lambda_i \frac{\partial \theta_j(\varepsilon)}{\partial \theta_i} + \lambda_j \\
&\qquad \lambda_i > \lambda_j
\end{aligned} \tag{7}$$

$$\begin{aligned}
&\varepsilon^{\alpha=1} > \varepsilon^{\alpha=0.5} \\
&\qquad \lambda_j j \frac{\partial \theta_j(\theta_i)}{\partial \varepsilon} > \frac{\lambda_i + \lambda_j}{2} \frac{\partial \theta_j(\theta_i)}{\partial \varepsilon} \\
&\qquad \lambda_j \frac{\partial \theta_j(\theta_i)}{\partial \varepsilon} > \lambda_i \frac{\partial \theta_j(\theta_i)}{\partial \varepsilon} \\
&\qquad \lambda_j > \lambda_i
\end{aligned} \tag{8}$$

The first two hypotheses from the theoretical framework can be derived from equation 7 and 8. If the benefits from individual i's own envelope is greater than the benefits individual i receives from their spouse's envelope, $\theta_i^{\alpha=1} \geq \theta_i^{\alpha=0.5}$ and $\varepsilon^{\alpha=0.5} \geq \varepsilon^{\alpha=1}$. Households where either individual takes all of the income, we would expect to see no difference across payment treatments, or $\theta_i^{\alpha=1} = \theta_i^{\alpha=0.5}$ and $\varepsilon^{alpha=1} = \varepsilon^{\alpha=0.5}$.

This section of the theoretical framework compares the expected outcomes within the same payment treatment and across gender.

$$\begin{aligned}
&\theta_m > \theta_f \\
&\qquad (\lambda_{im}(1-\alpha) + \alpha\lambda_{jm}) \frac{\partial \theta_{jf}(\varepsilon_m)}{\partial \theta_{im}} + (\alpha\lambda_{im} + \lambda_{jm}(1-\alpha)) - \frac{\partial L}{\partial \theta_{im}} > \\
&\qquad (\lambda_{if}(1-\alpha) + \alpha\lambda_{jf}) \frac{\partial \theta_{jm}(\varepsilon_f)}{\partial \theta_{if}} + (\alpha\lambda_{if} + \lambda_{jf}(1-\alpha)) - \frac{\partial L}{\partial \theta_{if}}
\end{aligned} \tag{9}$$

$$\begin{aligned}
&\varepsilon_m > \varepsilon_f \\
&\qquad (\lambda_{im}(1-\alpha) + \lambda_{jm}\alpha) \frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} - \frac{\partial T}{\partial \varepsilon_m} > (\lambda_{if}(1-\alpha) + \lambda_{jf}\alpha) \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f} - \frac{\partial T}{\partial \varepsilon_f}
\end{aligned} \tag{10}$$

Equation 9 can be rewritten in 3 parts.

$$Part1$$

$$(\lambda_{im}(1-\alpha) + \alpha\lambda_{jm}) \frac{\partial \theta_{jf}(\varepsilon_m)}{\partial \theta_{im}} - (\lambda_{if}(1-\alpha) + \alpha\lambda_{jf}) \frac{\partial \theta_{jm}(\varepsilon_f)}{\partial \theta_{if}} \tag{9.1}$$

$$Part2$$

$$(\alpha\lambda_{im} + \lambda_{jm}(1-\alpha)) - (\alpha\lambda_{if} + \lambda_{jf}(1-\alpha)) \tag{9.2}$$

$$Part3$$

$$\frac{\partial L}{\partial \theta_{im}} - \frac{\partial L}{\partial \theta_{if}} \tag{9.3}$$

Part one can be rewritten as, $\frac{\lambda_{im}(1-\alpha)+\alpha\lambda_{jm}}{\lambda_{if}(1-\alpha)+\alpha\lambda_{jf}}$ - $\frac{\frac{\partial \theta_{jm}(\varepsilon_f)}{\theta_{if}}}{\frac{\partial \theta_{jf}(\varepsilon_m)}{\theta_{im}}}$ and part two can be rewritten as $\alpha(\lambda_{im} - \lambda_{if}) - (1-$

$\alpha)(\lambda_{jf} - \lambda_{jm})$. If part 1 + part 2 is greater than part 3, than $\theta_{im} > \theta_{if}$.

$$Part1 : \alpha = 1$$

$$\lambda_{jm}\frac{\partial\theta_{jf}(\varepsilon_m)}{\theta_{im}} > \lambda_{jf}\frac{\partial\theta_{jm}(\varepsilon_f)}{\theta_{if}}$$
$$\frac{\lambda_{jm}}{\lambda_{jf}} > \frac{\frac{\partial\theta_{jf}(\varepsilon_m)}{\theta_{im}}}{\frac{\partial\theta_{jm}(\varepsilon_f)}{\theta_{if}}} \tag{9.1.1}$$

$$Part2 : \alpha = 1$$

$$\lambda_{im} > \lambda_{if} \tag{9.2.1}$$

$$Part1 : \alpha = 0.5$$

$$(\lambda_{im} + \lambda_{jm})\frac{\partial\theta_{jf}(\varepsilon_m)}{\theta_{im}} > (\lambda_{if} + \lambda_{jf})\frac{\partial\theta_{jm}(\varepsilon_f)}{\theta_{if}}$$
$$\frac{(\lambda_{im} + \lambda_{jm})}{(\lambda_{if} + \lambda_{jf})} > \frac{\frac{\partial\theta_{jf}(\varepsilon_m)}{\theta_{im}}}{\frac{\partial\theta_{jm}(\varepsilon_f)}{\theta_{if}}} \tag{9.1.2}$$

$$Part2 : \alpha = 0.5$$

$$\lambda_{im} + \lambda_{jm} = \lambda_{if} + \lambda_{jf} \tag{9.2.2}$$

Part 1 when $\alpha = 1$ is positive if and only if $\frac{\lambda_{im}}{\lambda_{if}} > \frac{\frac{\partial\theta_{jf}(\varepsilon_m)}{\theta_{im}}}{\frac{\partial\theta_{jm}(\varepsilon_f)}{\theta_{if}}}$. As mentioned before, $\lambda_i = \mu + \phi(1 - \mu$ and $\lambda_j = \phi\eta + 1 - \eta$. ϕ, μ, and η are likely to differ by gender, however within the same household the porportion of income the husband keeps is equivalent to the proportion the wife's husband keeps or in other words $\mu_m = \eta_f$ and $\eta_m = \mu_f$. Therefore, we can rewrite λ_{im} and λ_{jm} as $\lambda_{im} = \eta_f + \phi_m(1 - \eta_f)$ and $\lambda_{jm} = \phi_m\mu_f + 1 - \mu_f$. We can now directly compare $\lambda_{im} - \lambda_{jm}$ to $\lambda_{if} - \lambda_{jf}$.

$$\eta_f + \phi_m(1 - \eta_f) - \phi_m\mu_f - 1 + \mu_f = \mu_f + \phi_f(1 - \mu_f) - \phi_f\eta_f - 1 + \eta_f$$
$$\phi_m - \phi_m\eta_f - \phi_m\mu_f = \phi_f - \phi_f\mu_f - \phi_f\eta_f$$
$$\phi_m - \phi_f = (\phi_m - \phi_f)(\mu_f + \eta_f) \tag{11}$$

Table Y shows under what scenarios $\theta_{im} > \theta_{if}$ when $\alpha = 1$

Next we look at effort within payment group across gender. We can rewrite equation 10 in two parts under the two levels of α.

$$Part1 : \alpha = 1$$

$$(\lambda_{jm})\frac{\partial\theta_{jf}(\theta_{im})}{\partial\varepsilon_m} = (\lambda_{jf})\frac{\partial\theta_{jm}(\theta_{if})}{\partial\varepsilon_f} \tag{10.11}$$

$$Part1 : \alpha = 0.5$$

$$(\lambda_{im} + \lambda_{jm})\frac{\partial\theta_{jf}(\theta_{im})}{\partial\varepsilon_m} = (\lambda_{if} + \lambda_{jf})\frac{\partial\theta_{jm}(\theta_{if})}{\partial\varepsilon_f}$$
$$\frac{(\lambda_{im} + \lambda_{jm})}{(\lambda_{if} + \lambda_{jf})} = \frac{\frac{\partial\theta_{jf}(\theta_{im})}{\partial\varepsilon_m}}{\frac{\partial\theta_{jm}(\theta_{if})}{\partial\varepsilon_f}} \tag{10.1}$$

$$Part2$$

$$\frac{\partial T}{\partial\varepsilon_m} = \frac{\partial T}{\partial\varepsilon_f} \tag{10.2}$$

Table Y shows the expected outcomes for θ and ε across genders within the individual payment treatment.

Table Y:	Expected Outcomes Under Individual Payment Treatment for θ_{im} and θ_if				
	$\frac{\partial L}{\partial \theta_{im}} > \frac{\partial L}{\partial \theta_{if}}$			$\frac{\partial L}{\partial \theta_{im}} < \frac{\partial L}{\partial \theta_{if}}$	
	$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} > \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$	$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} < \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$		$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} > \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$	$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} < \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$
$\mu_m = 1$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} \sim \theta_{if}$	$\mu_m = 1$	$\theta_{im} > \theta_{if}$	$\theta_{im} \sim \theta_{if}$
$\mu_f = 1$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} < \theta_{if}$	$\mu_f = 1$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} \sim \theta_{if}$
	Expected Outcomes Under Individual Payment Treatment for ε_m and ε_f				
	$\frac{\partial T}{\partial \varepsilon_m} < \frac{\partial T}{\partial \varepsilon_f}$			$\frac{\partial L}{\partial \theta_{im}} < \frac{\partial L}{\partial \theta_{if}}$	
	$\frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} > \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f}$	$\frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} < \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f}$		$\frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} > \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f}$	$\frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} < \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f}$
$\mu_m = 1$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$	$\mu_m = 1$	$\varepsilon_m > \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$
$\mu_f = 1$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m < \varepsilon_f$	$\mu_f = 1$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$

Table A shows the expected outcomes for θ across gender under joint payment and Table B shows the expected outcome for effort across gender when households are in the joint payment treatment.

Table A:	Expected Outcomes Under Joint Payment Treatment for θ_{im} and θ_{if}				
	$\frac{\partial L}{\partial \theta_{im}} > \frac{\partial L}{\partial \theta_{if}}$				
	$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} > \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$			$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} > \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$	
	$\mu_m = 1$	$\mu_f = 1$		$\mu_m = 1$	$\mu_f = 1$
$\phi_f > \phi_m$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} \sim \theta_{if}$	$\phi_f > \phi_m$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} < \theta_{if}$
$\phi_f < \phi_m$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} \sim \theta_{if}$	$\phi_f < \phi_m$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} \sim \theta_{if}$
	$\frac{\partial L}{\partial \theta_{im}} < \frac{\partial L}{\partial \theta_{if}}$				
	$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} > \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$			$\frac{\partial L}{\partial \theta_{im}} < \frac{\partial L}{\partial \theta_{if}}$	
	$\mu_m = 1$	$\mu_f = 1$		$\mu_m = 1$	$\mu_f = 1$
$\phi_f > \phi_m$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} \sim \theta_{if}$	$\phi_f > \phi_m$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} \sim \theta_{if}$
$\phi_f < \phi_m$	$\theta_{im} > \theta_{if}$	$\theta_{im} \sim \theta_{if}$	$\phi_f < \phi_m$	$\theta_{im} \sim \theta_{if}$	$\theta_{im} \sim \theta_{if}$

Table B: Expected Outcomes Under Joint Payment Treatment for ε_m and ε_f					
	$\frac{\partial T}{\partial \varepsilon_m} > \frac{\partial L}{\partial \varepsilon_f}$				
	$\frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} > \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f}$			$\frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} > \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f}$	
	$\mu_m = 1$	$\mu_f = 1$		$\mu_m = 1$	$\mu_f = 1$
$\phi_f > \phi_m$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$	$\phi_f > \phi_m$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m < \varepsilon_f$
$\phi_f < \phi_m$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$	$\phi_f < \phi_m$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$
	$\frac{\partial T}{\partial \varepsilon_m} < \frac{\partial T}{\partial \varepsilon_f}$				
	$\frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} < \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f}$			$\frac{\partial \theta_{jm}(\theta_{im})}{\partial \varepsilon_m} < \frac{\partial \theta_{jf}(\theta_{if})}{\partial \varepsilon_f}$	
	$\mu_m = 1$	$\mu_f = 1$		$\mu_m = 1$	$\mu_f = 1$
$\phi_f > \phi_m$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$	$\phi_f > \phi_m$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$
$\phi_f < \phi_m$	$\varepsilon_m > \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$	$\phi_f < \phi_m$	$\varepsilon_m \sim \varepsilon_f$	$\varepsilon_m \sim \varepsilon_f$

The outcomes of the within payment across gender are not straightforward and depend on many factors that vary across men and women. In order to reduce the assumptions needed, we can compare changes in learning and effort within gender due to a shift in α, $\theta_i^{\alpha=1} - \theta_i^{\alpha=0.5}$ and $\varepsilon^{\alpha=0.5} - \varepsilon^{\alpha=1}$, across genders. This allows us to remove the marginal costs that is unknown and likely to be different across genders, $\frac{\partial L}{\partial \theta_i}$ and $\frac{\partial T}{\partial \varepsilon}$, from the equations. $\theta_i^{\alpha=1} - \theta_i^{\alpha=0.5}$ and $\varepsilon^{\alpha=0.5} - \varepsilon^{\alpha=1}$ can be written as:

$$\theta_i^{\alpha=1} - \theta_i^{\alpha=0.5}$$

$$(\lambda_i - \lambda_j)(1 - \frac{\partial \theta_j(\varepsilon)}{\partial \theta_i}) \tag{12}$$

$$\varepsilon^{\alpha=0.5} - \varepsilon^{\alpha=1}$$

$$(\lambda_j - \lambda_i)(\frac{\partial \theta_j(\theta_i)}{\partial \varepsilon}) \tag{13}$$

Therefore, we can compare men to women using equation 11 and 12 where λ_i, λ_j,$\frac{\partial \theta_j(\varepsilon)}{\partial \theta_i}$, and $\frac{\partial \theta_j(\theta_i)}{\partial \varepsilon}$ vary across men and women. The difference between men and women can be written as:

$$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} = \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$$

$$(\lambda_{im} - \lambda_{jm})(1 - \frac{\partial \theta_{jf}(\varepsilon_m)}{\partial \theta_{im}}) = (\lambda_{if} - \lambda_{jf})(1 - \frac{\partial \theta_{jm}(\varepsilon_f)}{\partial \theta_{if}})$$

$$\frac{\lambda_{im} - \lambda_{jm}}{\lambda_{if} - \lambda_{jf}} = \frac{1 - \frac{\partial \theta_{jf}(\varepsilon_m)}{\partial \theta_{im}}}{1 - \frac{\partial \theta_{jm}(\varepsilon_f)}{\partial \theta_{if}}} \tag{14}$$

$$\varepsilon_m^{\alpha=0.5} - \varepsilon_m^{\alpha=1} = \varepsilon_f^{\alpha=0.5} - \varepsilon_f^{\alpha=1}$$

$$(\lambda_{im} - \lambda_{jm})(\frac{\partial \theta_{jf}(\theta_{im})}{\partial \varepsilon_m}) = (\lambda_{if} - \lambda_{jf})(\frac{\partial \theta_{jm}(\theta_{if})}{\partial \varepsilon_f})$$

$$\frac{\lambda_{im} - \lambda_{jm}}{\lambda_{if} - \lambda_{jf}} = \frac{\frac{\partial \theta_{jf}(\theta_{im})}{\partial \varepsilon_m}}{\frac{\partial \theta_{jm}(\theta_{if})}{\partial \varepsilon_f}} \tag{15}$$

Both equations depend on the ratio of the differences in λ. From equation 15, we see that the ratio of λ's is dependent on the values of ϕ for men and women. If $\phi_m > \phi_f$ or men receive more utility from their wife's income than women receive from their husband's income, then the ratio of λ's is less than 1 since $(\lambda_{im} - \lambda_{jm}) < (\lambda_{if} - \lambda_{jf})$ with the opposite holding if $\phi_f > \phi_m$. From equations 13,14 and 15, there are a number of scenarios that can occur. Table 3 examines outcomes under different scenarios.

Table B:	Expected Outcomes for $\theta_{im}^{\alpha=1} - \theta_{im}^{alpha=0.5}$ and $\theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$	
	$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} > \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$	$\frac{\partial \theta_{jm}(\varepsilon_m)}{\partial \theta_{im}} < \frac{\partial \theta_{jf}(\varepsilon_f)}{\partial \theta_{if}}$
$\phi_f > \phi_m$	$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} < \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$	$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} \sim \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$
$\phi_f < \phi_m$	$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} \sim \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$	$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} > \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$
	Expected Outcomes for $\varepsilon_m^{\alpha=1} - \varepsilon_m^{alpha=0.5}$ and $\varepsilon_f^{\alpha=1} - \varepsilon_f^{\alpha=0.5}$	
	$\frac{\partial \theta_{im}(\theta_{im})}{\partial \varepsilon_m} > \frac{\partial \theta_{jf}(\theta_{jf})}{\partial \varepsilon_f}$	$\frac{\partial \theta_{im}(\theta_{im})}{\partial \varepsilon_m} < \frac{\partial \theta_{jf}(\theta_{jf})}{\partial \varepsilon_f}$
$\phi_f > \phi_m$	$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} < \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$	$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} \sim \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$
$\phi_f < \phi_m$	$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} \sim \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$	$\theta_{im}^{\alpha=1} - \theta_{im}^{\alpha=0.5} > \theta_{if}^{\alpha=1} - \theta_{if}^{\alpha=0.5}$

The outcomes without any assumptions is not conclusive. Both gender within payment treatment outcomes and difference in payment treatment across gender. However, the literature on household behavior, time poverty and gender differences in learning have found evidence that suggest how these factors relate across gender. A household where $\frac{\partial \theta_{jf}(\varepsilon_m)}{\partial \theta_{im}} > \frac{\partial \theta_{jm}(\varepsilon_f)}{\partial \theta_{if}}$ suggests that more information is transferred with the same level of effort from the husband to the wife than from the wife to the husband. This may be a result of multiple factors, men discount information from their spouse more than wives (Conlon et al., 2021) or men learn less from trained women than from trained men (BenYishay et al., 2020). A household where $\frac{\partial \theta_{jf}(\theta_{im})}{\partial \varepsilon_m} > \frac{\partial \theta_{jm}(\theta_{if})}{\partial \varepsilon_f}$ states that the husband's training is more effective in transferring knowledge than the wife's training. Similar to information transfer, men discount their wives' information therefore regardless of the wife's effort, information is poorly transferred. We expect that men in the household's will receive a higher benefit from their wife's income than the wife receives from theirs, $\phi_m > \phi_f$. When men in the household receive a positive income shock, household expenditure on personal and luxury goods increase, but when women in the household receive a positive income shock, household expenditure on household goods increases (Duflo & Udry, 2004). Men benefit from the investment in household goods purchased from their spouse's income, while women likely receive little to no benefits from the personal and luxury goods purchased by the husband. Finally, the literature on women's time poverty has consistently found that women have a higher demand on their time and face higher rates of time poverty than men, especially married women (Abdourahman 2010;Bardasi & Wodon 2010; Zilanawala 2016). From the literature we assume that the cost of training is higher for women than men due to the high demand for their time, $\frac{\partial T}{\partial \varepsilon_f} > \frac{\partial T}{\partial \varepsilon_m}$. η and μ depend on the household sharing attributes. Papers such as Udry (1996) find that men often over supply inputs on their plots while women under supply inputs on their plots. These production behaviors would indicate men have more control over the income in the household. Based on the outcomes from the theoretical model and the results from household behavior and gender literature, we form the following six hypotheses.

Hypothesis 1: Individuals in the individual payment treatment will learn more than individuals in the joint payment treatment $\theta_i^{\alpha=1} > \theta_i^{\alpha=0.5}$.

Hypothesis 2: Individuals in the joint payment will put forth more effort to train their spouse than individuals in the individual payment treatment,$\varepsilon^{\alpha=0.5} > \varepsilon^{\alpha=1}$.

Hypothesis 3: Women will put forth less effort training their spouse than men $\varepsilon_m > \varepsilon_f$.

Hypothesis 4: Men will learn at higher rates than women $\theta_m > \theta_f$.

Hypothesis 5: The change in learning across payment groups will be higher among men than women,$\theta_m^{\alpha=1} - \theta_m^{alpha=0.5} > \theta_f^{\alpha=1} - \theta_f^{\alpha=0.5}$.

Hypothesis 6: The change in the level of effort to train their spouse will be smaller among men than women, $\varepsilon_m^{\alpha=0.5} - \varepsilon_m^{alpha=1} < \varepsilon_f^{\alpha=0.5} - \varepsilon_f^{\alpha=1}$.

4 Data and Empirical Analysis

All data will be collected on android based tablets. Each player will be assigned a household ID and person ID. The android tablets will record total number of moves, each move made, time it took to complete, date they attempted the task, and whether they forfeited. To test our hypotheses we will use the following model.

$$Y_{ij} = \beta_0 + \beta_1 Female + \beta_2(Second_{ij}) + \beta_3(Joint_j) + \beta_4(Female_{ij} * Second_{ij}) + \beta_5(Second_{ij} * Joint_j) + \beta_6(Female_{ij} * Joint_j) + \beta_7(Female_{ij} * Second_{ij} * Joint_j) + X_{ij} + \Gamma_j + \varepsilon_{ij} \quad (16)$$

Where Y_{ij} is the outcome variables: inverse of total moves and total correct moves before error. We use the inverse of the total moves to reduce the penalty of large total number of moves and a positive estimator would indicate a better performance. Directly measuring men and women outcomes could cause our analysis to be biased due to unobservable gender specific variables that impact performance. To control for this, we include the dummy variable $Female_{ij}$ which equals 1 if the individual i from household j is a female. $Second_{ij}$ is a dummy variable that equals 1 if individual i from household j attended the second meeting. $Joint_j$ is a dummy variable that equals 1 if household j was in the joint 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 meeting level, this is to capture any correlation in outcome due to meeting specific effects. The hypothesis tests we will be conducting for each outcome variable are:

Hypothesis	Hypothesis Tests	
1	$\beta_3 + \frac{1}{2}\beta_6 < 0$	$\theta_i^{\alpha=1} > \theta_i^{\alpha=.5}$
2	$\beta_3 + \beta_5 + \frac{1}{2}(\beta_6 + \beta_7) > 0$	$\varepsilon^{\alpha=1} > \varepsilon^{\alpha=.5}$
3	$\beta_1 + \beta_4 + \frac{1}{2}(\beta_6 + \beta_7) < 0$	$\varepsilon_m > \varepsilon_f$
4	$\beta_1 + \frac{1}{2}\beta_6 < 0$	$\theta_m > \theta_f$
5	$\frac{1}{2}(\beta_6 + \beta_7) < 0$	$\theta_m^{\alpha=1} - \theta_m^{\alpha=.5} > \theta_f^{\alpha=1} - \theta_f^{\alpha=.5}$
6	$\frac{1}{2}(\beta_6) > 0$	$\varepsilon_m^{\alpha=.5} - \varepsilon_m^{\alpha=1} < \varepsilon_f^{\alpha=.5} - \varepsilon_f^{\alpha=1}$

In the experiment, to set a limit and reduce fatigue, we capped the ability to lose any more cash at 80 moves, however we incentivize finishing the game by giving an additional 1GhC. 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 individual has forfeited the round, they will receive a score equal to the highest number of moves by an individual that solved the game and the time will be set to that as well. If we find that a significant amount of individuals forfeit soon after 75, we will estimate the model using a Tobit regression as a robustness check on our OLS model. Finally, if we find that the data is unreliable after 75, we will top code the data to limit the effect this variation has on the estimates.

This study requires both spouses from a household to attend a meeting and follows that household throughout the experiment creating multiple situations where households could attrit. We predict the attrition will be higher for households where the spouse that comes to the second meeting is the wife. Women have a large time burden and attending a meeting may be difficult. We also expect households with the wife as the first spouse to not attend the first meeting at a higher rate than households in the husband first treatment group. We don't have any priors on attrition due to joint or individual payment treatment. Households where a spouse does not show up for the second day will not be dropped from the field experiment, but instead we will attempt to locate these individuals before the meeting and encourage them to attend. If they are unable to attend that meeting we will attempt to have them play the game and take the survey soon after the meeting. For a robustness check in our econometric model we will add a dummy variable for households that do not come to the second meeting, but take the game at a later date. If treatment groups have different levels of the second spouse not coming to the second meeting and we are unable to locate all households we will use Lee bounds to obtain confidence intervals that are robust to differential attrition (Lee, 2009).

4.1 In Game as is in Practice

A concern with lab in the field experiments, as with any experiment, is the external validity of its findings. The goal of this lab in the field was to simplify a complex system and directly observe information sharing. The mechanisms we elicit in this experiment to observe information sharing, household income and time costs, simulate much of information sharing in practice. We expect individuals who share information within the experiment will also share information about groundnut technology with their spouse. To test these assumptions, we have made two categories of hypotheses, information sharing in practice and income hiding in practice. The first set of hypotheses compares how well spouses know about each other's groundnut production as well as available groundnut technology.

Hypothesis 9: Households where spouses share information about the game will have a smaller knowledge and awareness gap of groundnut technologies than households that do not share information about the game.

Hypothesis 10: Households where spouses share information about the game will have spouses that accurately know their spouses groundnut practices.

Household game performance will be measured by the difference in outcomes between spouses. Theoretically, if information was perfectly transferred, we would expect to see the performance of the second spouse to be as good as the first spouse. However, we expect that on average the first spouse will do better and the larger that gap the poorer the performance of that household.

To test how in game behavior reflects behavior in practice, we use the survey responses on spouses' knowledge on each other's groundnut practice to estimate information sharing and their individual knowledge on groundnut technology. The individual responses will be used to create two indices, knowledge gap index and the practice knowledge index. The knowledge index measures the gap in both awareness and knowledge between husbands and wives within a household. The index for the knowledge gap is:

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

Where $Awareness_{ijk}$ is a dummy variable that equals 1 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 gap index measures the difference in husbands' and wives' knowledge of each other's groundnut practices.

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

Where $PracticeKnowledge_{ijk}$ is a dummy variable equal to 1 if individual i of household j correctly identified their spouse's groundnut practice k.

$$Y_{ij} = \beta_0 + \beta_1 TotalMoves_{ij} + \delta_j + \varepsilon_{ij} \tag{17}$$

Where Y_{ij} is the outcome variable either Knowledge Index or Practice Knowledge Index for individual i of household j, $TotalMoves_{ij}$ is the total number of moves individual i of household j took to solve the game in their final round. δ_j is a household fixed effect. ε_{ij} is an error term that has an expected value of 0. Standard errors will be clustered at the meeting level.

The second set of hypotheses compares income hiding with in game performance. This tests whether or not income hiding is also associated with information sharing.

Hypothesis 11: Households that perform well in the game hide income at lower rates than households that did not perform well.

To test Hypothesis 11, we follow Castilla & Walker (2012) and measure the difference in within household knowledge of on-farm income. We ask the husband their groundnut yield from the previous season and the groundnut yield their spouse received. We then ask the wife the same questions. We construct an income hiding variable from these responses.

$$IncomeHiding_{ij} = [Spouse\hat{I}ncome_{ij} - SpouseIncome_{ij}]$$

Where $Spouse\hat{I}ncome_{ij}$ 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.

$$Y_{ij} = \beta_0 + \beta_1 TotalMoves_{ij} + \beta_2 Female_{ij} + \beta_3 TotalMoves_{ij} * Female_{ij} + X_{ij}\Gamma + \delta_j + \varepsilon_{ij} \tag{18}$$

Where Y_{ij} is the outcome variable is Income Hiding for individual i of household j, $TotalMoves_{ij}$ is the total number of moves individual i of household j took to solve the game in their final round. $Female_{ij}$

is a dummy variable that is equal to one if individual i is a female. X_{ij} is a vector of control variables for individual i of household j consisting of age and education. δ_j is a vector of household controls: household demographics, and age gap between spouses. ε_{ij} is an error term that has an expected value of 0. Standard errors will be clustered at the meeting level. For this analysis, i will consist of only individuals who attended the second meeting and was not trained by the research team. This is done to observe directly how information from player 1 to player 2 correlates with player 2's knowledge of player 1's groundnut production.

Next we will explore information sharing between households that have a separate management scheme and households that have a more joint management scheme in practice. By exploring the impact management scheme of the household has within the game could highlight the pervasiveness of social norms and gender roles even in an abstract experiment. To test for heterogeneous effects among households that have joint management schemes and individual management schemes, we estimate the following econometric model.

$$\textbf{\textit{Total Moves}}_{ij} = \beta_0 + \beta_1 JointProduction_j + \beta_2 Female_{ij} + \beta_3 JointProduction_j * Female_{ij} + X_{ij}\Gamma + \delta_j + \epsilon_{ij} \tag{19}$$

Where $JointProduction$ equals 1 if households stated they produce under a joint management scheme, Γ_j is a vector of household controls: household demographics, age gap between spouses, and education of both spouses. $Female_{ij}$ is a dummy variable that is equal to one if individual i is a female. X_{ij} is a vector of control variables for individual i of household j consisting of age and education. δ_j is a vector of household controls: household demographics, and age gap between spouses. ε_{ij} is an error term that has an expected value of 0. Standard errors will be clustered at the meeting level.

5 Multiple Hypothesis Testing

In this Pre-Analysis Plan we have pre-specified 10 hypothesis tests. We will classify them by families based on outcome variables. Following Anderson (2008), we will classify each outcome variable as a unique family of hypothesis tests denoted by M. In the paper we will correct for multiple hypothesis testing following the free step-down resampling method (Westfall & Young, 1993). The free step-down resampling method computes an exact probability rather than the upper-bound.

6 Power Calculations

The power calculations are based on a 20 household pilot conducted in Tali, a groundnut growing community outside of Tamale Ghana. Tali was chosen based on its geographic, production, and size similarities to the communities we have chosen for the project. We do not conduct power calculations for the hypotheses comparing the lab in the field results to observable practice. The average number of moves it took individuals to complete the game was 32.375 moves with a standard deviation of 23.12. Table T has the six hypotheses and the minimum detectable effect size based on the data from the pilot.

Table T	Power Calculations for Hypothesis 1-6	
	MDES	Number of Standard Deviations
Hypothesis 1	3.51	.18
Hypothesis 2	4.66	.17
Hypothesis 3	3.51	.18
Hypothesis 4	4.66	.17
Hypothesis 5	2.27	.26
Hypothesis 6	2.68	.26

7 Budget narrative

7.1 Salary and benefits

All salaries and benefits for researchers working under this project are covered under the original proposal titled "Paying peanuts for food safety: Connecting smallholder farmers to premium groundnut markets and aflatoxin-mitigating technologies through innovative aggregator contracts". This budget is an addendum to the original proposal.

7.2 Operating Costs

The operating costs will be broken down into the costs of the pilot and the costs of the project. The pilot will consist of 20 households and 5 enumerators. Each enumerator will visit 4 households per day to take surveys before the meetings. Enumerators will be paid $50/day plus a day of training for a total of $1000. Each enumerator will have a tablet that costs $50/tablet. The pilot will require 25 tablets for a total of $1250. We will budget for both expected and max cash prize for the households. Each household can win up to 70GhC for a total possible cash prize of $241, but we expect households to make 25GhC on average for a total of $86. During the meetings we will provide snacks consisting of water sachets and crackers which cost a total of 1.2GhC/participant or $17 in total. The app that we will use will be designed by an app developing company based in Nepal which costs $2375. Finally, we will rent a vehicle to travel to the villages where we will be conducting the meetings. The rental truck costs 500GhC/day for a total cost of $345 plus $40 in fuel costs.

For the project, we have budgeted for a sample of 480 households and 5 additional enumerators to the ones in the pilot for a total of 10 enumerators. There will be 2 enumerator teams consisting of 5 enumerators each. We expect the experiment to take 25 days to complete, 12 days of household surveys, 1 day of assigning treatment, and 12 days of community meetings. The total enumerator costs will be $12,750 this comes from $12,000 for 12 enumerators over 20 days, $250 from the training of 5 additional enumerators, and $500 for 10 enumerators to inform households when the meetings will take place. The same snacks will be given as in the pilot, we will budget for a total of $200 for snacks. The total cash prize that can be awarded to 480 households is $5,793, but we expect an average cash prize of $2897 or 35 GhC/household. For the 25 field trips we budgeted $2,321 for truck rentals and $257 for fuel. I estimated traveling 40 miles round trip per field visit with an estimated 15mpg and a cost of $3.7 per gallon of fuel in Tamale Ghana. Finally, we will need an additional 25 tablets at $50 per tablet for a total of $1250. The total max amount budgeted for the pilot and the experiment is $27,687, with an expected cost of $24,635

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