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Gender, information and the efficiency of households' productive decisions: An experiment in rural Togo

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Abstract. We explore how the capacity of farm households to reach efficiency and share infor-mation on production is related to their consumption decision-making process. West African farm households often cultivate several plots, and there is extensive evidence of allocative inefficiencies (Udry, 1996). We design an experiment with Togolese cotton producers, contextualized as an input allocation game, and build a model based on its findings. We further test the model's predictions using our lab-in-the-field data. The cotton producers are found to allocate too few inputs to their wife's plot, failing to maximize household aggregate profits. They do transfer more inputs to their wife's plot when the returns from that plot are increased. Yet, when we experimentally manipulate information on these returns, informational frictions on average do not impact decisions. We attribute these experimental findings to the role that conflict in consumption plays in creating production inefficiencies. The model predicts that both efficiency loss and responses to asymmetric information are heterogenous. Moreover, we show that spouses are unable to communicate on the returns effectively and cannot avoid extra losses, though the damaging effects of private information vanish if information is verifiable ex post. We present evidence consistent with these predictions.

JEL classification: Q12, C72, D13, D82, C91, C93.
Keywords: farm households, household production and intra-household allocation, non-cooperative game theory, asymmetric and private information, lab-in-the-field experiment.

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1 Introduction

Smallholder agriculture represent 80 percent of all farms in Africa (AGRA, 2014). Yet, productivity levels are low, and progress has been slow (Wiggins, 2014). Small-scale farms are typically family-run businesses, very often with members of the farm household cultivating separate plots (Guirkinger and Platteau, 2015). Productivity levels are low and progress has been slow (World Bank 2008)XXXX. Farm households are repeatedly found to make inefficient allocations of productive resources across plots, especially in West Africa. [1]. Most often, within-household misallocation is gendered with too few inputs used on female-controlled plots (Doss, 2018). Yet little is known about the causes of these inefficiencies.

Determining the exact source of allocative inefficiency is key to designing solutions to raise the production capacity of farm households. While long-term interactions between spouses should offer an incentive to maximize household income (Browning et al., 2014), there is growing evidence that spouses hide actions or resources from each other (Anderson and Baland, 2002; Ashraf, 2009) and that they fail to communicate effectively (Ziparo, 2016; Ashraf et al., 2016). However, the extent to which asymmetric information is problematic in households has been questioned (Browning et al., 2010) [2] and existing evidence on the role of private information on spouses' decisions is at best mixed (Mani, 2011; Kebede et al., 2014). Recent contributions point to heterogeneity in response to private information - see, e.g. (Hoel, 2015) - but fall short of offering a theoretical framework to understand the roles of private information and communication failures within the household.

To fill this gap, we investigate the farm household's capacity to reach efficiency and share information on the production side. We explore, both theoretically and empirically, the heterogeneity in responses to private information on production. To do so, we design an experiment, build a model consistent with the key findings from our experiment, and test the model's predictions further. To the best of our knowledge, this is the first paper to link heterogeneity in intrahousehold expenditure arrangements to the capacity to reach efficiency and share information in agricultural production. We highlight how conflict in consumption allocation impacts inefficiencies in production. We show that the extent of allocative inefficiency in production is heterogenous, like responses to information frictions and to increased returns on investment in the wife's plot. Our model suggests it is spouses' inability to communicate effectively that can generate an extra loss of efficiency under private information. When private information is verifiable ex post, there are no longer any extra losses in efficiency from information friction. We take these predictions back to the data and find evidence consistent with the theoretical predictions.

For our experiment, we build on standard lab-in-the-field games of resource-sharing within the household (Munro, n.d.), adding an information component. The experiment, contextualized as an input allocation game, involves couples of Togolese cotton producers living in marital relationships. Each couple plays a series of two games. In all rounds, spouses can communicate prior to the decision, which is made privately by the husband. First, we ask each husband to

[1] Following Udry (1996)'s seminal paper, evidence of allocative inefficiencies in agriculture was gathered by Akresh (2008) for Burkina Faso; **?** for Ghana; Rangel and Thomas (2012) for Ghana and Senegal; Andrews et al. (2015) for Uganda; and Guirkinger et al. (2015) for Mali.

[2] They argue that it "is probably less problematic in households than in other types of relationship (say, between employers and employees or insurers and insurees), because the very nature of the relationship often implies deep mutual knowledge and improved monitoring ability".

decide whether to invest in his own plot of land with low returns or in his wife's land with high returns but where the payoff will be to her rather than to him. Incentives are such that any deviation from allocating all of the endowment to his wife's land implies a loss of efficiency to the household.

We find that male farmers allocate too few inputs to their wife's plot in the game, failing to maximize household aggregate profits. We observe efficiency losses of 17.8 percent. In the second round, we triple the returns on investing in female-controlled plots. Men respond to increased returns from their wife's plot by investing more in it. In this second round, we also experimentally manipulate the information available to husbands. We randomly assign couples to one of three treatments: (1)*full information*, as in the base game, (2) *hidden information*, in which women are offered the opportunity to hide the true return from their husbands, (3) *verifiable information*, in which, while women can hide the true return from their husbands, the information is verifiable ex post. Private information held by women on their plots' returns has no effect on average on men's allocation decisions, whether or not this information is verifiable ex post.

We then propose a non-cooperative model of household production and consumption decisions and study conditions under which efficiency in production is reached under full information on returns from plots. The model is sequential. Men first decide how much to allocate to the female plot and then each spouse chooses his/her consumption bundle. Spouses jointly consume some household public goods, such as cooking, home maintenance, child care and education. Notably, preferences for these public goods differ across spouses [3] This has two important implications.

First, we show that even non-cooperative spouses find optimal to maximize joint agricultural income when both contribute to the provision of a household public good (Bergstrom et al., 1986).However, in equilibrium not all spouses in all households contribute to the provision of all goods. Three regimes of household behavior are obtained endogenously according to spouses' preferences and relative incomes: (1) a joint contributor regime in which both spouses choose to contribute to one public good, (2) a breadwinner regime in which only one of the spouses contributes to all public goods and (3) a specialization regime in which each chooses to contribute to separate public goods. [4]. Importantly, productive decisions critically depend on the regimes identified above: male farmers efficiently allocate inputs between their plot and their spouse's plot under the joint contribution regime, somewhat inefficiently under specialization and very inefficiently when they are the household breadwinners.

Second, when asymmetric information is added to the model, we show that it aggravates allocative inefficiency in production only under specialization, having no impact on households under joint contribution and on those with a breadwinner. We also show that, even though communication between spouses is possible, husband and wife do not communicate effectively and cannot avoid additional losses due to the information asymmetries. This, in turn, implies that ex post verifiability may help curb the extra loss from private information. If inefficiencies were rooted in difficulties enforcing a marital agreement, ex post verifiability would not be effective in limiting the deleterious effects of private information.

Our model predicts heterogeneity in the extent to which farm households make inefficient

[3]Note that we do not stipulate the nature of the public good (children's education, home maintenance, etc.) for which preferences are heterogenous. This can differ across households or be dictated by a social norm.

[4]The specialization regime is akin to the separate-sphere regime described in Lundberg and Pollak (1993), but endogenously determined given spouses' preferences and relative incomes rather than dictated by social norms

production choices under information asymmetries. We examine these predictions in the light of the experimental data, analyzing heterogeneity in the impact of our treatments across households. We classify households, albeit imperfectly, in three different regimes according to the choices made in the first round of the experiment: very efficient, somewhat efficient, very inefficient. We analyze how these different households respond to the information treatments in the second round of the experiment. Comparing choices made under the *hidden* and *full* information treatments, we find that the effects of asymmetric information are heterogenous. It is only the households that experienced the largest losses in the first round whose efficiency losses increase. These are a mix of breadwinners and households in the specialization regime. Since only the latter are expected to be affected, we obtain a lower-bound for households in the specialization regime. Comparing choices made under the *verifiable* and *full* information treatments, there is no heterogeneity in impact and none of three groups of households responds to the information friction. As predicted by the model, when spouses know that the information will be revealed ex post, information friction does not affect the efficiency of decision.

This paper contributes to the farm household literature by investigating the role of differences in preferences within the household. In the standard farm household model, households work as an economic unit making production and consumption decisions (Singh et al., 1986). When markets fail, these decisions are no longer separable (LaFave and Thomas, 2016), and production can no longer be treated as independent of household members' preferences. In this setting, we expect inefficient allocation of resources across households but efficient allocation within the household. Our contribution is to highlight another possible source of inefficiency involving violation of the separability property.

Our work also sheds new light on the role of private information in household decisions. Asymmetric information has been found to affect household decisions and limit cooperation within the household (Ashraf, 2009; Kebede et al., 2014). One explanation suggested is that information asymmetries reduce spouses' ability to enforce marital agreements (Fafchamps, 2001). In contrast, we focus here on conditions under which agreements are self-enforced, exploring different regimes of decision-making. Our model offers two novel implications: (1) heterogeneity in the ability of farm households to reach allocative efficiency, (2) heterogeneity in the response of farm households to asymmetric information. These predictions are in line with recent evidence (Angelucci and Garlick, 2016; Hoel, 2015; Hoel et al., 2018).

In addition, we contribute to a small and emerging literature on the role of communication within the household (Ziparo, 2016; Ashraf et al., 2016).We show that communication fails to solve the information asymmetries, leaving it intact. However, if the information is *verifiable* ex post, even though privately held at the time of the decision, the husband can trust his wife to truthfully reveal it, and the household should not suffer additional efficiency loss from the asymmetric information. In contrast, the inefficiency will not be mitigated by ex post verifiability if the issue is imperfect enforcement of marital agreements. Our experimental findings from the *verifiable*information treatment are not consistent with the implications from a model of limited enforcement, but consistent with our model. As such, this paper provides the first lab-in-the-field experiment testing cheap talk in the household.

We investigate non-cooperative interactions between spouses. [5] Our model is closest to

[5]In a static collective model, the household should maximize profit and then allocate consumption according to

Browning et al. (2010)'s model of consumption choices (BCL 2010). They extend Bergstrom et al. (1986) to a setting with many public goods. BCL (2010) find that, in general, household members will either specialize in the provision of certain household public goods or jointly produce at most one. (Only) in the latter case, spouses fully pool income as inBergstrom et al. (1986). Our model extends BCL (2010) in two ways. First, we add a production stage. We model households engaged in agricultural production, thereby endogenizing spouses' incomes generated from female and male-controlled plots.Boone et al. (2014) generalize BCL (2010) to the case of endogenous labor income and show that there is no regime under which spouses pool income. Unlike Boone et al. (2014), we find a regime where spouses jointly contribute to a public good and therefore pool income. [6]Second, we extend the model to include asymmetric information and to allow for cheap talk between spouses, showing that communication between spouses cannot relieve the additional efficiency loss from information asymmetries. This last result contrasts with predictions from models in which spouses are involved in non-binding agreements.

To summarize, allocative inefficiency in production decisions may arise because of the nature of the intrahousehold decision-making process. Depending on spouses' preferences and their income gap, households may operate according to different behavior regimes. As a result, asymmetric information within the household will exacerbate inefficiency for some households but have no effect on others. Since the increase in efficiency loss under asymmetric information may be due to ineffective communication between spouses, it might be avoided if agricultural development programs targeting women also provided information to their spouses.

The rest of the paper is structured as follows. In the next section, we describe the sample and our experiment and present the key stylized facts gathered from it. In Section 3, we outline our model and describe its theoretical predictions. We test the heterogeneity in responses predicted by the model in Section 4 and we conclude in Section 5.

2 The setting, experimental conditions and preliminary evidence

The objective of this section is to describe the experimental setting, data collection, experimental conditions and our main findings from the experiment. The experiment is designed as a game of input allocation across female- and male-controlled plots. It is similar to an investment game except that payoffs are paid individually to each spouse. We expect three key elements to condition choices: returns on investment (inputs), private information held on these returns and communication between spouses. These key conditions are also the focus of other papers in the experimental literature (e.g. Ashraf, 2009; Kebede et al., 2014; Hoel, 2015).Importantly, the use of lab-based findings to mirror real-life decisions in agriculture has found some support in the

a sharing rule that cannot make one of the spouses better-off without making the other spouse worse-off (Browning et al., 2014). When limited commitment is introduced (Mazzocco, 2007; Voena, 2015), household members may renegotiate the sharing rule but production efficiency should be attained for those who remain in a cooperative equilibrium. An alternative model can take into account the endogeneity of spouses' outside options (Basu, 2006). The additional income gained in the experiment is too small for outside options to be affected. Thus, this alternative model cannot explain our experimental findings.

[6]results are also in line with those of Doepke and Tertilt (2018), who extend BCL (2010) to an environment in which household public goods are produced inside the household. As in our model, when spouses specialize in the provision of different public goods, there is no income-pooling. However, given that their model exhibits a continuum of public goods each of which is infinitesimal, joint contribution to a public good is not sufficient to guarantee the neutrality of income redistribution in the family.

literature (Hoel et al., 2018).

2.1 Experimental setting and data collection

The experiment was conducted in Togo, in the Region des Plateaux. According to the most recent national census, 97 percent of the population in Togo is employed in agriculture, 51 percent of agricultural producers are female, and 82 percent of them live in households headed by a man (National Agricultural Census 2012-2014). Region des Plateaux is the main cash crop production area of the country. Cotton is one of the main cash crops cultivated in Region des Plateaux, along with coffee and cacao.

Participants were recruited with the help of Nouvelle Societe Cotonnaise du Togo (NSCT) which is in charge of the cotton industry in Togo. Our sample was drawn from the latest census of cotton producers conducted in the region by NSCT, which identified 15,515 cotton producers, 1,081 of them women.[7] We focused on couples both of whom are involved in cotton production, restricting to individuals aged 18 and above. After excluding polygamous households and couples residing in the remotest areas, our sample contained 150 couples out of the total population of 359 couples. This was reduced to a final sample size of 141 couples after verification of marital status.

The experiment took place in NSCT facilities and in school buildings located in five central localities in the region during the month of October 2016. On each site, we interviewed participants from several nearby villages. An experimental session, followed by survey data collection, lasted for two hours. To avoid contamination of untreated households, we interviewed participants from a given geographical area on the same day. Ten trained field experimenters supervised by one of the authors worked in pairs [8]. Protocols were provided in both French and Ewe and field workers were also fluent in the other local languages (Ife, Moba, Lamba, Kotokoli and KabyÃ¨).

When participants arrived, husbands and wives were separated. They first received a show-up fee and were then invited to participate in the experiment. We recorded the allocation choices made by husbands during the experiment, which is our main outcome of interest.XXXX Directly after completion of the experiment, a survey was administered separately to husbands and wives. After a short debriefing on the game, the survey includes questions on demographics, assets, education, literacy/counting tests, occupations, social preferences and risk aversion. We also inquired about information-sharing within the couple, about who decides how to exploit the individual's main plot and about who is responsible of the main goods produced by the households and main expenditures. Male and female respondents also reported itheir individual share of expenditures on broad categories of expenses.

Two remarks are in order. First, we decided to study monogamous rather than polygamous households, knowing that only 17% of men aged 20-49 in Togo (20 percent in the Plateaux Region).[9] Our findings are thus representative of decision-making outcomes for 80 percent of men and women living in a union and producing cotton in the Region des Plateaux.

Second, when conducting experiments with couples, one challenge is that there is a risk that the behavior observed in the lab may change once the spouses leave the lab but continue interacting, making the experiment less informative. To obtain more reliable information, we

[7] The census was presented at the NSCT board meeting in September 2016.

[8] Training of field experimenters and piloting of the experiment took a total of two weeks.

[9] These statistics are computed using DHS 2010 data.

gave the players the opportunity to hide their payoffs. [10]In our case, one concern is that spouses transfer resources once the experiment is over. Debriefing data, though self-declared, provides us with some evidence that individuals did not expect to obtain direct monetary transfers from their spouse as a result of their participation to the experiment (only 2 individuals of each gender declared they did expect direct transfers, they account for less than 2 percent of the sample). Yet they could have made in-kind transfers to their spouse in the form of larger contributions to the provision of household public goods.

2.2 Sample description

Table 2.2.1 to 2.2.3 provide some summary statistics from our surveys of male and female participants. According to Table 2.2.1, , male and female cotton producers are in a marital arrangement. The male is typically the head of household. Most couples are in a long-term relationship (average 19 years), with 4.8 children on average. [11] There is a seven years gap in age between male and female on average (men 44, women 37 years old). About 49 percent of men and women attended or completed primary school. Though the level of literacy is higher for men than for women, both spouses scored high on numeracy. [12]. The spouses' income is spent on different household public goods: men spend more on health while women's spending is more food-related. Finally, there is some heterogeneity in the farmers living standards: just fewer than 10 percent experienced hunger in a three-months period prior to the survey while more than half of them own a motorcycle.

Agricultural production is described in Table 2.2.2. Males and females alike control the production of cotton on at least one plot of the farm household. Average plot area controlled by female (male) is 1.74 (7.34) hectares (Table 2.2.2). Men and women interpret "control of one's plot" differently. Roughly 66% of females consider that they control a plot if they have total control over the income it generates and over input choices. By comparison, 83% of men consider they ought to control both to define the plot as their own.

Consistent with evidence from other West African countries, information-sharing within the household is imperfect (Table 2.2.2). Though 74 % (respectively 57 %) of male (female) state that they have a good knowledge of the value of produce on their spouse's main plot during the last agricultural season, 55 % (respectively 46 %) still would want to know more. Similarly, while a large proportion state that their spouse knows how much they produce on their main plot, about 40% still think their spouse would like to know more. Asymmetric information will be one of the key elements that condition input allocation choices that we will experimentally vary in the game.

Also consistent with evidence gathered in the sub-region (Doss, 2018), men are responsible for making the input allocation decision (Table 2.2.3). Indeed, according to female respondents, most husbands have a say in the allocation of inputs to the female-controlled plots. Men are in most cases the sole decision-makers. On average across the different types of inputs (domestic and

[10]We used two means: private payments to players and a system of lotteries that could allow them to conceal the exact value of these payments (more on that below).

[11]Husbands also present a non-negligible number of off-springs outside the official union: they have on average 2 children with other women, while the wives' average is 0.3.

[12]Most of the game instructions were read out loud with a verbal description of individual payoffs for each allocation of input. Our choice of delivery for games instruction thus seems to fit the skills of the participants

hired labor, fertilizers and seeds) used on female plots, 61 percent of them make the allocation decision on their own, and 19 percent share the decision with their wife. On average, only 17 percent of female choose on their own how much inputs they use on their own plots. In the experiment and the model, men are responsible for the allocation of inputs across plots of land.

2.3 Experimental conditions

After receiving a show-up fee, participants were told they may earn more depending on the decisions made in a series of two games. These games are contextualized as input allocation games to place the subjects in familiar decision-making situations and to address the paper's research question.

Men are the ones making a decision, women's role in the games is to discuss with their husband prior to the decision. Men have to decide how much of a total of 10 tokens (input units) to allocate in two boxes of different colors. Participants are told that the boxes represent plots and the different colors indicate the identity of the person owning the income generated on the plot (husband or wife). A male participant has to decide whether to invest on his own plot of land with low returns or on his wife's land with high returns but a payoff that will be paid to her and not him. We chose to have constant returns to scale production functions for the sake of simplicity. In all treatments, there is only one action that maximizing the household payoff: to allocate all inputs to the wife's plot.

Treatments Figure 1 describes the overall structure of the experiment. The base treatment (BT) takes place at the first round and rules are common to all participants. Importantly, in BT, all information is common knowledge to husbands and wives. Choices made under BT allow us to test the efficiency in decision-making at the farm-household level and estimate efficiency losses under full information about returns. Given that the return on female plots is twice as high as on male plots, we have the following:

$$\textbf{Female Payoff} = 2y$$
$$\textbf{Male Payoff} = 10 - y$$

where y is the number of tokens allocated to the wife's plot. At BT, the efficiency loss, expressed as discarded surplus as a share of the maximum potential household earnings, can be written as follows:

$$\textbf{Efficiency Loss} = 1 - \frac{10+y}{20}$$

Each token has a value of 100 FCFA (about US \$ 0.17). Thus, for each token that a husband does not invest on the female plot, the household incurs a monetary loss of 100 FCFA. The maximum household surplus at BT is 2,000 FCFA, i.e. US \$3.42 at the current exchange rate.

The second-round game allows us to test if and how households react to (i) an increase in the returns on wife's plot and (ii) informational asymmetries. Between the first and second rounds, we increase the ratio of returns from two to three. We thus call the second-round game "the productivity treatment", or PT. Given that the return to female plots is now three times as high as on male plots, we have the following:

$$\textbf{Female Payoff} = 3y$$
$$\textbf{Male Payoff} = 10 - y$$

where y again is the number of tokens allocated to the wife's plot. Thus, the efficiency loss in the second round can be written as follows:

$$\textbf{Efficiency Loss} = 1 - \frac{10+2y}{30}$$

Marginal loss is higher in PT compared to BT. For each token that husbands do not invest on the more productive female plot, the household forgo 200 FCFA. The maximum household surplus at BT is 3,000 FCFA, i.e. US \$5,14 at the current exchange rate.

In addition to increasing returns to female plots, we also randomly assigned couples to one of three treatments:

1. a*full* information treatment in which the experimenter provides the information on the returns (ET, for experimenter treatment),
2. a *hidden* information treatment (HT, for hidden treatment) in which the experimenter only informs the wife of the value of the return to her plot. Husbands are informed by their wife.
3. a *verifiable* information treatment in which husbands also get the information from their wife, both knowing that the experimenter will reveal the true return after the decision is made (RT for revealed treatment).

The experimenter treatment has the same design as the base treatment, except that that returns to investment on wife's plot is now three times as high as the return to investment on husband's plot. The hidden treatment is very close in design to ET, except that women can strategically manipulate the information on returns to their plots. In ET (respectively HT), the experimenter (respectively the wife) is in charge of communicating this piece of information. As for RT, it is very close in design to HT, except that the information is asymmetric prior to decision-making but verifiable ex post. Note that in the informational treatments (HT and RT), the experimenter tells spouses that the returns to female plots are at least as large as in the base treatment (BT). Appendix 1 provides a thorough description of the protocol.

Communication Once they had received all the instructions and had shown that they understood them, husbands and wives were instructed to talk to each other for five minutes before men make their decisions privately. In the real world, while women may have an informational advantage concerning returns on their own plots, spouses can be expected to talk about returns on their plots. Indeed, communication between spouses may help them lessen the negative impact of the informational asymmetry. In the experiment, we allow for pre-play communication between spouses in all treatments and do not monitor their discussions. XXXCOMMENTAIRE NON RESULUXXX

The issue of couple lab behaviour As pointed out earlier, one issue with lab experiments recruiting couples is that lab behavior may be undone outside the lab, which would compromise the extent to which we may learn about their behavior by observing choices made in the lab.

In our experiment, , where the men made the decisions, the women knew the returns from each allocation and, despite our privately-made payments, could have guessed the decision simply from the amount paid directly to them. To avoid this problem, prior to making their decisions, both husband and wives knew that their earnings will be partly determined by a series of two lotteries. The outcome of the first lottery determines whether they are remunerated on the basis of decisions made at the first round or at the second round. The second lottery introduce a state of the world in which they may earn zero. However, expected earnings in each round are equal to the payoffs without the lottery.[13] Both spouses knew the basic structure of the lotteries, but wives could not observe the lotteries outcomes. [14] In the debriefing following the games, most women (53 percent) declared they did not know how much their husband earned in the lab; only 26 percent were confident about the expectation they had about men's earnings.

2.4 A first look at the experimental evidence

Figure (5) provides a reminder of the structure of the experiment.[15] In Table (1), we compare investment decisions, efficiency losses and payoffs under each experimental condition.

Full information, in the sense of shared knowledge of the experimental conditions, which all participants experience in the first round (BT). Despite the full information condition, we find that most fail to maximize aggregate profits (first column of Table 2.3.1). On average, they invest 6.42 tokens in their wife's plot, short of the optimal investment had they maximize household aggregate payoff (i.e., 10 tokens). Decisions husbands take yield an average efficiency loss of 17.8 percent. Husbands decide to forego 356 FCFA in aggregate earnings to the household in order to have full control over them. Their decisions yield average earnings of 1,287 FCFA that are paid to women. [WE ARE DESCRIBING AVERAGE EARNINGS LOSSES AND AVERAGE WIFE EARNINGS. WHAT IS UNCLEAR?] Recall that we run a series of two lotteries at the end of both rounds. As a result, husbands can hide their earnings from their wife (the opposite does not hold). forgone aggregate income may thus be an optimal response when a marital agreement over the sharing of income is costly to enforce. If so, the aggregate earnings loss to the household would provide a measure of these transaction costs. [16]

[13] With 50% chance of drawing round 1 or round 2, maximum expected earnings are $(2,000 + 3,000)/2 = 2,500$ FCFA, representing US$4.28 at current exchange rate and PPP$11.64. Estimated annual income per capita is PPP$1,700.

[14] See Appendix 1 for more details on the structure of the lotteries.

[15] BT is the first round or*base treatment*, PT or *productivity treatments* is the set of second-round treatments, HT and RT are the informational treatments – respectively *hidden treatment* and*revealed treatment*, ET is the *experimenter treatment*.

[16] On average, PPP $1.65.

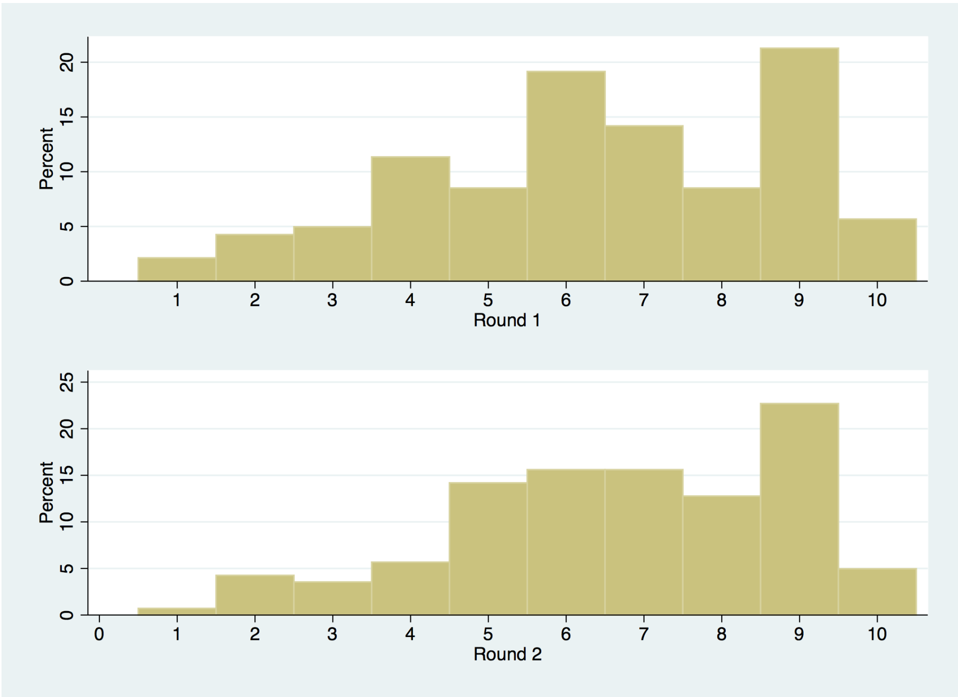
Table 1: Effect of informational treatments on decisions, efficiency and payoffs

	Base treatment (round 1)	Productivity treatment (round 2)			
	Average outcome in BT	Average outcome in the control group (ET)	Hidden treatment effect	Revealed treatment effect	Difference (round2 - round 1)
Tokens invested in female account	6.42	6.79	-.26	.06	.28
	(0.19)	(.36)	(.48)	(.44)	(.13)
Efficiency loss to the household	.17	.21	.01	-.004	4.04
	(.009)	(.02)	(.03)	(.03)	(.007)
Male payoffs	356	320	26.5	-6.7	-29.3
	(19.51)	(36.1)	(48.5)	(44.6)	(13)
Female payoffs	1287	2038.4	-79.6 20.3	729	
	(39.02)	(108.4)	(145.5)	(133.8)	(35)
Household aggregate payoffs	1644	2358	-53.1	13.5	700
	(19.50)	(72.2)	(97.0)	(89.2)	(24.6)

Notes: Estimates are obtained from OLS regression of dependent variable (column 1) on treatment conditions. Column 2 gives the constant term where ET is the omitted category. Column 2 and 3 are treatment effects (respectively of HT and RT). Last column is the coefficient on a round dummy in a pooled regression. Robust SE in parenthesis.

The empirical distributions of transfers are shown in Figure (1). We observe 5 percent of the data at $BT = PT = 10$ and no mass at $BT = PT = 0$. The remaining 95 percent show intermediate values of transfers.

Figure 1: Distribution of transfers



Source: own data sources

Recall now that a randomly selected fraction of participants also faces the full information condition at the second round (ET). Our findings for this group are qualitatively consistent with those at BT (second column of Table (1)). Even as we increase the returns to investments into wife's plot, men fail to maximize household aggregate output. In comparison to BT, they slightly increase the number of tokens they invest in their wife's plot to 6.72. Their decisions also yield significantly higher average earnings of (2038 FCFA) paid to their wife. Despite the increased investment to the wife's plot, aggregate losses to the household are significantly larger in both absolute and relative terms. Households at ET incur an average efficiency loss of 21.3 percent, a significant 3.5 p.p. increase as compared to BT. In monetary terms, this represents an average of 641 FCFA in forgone earnings to the household. [17] Average male earnings are 320 FCFA. This implies that, on average, men are willing to forgo 2 FCFA in aggregate earnings to the household for each additional FCFA over which they have full control.

More generally, comparing round 1 (BT) to round 2 (PT), in the last column of Table (1), investments to female-controlled plots also slightly increase on average but efficiency loss significantly increases by 4 p.p.. Male earnings significantly drop by an average 29 FCFA while female earnings significantly increased by an average 730 FCFA. Going from round 1 to round 2 results in higher household aggregate earnings and at the same time higher forgone household earnings (average change in forgone earnings of +299 FCFA).

Experimental conditions in round 2 differ from those in round 1 along two dimensions: we increased the returns to investing in female-controlled plots and we manipulated the extent of information over these returns. Nevertheless, differences in choices made by husbands between ET to BT are driven only by the increased returns (see second paragraph in this section). [18]

We now focus on comparing the informational treatments (HT and RT) to ET (columns 2, 3 and 4 of Table (1)). The random assignment to treatment insures that differences in choice can be attributed exclusively to the treatment conditions. Comparing HT to ET, we can isolate the effect of empowering female with a piece of information that is held hidden (Hidden treatment) from their husband. Husbands know the difference in returns in round 2 is at least as large as in round 1, but do not precisely know how much larger it is. Women are endowed with this information which they can attempt to communicate to their husbands before men make the allocation decision. Surprisingly, tin HT the hidden information has a small and statistically insignificant effect on the number of tokens men invest in female-controlled plots, on efficiency loss (statistically insignificant 1.8 p.p. effect) and on aggregate forgone earnings (statistically insignificant 27 FCFA increase). Condition RT is very similar to HT except that in RT both spouses know that private information will be revealed ex post. We find that the average effect of RT is also small in magnitude and statistically insignificant. Thus, we can conclude that on average, husbands do not respond to the fact that their wife hold private information, regardless of whether this private information is ex post verifiable.

To sum up, we find that increasing returns to investment in female-controlled accounts leads to increased investment on these plots but also to increased efficiency losses. We find little average impact of informational asymmetries on husbands input allocation choices.

It may be that our informational treatments do not aggravate inefficiency if ex ante communication between spouses is effective at wiping out the asymmetry of information. Yet, we still observe large efficiency losses in the absence of informational frictions. How can we explain allocative inefficiency under full information? We conjectured that these inefficiencies arise from difficulties to enforce a marital agreement over the sharing of income. But if this explanation were to hold, we would expect (1) informational frictions to aggravate the inefficiencies, (2) ex post revelation to be ineffective in curbing the extra efficiency loss from the informational friction.

[17] That is PPP $2.97.

[18] The difference could also capture changes associated with other factors that change with time. These would include learning effects. Since we had participants play several rounds for practice prior to round 1, we are reasonably confident that the learning would have already took place during the practice rounds. Also, participants are not learning about other participants' behavior between rounds.

Our findings from the informational treatments are not consistent with this explanation: we do not find that on average inefficiencies are any worse in our informational treatments.

In the reminder of the paper, our objective is to offer an explanation for the observed efficiency losses under full information and the heterogeneity in response to the treatment conditions. As we will see in section 3, the model give clear predictions regarding optimal response to increasing returns and private information for different households arrangements, that we test in section 4.

3 Theoretical Framework

In this section, we provide a theoretical framework rationalising the key finding of the experiment. We analyze decision-making in the farm household with respect to the three key determinants - studied in the experiment - affecting the allocation of productive resources: returns to input, private information held on these returns and communication between spouses. We obtain fine predictions on the effects of these dimensions: we obtain several testable predictions that allow to go back to the data and test the validity of our theoretical framework.

3.1 Benchmark model: full information

Consider a married couple who has to decide both on the allocation of productive inputs and on expenditures, given individual preferences and individual budget constraints.

We assume that spouses farm separate plots[19] and their individual income depends on an exogenous income Y^j and on the production of the individual plots. We assume that the husband and the wife have different production technologies and that the input productivity on the land of the husband is lower than the one of the wife. [20]. Thus, the agricultural income (assuming output prices normalised to 1) of the two spouses is:

$$I^H = f^H(x^H) = x^H,$$
$$I^W = f^W(x^W) = kx^W,$$

where k is the difference in productivity between the husband and the wife and x^i the amount of input on the plot of each spouse.

Assumption I: $k > 1$.

We also assume that the husband is the owner of the household's inputs B, and that he has to decide how to allocate them across plots. Hence, following the allocation, husband and wife use the same input in different proportions. The only difference in their production technology is the difference in marginal returns on investment. The total income of each spouse, R^j, is given by:

$$R^H = Y^H + I^H = Y^H + (B - t),$$
$$R^W = Y^W + I^W = Y^W + kt,$$

where $t \in [0, B]$ is the amount of inputs that the husband decides to invest on the wife's plot. The household's income is then $R^H + R^W$. We start by analyzing a problem where both the

[19]The individualisation of plots in farm households is a growing phenomenon that has been largely debated in the recent development literature. See Guirkinger and Platteau (2017) for a review.

[20]We assume a linear production function for each spouse. This is a simplifying assumption: we assume that we are located on the side of the real production function where the wife's plot is more productive than her husband's. We thus use the linear approximation to simplify computations and match the experimental design.

exogenous income and the productivityof the female-controlled plot of land are perfectly known. The efficient production decision is to give all the resources to their wife to use on her plot. This choice maximizes the household income, allowing the amount of income available to finance both household public good provision and private consumption to be the highest possible (See Appendix A for the proof).

In our environment, husband and wife have also to decide resource allocation across private consumption and public good provision. In developing countries the occurrence of frequent income shock, short life expectancy, gender norms may they lead to commitment problems. [21] Thus, we assume the spouses to behave non-cooperatively in the consumption decision process and we study the incentives to maximize productive income, given individual incentives in consumption. Our theoretical model is based on the one developed by Bergstrom et al (1986): we extend it to have a number of public good greater than one since we are interested in the emerging of intra-household specialisation equilibria. A key assumption in this respect is that spouses have different relative preferences for the different public goods.

We assume preferences of each spouse take the following form:

$$U^H = \log(c^H) + \log(Q_A) + \log(Q_B),$$

for the husband, and

$$U^W = \log(c^W) + \alpha \log(Q_A) + \log(Q_B),$$

for the wife, with c^j being the private consumption of each spouse $j = H, W$, $Q_A = q_A^H + q_A^W$ and $Q_B = q_B^H + q_B^W$ being two continuous public goods, and $q_i^j, i = A, B$, being the individual contributions to those public goods. The contributions of the two spouses are perfect substitutes.

Assumption II: $\alpha > 1$.

$\alpha > 1$ implies that the wife has a stronger preference for good A relative to good B and a stronger preference for this good with respect to the other spouse.

The individual budget of spouse j, given his/her income, is the following:

$$R^j = c^j + q_A^j + q_B^j.$$

The intra-household input and consumption allocations are determined sequentially. First, the husband determines the optimal amount of transfers and then, both spouses decide, simultaneously, their contribution to the household public goods. We will, thus, solve the household's problem by backward induction. We first determine the optimal household consumption decisions as a function of transfers. Then, we compute the optimal allocation of productive resources.

In the second stage each spouse maximises, for a given level of inputs given to the wife (t), his/her own utility choosing his/her own level of private consumption $c^j(t)$ and their own contribution to the public good ($q^j(t)$), given their income ($R^j(t)$) and taking as given the contribution of the other. The optimal consumption allocation allows to define, for each spouse, his/her indirect utility V^j.

Then, in the first stage, the husband determines the optimal level of transfers, t, taking as

[21] See Baland and Ziparo (2018) for a richer discussion.

given the intra-household equilibrium of the second stage. He maximizes:

$$\max_t \quad V^H(t)$$

$$\text{subject to } t \leq B.$$

where $V^H(t)$ is the indirect utility of the husband.

Assumption III: $k < \bar{k}$.

$\bar{k}$ is the maximum level of productivity below which there is no change in public good responsibility in the household (see below). Given that our experiment induces only a marginal increase in productive inputs, we expect to observe no change in public good contribution regime in our experimental set up. Also, in real life, the difference in input productivity is not so large.

Solving this problem by backward induction , we have the following proposition (see appendix for the proof):

Proposition 1 *Under Assumption I-III, there exists four threshold level of the relative income* $S = \frac{Y^H+B-t}{Y^H+B-t+Y^W+kt}$ *of the two spouses that determine optimal public good contributions and transfers:*

$$\begin{array}{llllll}
(i) & q_A^H = q_B^H > 0 & q_A^W = q_B^W = 0 & t^* = 0 & \textit{for} & S > S_4 \\
(ii) & 0 < q_A^H < q_B^H & q_A^W > 0, q_B^W = 0 & t^* = B & \textit{for} & S_3 < S \leq S_4 \\
(iii) & q_A^H = 0, q_B^H > 0 & q_A^W > 0, q_B^W = 0 & B > t^* > 0 & \textit{for} & S_2 < S \leq S_3 \\
(iv) & q_A^H = 0, q_B^H > 0 & q_A^W > q_B^W > 0 & t^* = B & \textit{for} & S_1 < S \leq S_2 \\
(iv) & q_A^H = q_B^H = 0 & q_A^W > q_B^W > 0 & t^* = 0 & \textit{for} & S \leq S_1
\end{array}$$

As it is shown in the proof or proposition 1, the spouses' contributions to each public good depend on the relative total income (labour plus agricultural) of each spouse. In particular, we can define three regimes: the **bread-winner regime** that occurs when one spouse is much more rich than the other and he/she becomes the only contributor to both public goods; the **joint-contribution regime** where spouses contribute simultaneously to one of the two public goods when resources are asymmetrically distributed across spouses; the **separate sphere regime** when spouses have comparable resources and each spouse specialises in his/her preferred public good.

When deciding the optimal allocation of resources the husband takes into account which regime prevails in the second stage. When the husband is the **bread-winner,** the wife would rather spend her limited income on the consumption of a private good. As long as the change in productivity does not change the regime , there is no benefit to him from sharing even if told that the investment would be much more profitable on his wife's plot, as he expects her to spend any additional income she would get on her own consumption.

When the **joint-contribution regime** kicks in, income neutrality allows spouses to reach productive efficiency. This is when the wife is not getting enough of her preferred public good from the contributions of her husband and wants to complement his contribution. Through their joint provision, they act as if they were pooling income. Thus, husbands would find it advantageous to make efficient farm decisions. Given the game settings, they would transfer all of the resources to their wife.

As the income gap between spouses decreases further, spouses may find it more advantageous to switch to a regime where each of them contributes to only one public good. **A separate sphere regime may arise when husband and wife care differently about distinct household public goods**. As a man's income decreases relatively to his wife's, he may be getting too much of his wife's preferred public good to equate the marginal utility he gets from this public good to the marginal utility he gets from consuming the other goods he cares about (private and public). He will thus prefer to solely contribute to the other public good. When each contributes separately to one public good, what is the husband's incentive to share any additional resources with his wife? She would spend the additional income on her private good but also on her preferred public good, from which he benefits. However, he knows his wife cares more about this particular public good than he does, so he will not invest all of the extra resources to the wife's plot but rather invests on his wife's plot until he equalizes the marginal benefits he derives from each public good. We would thus observe some partial sharing. In addition, in this case, it is not enough for him to know that the returns to his wife's plot are much higher, he needs to know how much higher they are in order to find the optimal level of transfer.

3.2 Unobserved wife's productivity and communication

We have identified one source of production inefficiency in the conflicting interests in consumption allocations. One additional source of inefficiencies may come from information asymmetries. In particular, the husband may be poorly informed about how much more productive the wife's plot is than his own. Even if the wife has correct information about her agricultural returns, she may be unable to effectively communicate them to the husband, again, due to the existence of the conflicting interests in consumption.

Thus, in line with the experimental setting, we now study the equilibrium in transfers and public good provision when the wife's higher productivity is not completely observed by the husband. We assume that the husband knows that his wife's plot is more productive than himself but but not by how much (k). The wife is completely informed, meaning she knows the value of both her productivity and her husband's. She is also aware that her husband does not have complete information.

We want to understand whether the wife can credibly inform the husband with respect to her productivity realization. We, thus, introduce a communication phase that takes place before the transfer stage in which the wife send a message to the husband about her productivity realization. Communication is costless (cheap-talk) in the sense that the wife does not pay a direct utility cost of sending a particular message. This means that sending one message rather than another does not require an investment in terms of utility.

There are three stages of the game: the first one in which the information transmission takes place; the second one in which, based on the signal given by the wife, the husband decides how much to transfer; the third in which spouses contribute to the public goods and to private consumption. After the wife sends a signal m to the husband with respect to her productivity, transfers followed by public good contributions take place.

We study the perfect Bayesian equilibrium of the three stage game. The communication technology of the wife corresponds the all possible k belonging to its probability distribution: $M = [k^L, k^H]$ is the set of feasible signals. The equilibrium will consist of a family of signaling rules

$h(m|k) : \int_M h(m|k)dm = 1$ and an equilibrium of transfers $t(m)$ and public good contribution $q(m) = (Q_A(m), Q_B(m))$ such that:

$$\max_m \quad U^W(t(m), Q_A(m), Q_B(m)|k),$$

and the husband solves:

$$\max_t \quad E[V^H|m]$$

Solving this problem - and defining $S_3(II) < S_3$ and $S_4(II) < S_4$ the new threshold values under Incomplete Information , we have the following proposition (see appendix for the proof):

Proposition 2 *The perfect Bayesian equilibrium is characterized by the wife always sending a non-informative signal; the husband sending transfers as following:*

$$\begin{array}{llll} \textit{(i)} & t^{**} = 0 & \textit{for} & \frac{Y^H}{Y^H+Y^W+k^H B} > S_4(II) \\ \textit{(ii)} & t^{**} = B & \textit{for} & S_3(II) < \frac{Y^H}{Y^H+Y^W+k^L B} < \frac{Y^H+B}{Y^H+Y^W+k^H B} \leq S_4(II) \\ \textit{(iii)} & B > t^{**} > 0 & \textit{for} & \frac{Y^H}{Y^H+Y^W+k^L B} \leq S_3(II) \end{array}$$

in case (iii) $t^{**} < t^*$.

The signal does not affect the transfer, only income distribution between spouses and the productivity difference matter. The husband uses transfers as;a means to balance the marginal utilities he derives from the two public goods. Thus, he transfers resources to his wife's because of her productivity advantage, so that she can finance her preferred public good. When there is high income inequality, only one spouse finances both public goods resulting in no intra-household transfers. Conversely, when income inequality is low, each spouse specialises in the production of one public good. Asymmetry of information on the wife's productivity has an effect on input allocation only in this situation. Because the husband does not observe his wife's productivity realization, he cannot anticipate how much she will invest in her preferred public good. Thus, unlike the case where there is perfect information, in this case he will decrease the amount of inputs transferred to his wife. Figure 1 summarizes the analytical approach of the decision-making process.

The model give us clear predictions about the relationship between transfers and productivity in the household, and how asymmetries of information affect them. We can summarize these predictions as follow. First, we expect transfers to be "intermediate", meaning strictly between 0 and B, for households in which spouses have "separate spheres" when contributing to public goods. Second, the amount transferred increases when the wife's productivity increases. Third, the increase is lower when the husband does not precisely observe the new productivity. We now turn to the description of our second round of games to test these empirical predictions.

3.3 Discussion: altruism and productivity advantages in public good provision

A natural extension of the paper would be to assume spouses are altruist toward each-others. Even if the scope for altruism to reduce inefficiencies in developing countries seems lesser than in developed ones as the occurrence of arranged and teenage marriages is higher (see Baland and

Ziparo, 2018 for a discussion), it seems natural to assume some emotional attachment between spouses.

Form a theoretical prospective, a level of altruism that would equate the weight given to the own consumption and the pertner's one would imply efficient contribution to public good and, thus, efficient allocation of resources. As discussed for the cooperative case, we can rule out this hypothesis since an important part of the empirical evidence points to inefficiency in production.

A low but positive level of altruism would imply higher contribution to the public goods for both spouses and so reduce the scope of existence of the separate sphere and the bread winner regime.

4 Testing the model's predictions

In section 2, we highlighted three key findings from the experiment. First, allocative inefficiency in production arises even when there are no informational problems. Second, men respond to a rise in returns on female plots by increasing their allocation towards them. Third, we find no response on average to private information. In this section, we test two implications of our model as to the response to private information. In the first sub-section, we consider the heterogeneity in the response to private information. We first explain how we proceed to test for it and then present our findings. In the second sub-section, we turn to the implication of ex post verifiability on the response to asymmetric information. In the last sub-section, we provide some evidence on the external validity of our experimental findings.

4.1 Testing for heterogenous response to asymmetric information

We expect asymmetric information to aggravate allocative inefficiency in production under specialization but to have no impact on households under joint contribution and on those with a breadwinner. To test these predictions, we contrast choices under *hidden treatment* (HT) – i.e., with female-held private information on the return to female plots – and under *experimenter treatment* (ET) – i.e., under full information on returns. Importantly, while in section 2 we examined the average impact of asymmetric information and found none, we here differentiate the impact according to choices made in the first round of the game (base treatment or BT). Indeed, in this first round, we observe some of the male farmers close to efficiently allocating inputs between their plot and their spouse's plot and classify these spouses as joint contributors. We also observe men who keep most units of inputs for themselves, resulting in a very inefficient allocation: they are the breadwinners according to our model. A third category corresponds to those in the specialization or separate-sphere regime: we observe them making somehow inefficient decisions under full information at BT.

Breadwinner husbands are not expected to transfer any input under asymmetric information for the same reason they are not expected to transfer any under full information. This type knows that if his wife were to gain some extra income, she would spend it entirely on her private good.

We also expect no response to asymmetric information from the joint contributors. That is because husbands should not care about the exact magnitude of the return: it is sufficient for them to know that it is higher on their wife's plot. Indeed, women in these households are not getting enough of their preferred good, so they can be expected to spend the extra income they get from the game on the provision of this good. Husbands benefit from making the efficient production allocation as they can still equate the marginal utility they get from their wife-preferred public good to the marginal utility they get from consuming the other goods they care about. It suffices that men in joint contributor couples know that returns on their wife's plot are higher than their own returns to make the efficient production allocation.

In contrast, we expect husbands in the specialization regime to give less to their wife under asymmetric information. In this regime, wives are expected to spend the additional income they could earn in the game on their preferred public good, from which husbands benefit, but also on their private good. Because each husband know his wife cares more about a particular public good than he does, he does not transfer all of the extra resources to his wife's plot but rather invests on his wife's plot until he equalizes the marginal benefits he derives from each public good, resulting in a somehow inefficient production allocation even under full information. Importantly, it is not enough for him to know that the returns to his wife's plot are much higher, he needs to know how much higher they are in order to find the optimal level of transfer. Under asymmetric information, he expects his wife to have an incentive to overstate the extent of these returns in order to get a higher transfer. He is thus expected to respond to the informational asymmetry by reducing the level of the transfer. Moreover, the asymmetric information treatment HT should affect more those who are further away from efficiency under full information.

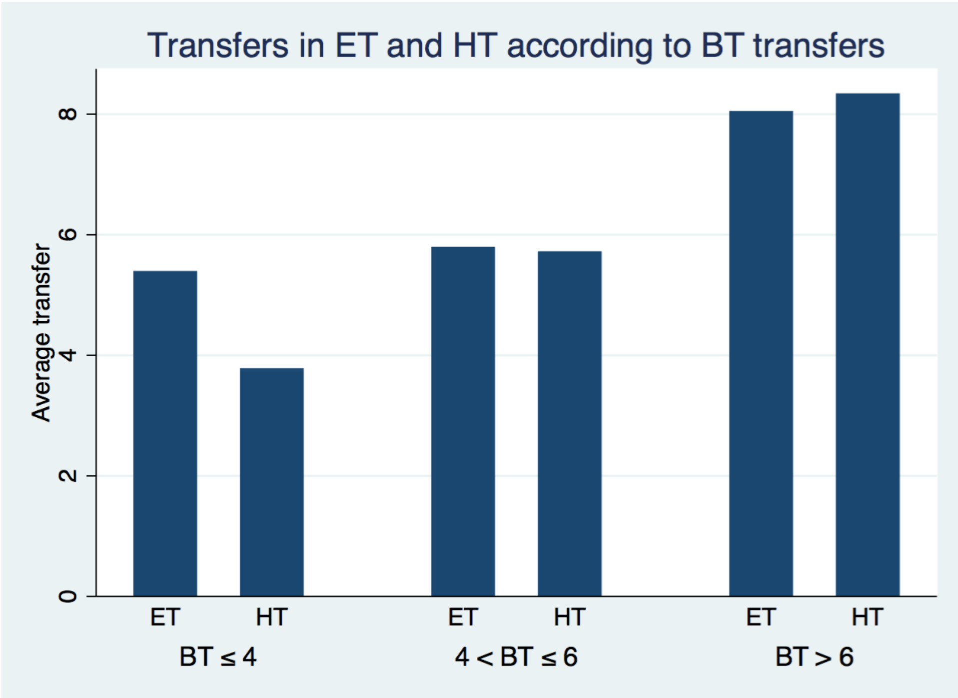
One caveat is in order. Theory predicts breadwinner husbands to choose $BT = PT = 0$, those who jointly contribute to a public good with their wife to choose$BT = PT = 10$ and households in a separate sphere regime to transfer some intermediate amount $0 < BT < 10$ and $0 < PT < 10$. In the data, no couples behave as strict breadwinner and very few households behave as strict joint contributors (a total of 8). However, because husbands may also hold social preferences (e.g., altruism, aversion to inequality), breadwinner husbands may decide to give a small amount to their wife and joint contributors to keep some for themselves.

We distinguish between 3 categories of households according to the number of tokens allocated to the wife's plot at BT. Variables$BT_category_j$ ($j = 1, 2, 3$) single out husbands who made low (lesser or equal to 4 for$j = 1$), intermediate (from 4 to 6 for$j = 2$) and high (greater or equal to 6 for$j = 3$) transfers to their wife at BT. [22]

We first plot transfers in ET and HT according to the level of transfers at BT, as described above (Figur(2)). Average transfers are similar in ET and HT in the two highest categories($j = 2, 3$) and lower in HT compared to ET for the lowest category ($j = 1$).

[22] We also discuss the robustness of the findings to the specific thresholds chosen for defining the categories.

Figure 2:

1. 

Source: own data sources

Because breadwinners are not expected to respond to asymmetric information, the estimated impact on the lowest category is interpreted to be a lower-bound for the effect of the informational asymmetry on the separate-sphere type. Note that our findings are robust to a certain extent to the choice of thresholds in BT. Yet we have too few observations with $BT <= 1$ to distinguish responses of breadwinners from those of separate sphere type.

Equation(1) can be extended to test for heterogenous impact as follows:

$$Y_i = a_2 + b_2 HT_i + c_2 LowTransfersBT + d_{2j} HT * LowTransfersBT + \epsilon_i \tag{1}$$

where Y_i is the number of tokens transferred in either ET or HT, and the omitted $BTcategory_j$ is low transfers at BT. As previously, HT is a dummy variable taking value 1 if spouses are randomly assigned to HT and 0 otherwise. The omitted category is intermediate/high transfers at BT ($j = 2, 3$). We expect no effect for $j = 2$ and $j = 3$ (i.e., to not reject the null hypothesis that $b2$ =0). We also expect a negative effect $d2 < 0$ for j=1, i.e., a negative impact from the informational friction for those who made low transfers at BT.

In Table 2, we show that the impact of asymmetric information is small and insignificant for those who made intermediate/high transfers at BT. Only those who made low transfers at BT respond to the informational frictions and they do so by decreasing the transfer they make to the female-controlled account by about 2 units of input (out of 10), as statistically significant drop. This drop yields a loss in efficiency of about 13 percentage points, corresponding to about 19 percent change. [23] This effect, which was hidden when we looked at the average treatment effect,

[23]The decrease in efficiency for those who made low transfers art BT is $2/30 * 1.9 = 0.13$. Under full information ($HT = 0$), these households would experience an efficiency loss of 0.69. The relative loss due to private information for these households is thus $0.13/0.69 = 0.18$.

is consistent with our prediction that the informational friction hurts separate-sphere households. The estimated effect is a lower-bound on the impact on separate-sphere households since the those who made low transfers at BT are a mix of separate-sphere and breadwinner households.

Table 2: Estimation of the effects of the informational asymmetry on transfers: heterogenous effects according to past transfers.

	Estimates	S.E.	t	$P > t$
HT	.29	.45	.64	.525
Low transfers at BT	-1.87	.83	-2.25	.027
Interaction w/ low transfers at BT	-1.90	.97	-1.95	.054
Intercept	7.27	.37	19.17	.000

Source: Authors' computations from own data sources

4.2 Testing for the effect of ex post verifiability

What could be driving the loss in efficiency experienced by separate-sphere households when information is asymmetric? To provide some light on this question, we contrast choices made under full private information (HT) to choices made when both spouses know that the information will be revealed ex post (RT). Recall that throughout our experiment spouses can discuss among each other. This is especially true during the informational treatments: the experimenter does not provide much information on returns on female-controlled plots, only indicating that they are at least as high as in the base treatment. According to our model, the detrimental effect of asymmetric information arises because spouses are unable to communicate effectively. When information is verifiable ex post, the cheap talk game breaks down and wives in separate-sphere households have a strong incentive to truthfully reveal their returns as long as there is some social cost from lying. Empirically, this implies that we should no longer find a difference between revealed treatment (verifiable information) and experimenter treatment (full information on returns) for the separate-sphere type. Or, equivalently, we should find that wives in separate-sphere households benefit from higher transfers under RT than under HT.

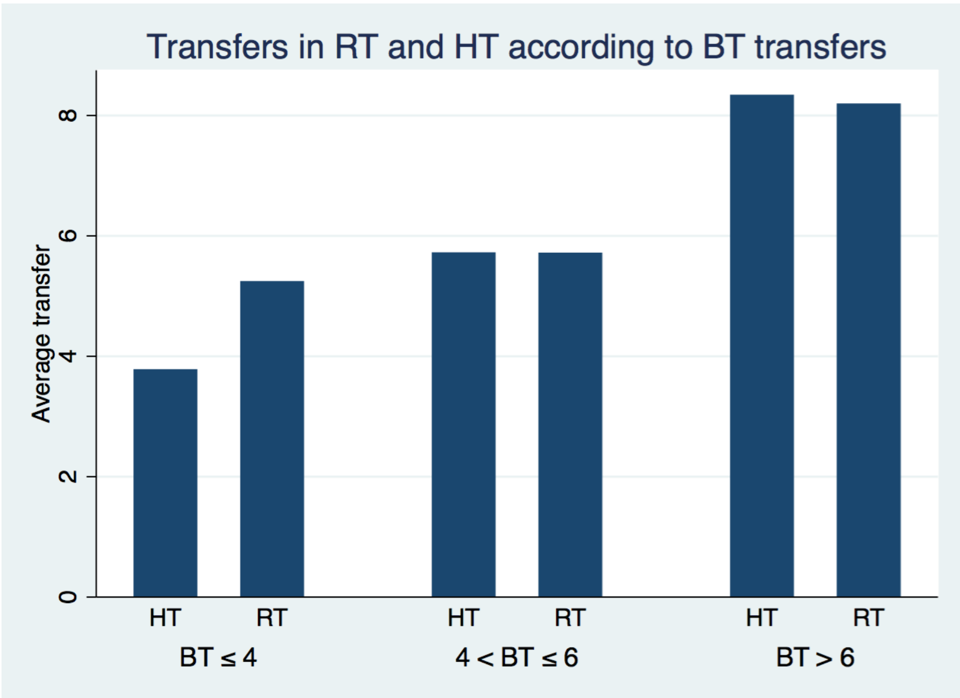
We find that for households who made low transfers at BT, transfers under RT are significantly higher than transfers under HT (Figure 3 and Table 3). Actually, they are the only households responding to information verifiability: the impact of asymmetric information is small and insignificant for those who made intermediate/high transfers at BT. These heterogenous impacts are consistent with the evidence gathered from contrasting HT and ET. When contrasting RT and HT, the estimated impact for those who made low transfers at BT is interpreted as a lower-bound for the impact of information verifiability on separate-sphere households. Notice that, as expected, it is of the same order of magnitude that the one obtained by contrasting HT and ET for those who made low transfers at BT.

Table 3: Estimation of the effects of non-verifiability on transfers: heterogenous effects according to past transfers.

	Estimates	S.E.	t	$P > t$
HT	.40	.35	1.13	0.262
Low transfers at BT	-1.91	.80	-2.39	.019
Interaction w/ low transfers at BT	-1.86	.94	-1.97	.052
Intercept	7.16	.25	28.29	.000

Source: Authors' computations from own data sources

Figure 3:



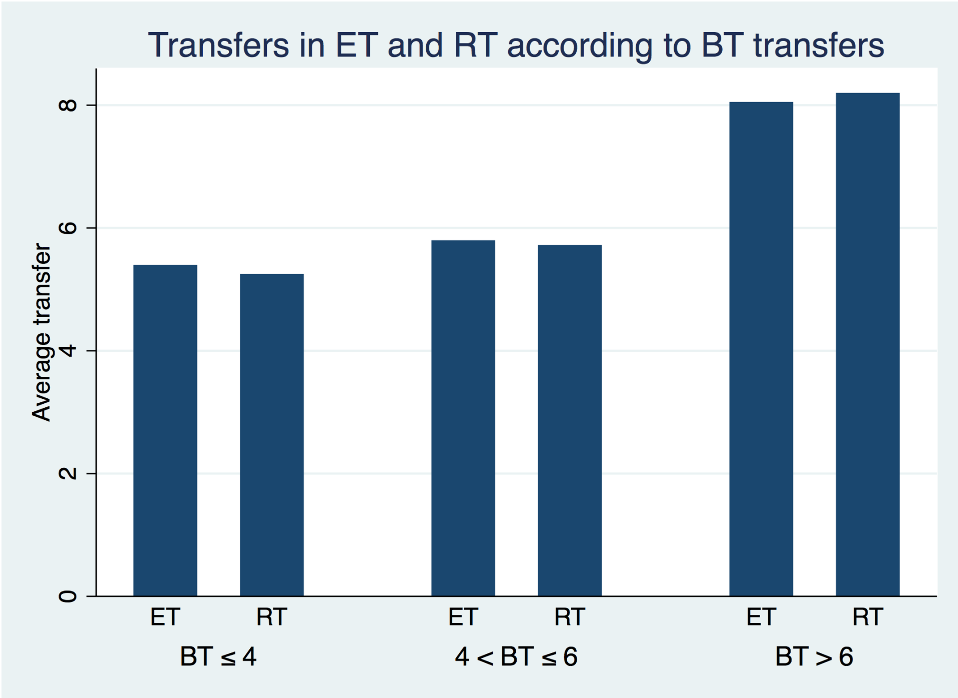
Source: own data sources

These findings are consistent with our model predictions: some households incur a loss due to the informational friction, but this loss can be overcome when information is verifiable ex post as women truthfully communicate with their husband about the true value of their returns. This points to communication failure between spouse as the source of the loss in efficiency in the presence of private information.

An alternative explanation for the loss in efficiency under private information is that spouses cannot perfectly enforce their agreements. If this were the case, we would expect all households to experience the same transfers on average under RT and under HT, including separate-sphere households. Household response should not depend on the level of transfers made in BT. Moreover, if limited commitment were to blame for the extra loss in efficiency due to the informational asymmetry, information verifiability should not make a difference to any of the households.

For the sake of completeness, we also provide a comparison of transfers under ET and RT (Figure4). As expected, there are no statistically significant difference in transfers for any of the types of households we identify based on the level of transfer at BT (Table 4).

Figure 4:



Source: own data sources

Table 4: Estimation of the effects of verifiability on transfers: heterogenous effects according to past transfers.

	Estimates	S.E.	t	$P > t$
ET	.11	.45	0.25	0.805
Low transfers at BT	-1.91	.80	-2.39	.019
Interaction w/ low transfers at BT	.03	1.15	.03	.975
Intercept	7.16	.25	28.22	.000

Source: Authors' computations from own data sources

To sum up, we find experimental evidence of inefficient allocation decisions, consistent with other findings based on observational studies. Moreover, we find two pieces of evidence consistent with the model's predictions. First, the efficiency loss due to asymmetric information is heterogenous according to past observed behavior under full information. Specifically, the extra loss is concentrated among those who experienced strong inefficiency (transfers lesser or equal to 4 input units) in the base treatment. Since only households in a separate sphere regime are expected to respond to the informational asymmetry, we interpret this effect as a lower bound of the effect on households. The heterogenous response to asymmetric information is thus in line with the model's prediction.

The second piece of evidence relates to the experimental manipulation of verifiability. The evidence is not consistent with asymmetric information making it harder to enforce agreements. The evidence shows heterogenous responses that is consistent with the model's prediction. For some households, agreements are self-supporting, and spouses do not need to be able to communicate over the exact value of returns to the female plot. For others (in a separate sphere regime), failure to communicate could explain the extra loss incurred under the informational asymmetry.

4.3 External validity

In order to check whether the findings from the lab-in-the-field may be informative about the actual real-life decision processes of our sample of farmers, we make use of the survey data. To proxy for the conflict of preferences between spouses, we examine whether spouses who have children from previous unions respond differently to the informational treatments in the game.

Lines 1 and 2 of Table 5 are in line with the model's predictions. First, private information does not affect game decisions when there are no other children from previous unions (lines 1 and 2, column 1). Second, when either the husband or the wife has children from other unions, the allocation to the wife decreases with each additional out-of-wedlock child (lines 1 and 2, column 2). Efficiency losses are avoided when the information is ex post verifiable (lines 1 and 2, columns 3 and 4).

Table 5: Heterogeneity by number of children from previous unions

	HT vs ET: Fully private information	Interaction effect ($T * X$)	RT vs ET: Private informati with ex post verifiability
Number of children wife has from previous union	-.09 (.50)	-.71*** (.27)	.19 (.46)
Number of children husband has from previous union	.06 (.55)	-.22* (.12)	.20 (.50)

Source: Authors' computations from own data sources

5 Conclusion

- Farmers may make inefficient production decisions in part because of intrahousehold dynamics.
- Asymmetric information within the household may exacerbate inefficiency, though not all households respond to it
- Communication between spouses may not be an effective tool to alleviate the problem.

- Results call for caution in designing gender-sensitive agricultural policy as these may backfire depending on intrahousehold dynamics.
- Though the lab-in-the-field has limited external validity, the model itself may be relevant for looking at investment decisions of poor households with multiple businesses held by different members (Bernhardt et al., 2017).

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6 Appendix A

The purpose of this note is to briefly describe the experimental games and provide a summary of the protocols (full version available in French and Ewe upon request).

Context and general instructions Each couple is invited to participate to 2 games. Game 1 (*BT* in the text) is the same for everyone. Couples are randomly assigned to 3 versions of Game 2 (*ET*, *RT* and *HT* in the text). At registration, each couple receives an identification tag featuring the letter corresponding to their Game 2 assignment and their order of arrival.

Husbands and wives are located in separate areas and assigned individual experimenters. To ensure confidentiality, places are picked so that experimenter-participant pairs are not at hearing distance from each other. During the experiment, each experimenter reads the instructions, explains and tests their assigned participant's understanding by probing them with questions. The game moves forward only after each participant provides correct answers to all questions.

Participants are told they can each earn money during the games. The amount they will get is based on both the decisions made by the husband during the games and the outcomes of two lotteries. These lotteries take place at the end of the games. The first lottery selects either game 1 gains or game 2 gains. As a result of the second lottery, the gain amount selected by the first lottery may be increased or reduced – there is even a chance they earn nothing. To help them understand the second lottery, the experimenter refers to uncertainty in agricultural production related to unexpected events (weather, pest) that may act as positive or negative shocks and how, when these events are extreme, farmers may lose everything.

Both husbands and wives know that their gains will be partly determined by the lotteries. They know the basic structure of the lotteries, but wives are not invited to observe the outcome of the lottery. Payments are made in an individual and confidential way to each of them. Husbands are informed that no one, including their wife, will know or can guess the decision they made and how much they will earn. Wives are informed that no one, except their husband, will know or can guess how much they will earn and that they will be told in the instructions if otherwise.

Game 1 (Base Treatment, same for all):

Of common knowledge to both men and women:

- There are two separate farmlands (plots). The woman is responsible for one of them, the man for the other.
- Each couple is provided with an endowment of 10 units of input to allocate between the two plots.
- Returns on each plot is constant but they are twice as high on the female's plot compared to the male's plot. In other words, yields increase linearly with the amount of input units used on each plot but the increase is twice as high on the female's plot compared to the male's plot.
- Each couple is allowed to talk freely for 5 minutes after they receive all instructions.
- The husband makes the allocation decision. He makes this decision privately after they are done talking.

- Each man is informed of potential gains from game 1 for himself and for his wife. Women neither observe nor are told about their husband's choice. They are not told how much they may earn from game 1.
- Both are invited to proceed to game 2.

Game 2:

Experimenter Treatment (ET)

Same as Base Treatment (BT), with the only difference that now returns on female's plot are three times higher than on male's plot. Participants are explicitly told that this is the only difference with the previous game. The experimenter reads instructions and probes to test for understanding. Men make a decision. As in BT, each man knows the potential gains he and his wife may make from game 2. As in BT, wives do not.

Revealed Treatment (RT)

There are three differences with BT that both members of the couple are informed of:

1. The experimenter tells husbands that returns on their wife's plot is at least as large as in game 1 and that the returns on their own plot is unchanged.
2. The wife, rather than the experimenter, is now in charge of communicating the information on the returns on her plot.
3. Male and female participants know that husbands will learn from experimenters the returns on their wife's plot once they made their allocation decision.

As in BT, each man knows the potential gains he and his wife may make from game 2. As in BT, wives do not, nor do they know the decision made by their husband.

7 Appendix B

Figure 5:

Images/scheme.pdf

Source: own data sources

8 Appendix C

8.1 Benchmark cases of optimal decision making with cooperative making process.

8.1.1 Optimal consumption allocations

We define γ as being the pareto weight of the wife and $(1-\gamma)$ that of the husband. Thus, the household maximisation problems is the following:

$$\mathrm{Max}\, \gamma U_i^W + (1-\gamma) U_i^H \tag{2}$$

which gives the optimal consumption levels:

$$Q_A^* = \tfrac{1+(\alpha-1)\gamma}{3+(\alpha-1)\gamma}(Y^H + Y^W)$$
$$Q_B^* = \tfrac{C^{*W}}{\gamma} = \tfrac{C^{*H}}{(1-\gamma)} = \tfrac{1}{3+(\alpha-1)\gamma}(Y^H + Y^W)$$

8.1.2 Optimal transfers

In this case the indirect utility of the husband is going to be:

$$V^H(t) = \log\left(\frac{1+(\alpha-1)\gamma}{3+(\alpha-1)\gamma}(Y^H + B - t + Y^W + kt)\right) + \\ (2-\gamma)\log\left(\frac{Y^H + B - t + Y^W + kt}{3+(\alpha-1)\gamma}\right)$$

This is clearly maximized for $t^* = B$.

9 Proofs

[Proof of Proposition 1]
Going backward, the two stages game has the following decision structure:
In stage 2, the spouses simultaneously solve the following maximization problems:

$$\max_{c^j, q_A^j, q_B^j} \log(c^j) + \log(Q_A) + \log(Q_B), \ \textit{for j=H, W}$$

$$\text{subject to } c^j + q_A^j + q_B^j \leq R^J.$$

The first order conditions for this maximisation problem for both spouses give the following set of equations:

$$\begin{array}{c} q_A^H + q_A^W \geq R^H - q_A^H - q_B^H, \\ q_B^H + q_B^W \geq R^H - q_A^H - q_B^H, \\ q_A^H + q_A^W \geq \alpha(R^W - q_A^W - q_B^W), \\ q_B^H + q_B^W \geq R^W - q_A^W - q_B^W. \end{array} \tag{3}$$

For each spouse to contribute to both public goods, we should have all four equations being satisfied with equality. However, it is immediately clear that this is impossible. The spouses contribute at most to one public good, either A or B. Also, in equilibrium, the wife always contributes more to good A than B, and the contrary is true for the husband.
We are now going to study the different regimes of contribution to public goods. Let $S = R^H/(R^H + R^W)$ be the husband's income share. Table 1 presents all cases. We define four thresholds: $S_1 = R^H/3$, $S_2 = 2/(3+\alpha)$, $S_3 = 2\alpha/(1+3\alpha)$, and $S_4 = 3\alpha/(1+3\alpha)$. As the husband's income share decreases from S_4, the wife starts contributing to Q_A until the household reaches the separate sphere regime where each spouse specializes in the production of one public good (when $S_2 < S < S_3$). As S decreases further, the wife starts contributing to both goods until the husbands stops contributing altogether (when $S < S1$).
Then, in the first stage, the husband determines the optimal level of transfers, t, taking as given the intra-household equilibrium of the second stage. Thus, he solves the following problem:

$$\max_t \quad V^H(t)$$

$$\text{subject to } t \leq B.$$

where $V^H(t)$ is the indirect utility of the husband.

In this case, the indirect utility of the husband varies depending on the relative income interval, that changes with equilibrium transfers, in which the household ends up in. We focus here on the cases in which the husband is richer, his initial income share being greater than 1/2.
The husband's indirect utility in the second stage is

$$\begin{array}{rcl} V^H(t) = 3\log\left(\frac{Y^H+B-t}{3}\right) & for & S(B) > S_4 \\ V^H(t) = 3\log\left(\frac{\alpha}{1+3\alpha}(Y^H+B-t+Y^W+kt)\right) & for & S_3 < S(B) < S(0) \leq S_4 \\ V^H(t) = 2\log\left(\frac{Y^H+B-t}{2}\right) + \log\left(\frac{\alpha Y^W+kt}{1+\alpha}\right) & for & S(0) \leq S_3 \end{array}$$

with $S_1^H = Y^H/(Y^H+Y^W+kB)$ the husband's income share when he transfers the total assets B to his wife, and $S_2^H = (Y^H+B)/(Y^H+Y^W+B)$ that when he keeps all the assets.
For $S(B) > S_4$, it follows immediatly that $t^* = 0$. For $S(0) < S_4$, when both spouses contributing to the same public good, $t^* = B$. Instead, for $S(B) < S_4 < S(0) \leq T_4$, we have that either $t^* = B$ or $t^* = B$ depending on the level of k. In particular, $t^* = B$ ($t^* = 0$) for $k \geq \frac{1+3\alpha}{3\alpha}$ (<).
Finally, when $S(0) < T_3$, the husband solves the following maximization problem:

$$\begin{gathered} \max_t \quad 2\log\left(\frac{Y^H+B-t}{2}\right) + \log\left(\frac{\alpha Y^W+\alpha kt}{1+\alpha}\right) \\ \text{subject to } t \leq B. \end{gathered} \tag{4}$$

The optimal level of transfers in this case is

$$t^* = \frac{Y^H+B}{2} - \frac{2Y^W}{3k}. \tag{5}$$

Also, when $S(B) \leq S_3 < S(0)$ we can identify the level of transfers that induces a regime change from joint contribution to specialization: $\bar{t} = [(1+\alpha)(Y^H+B) - 2\alpha Y^W]/[2\alpha k+1+\alpha]$. Since it can easily be shown that $t^* = [(Y^H+B)/2] - [2Y^W/(3k)]$ is always bigger than $\bar{t}$, it follows that this is the optimal level in this case.
[Proof of Proposition 2] Going backward, the three stages game has the following decision structure:
In stage 3, the spouses simultaneously solve the following maximization problems:

$$\max_{q_A^W(m), q_B^W(m)} \log(Y^W + kt(m) - q_A^W(m) - q_B^W(m)|k) + \alpha\log(Q_A(m)|k) + \log(Q_B(m)|k)$$

$$\max_{q_A^H(m), q_B^H(m)} \log(Y^H + B - t(m) - q_A^H(m) - q_B^H(m)|m) + E(\log(Q_A(m))|m) + E(\log(Q_B(m))|m)$$

in stage 2, the husband solves:

$$\max_t \quad E[V^H(t)|m]$$

In stage 1, the wife solves:

$$\max_m \quad V^W(m)$$

This means that in stage 1, the husband decides his contribution to the household public goods based on the expected behaviour of the wife, given the observed wife's income and the productivity inferred through the message she sent at stage 1; the wife, instead, is perfectly informed. Again, in stage 2, the husband decides how much to send to the wife, based on the message she sent in stage 1. Finally, when deciding which message to send the wife takes into account how it is going to affect the husband's behaviour in stage 2 and 3.
We first study the equilibrium in public good provision and transfers with asymmetric information and, then, we study the communication equilibrium of the first stage of the game. In stage 3, the first order conditions of the maximisation problem of the wife are the same as the complete information problem. The first order condition for good A of the husband becomes:

$$\frac{1}{Y^H+B-t-q_A^H-q_B^H} = \int_{\underline{k}}^{\overline{k}} \frac{1}{q_A^H+q_A^W(x)} F(x)dx$$

.
As before, we study how the husband contribution varies with (expected) relative income. We make one simplifying assumption: the $\underline{k}-\overline{k}$ interval is such that the distribution of expected relative income when all the resources are given to the wife is smaller than the smaller contribution interval (either $T2-T3$ or $T3-T4$ or $T4-1$). We also assume that $E(k)=k'$. When the relative income of the husband is very high $q_A^W(k)=0$ for every k. Then, we want to identify the level of (actual) relative income at which the wife starts contributing to good A. We know that this level is exactly equal to T4 when the husband is completely informed. Now, let's assume we are in T4 and the husband has rational expectations about the productivity of the wife. We can define $k^4 : \lim_{k\to k^4} q_A^W(k) \to 0$. The first order condition of the husband becomes:

$$\frac{1}{Y^H+B-t-q_A^H-q_B^H} = \int_{\underline{k}}^{k^4} \frac{1}{q_A^H} F(x)dx + \int_{k^4}^{\overline{k}} \frac{1}{q_A^H+q_A^W(x)} F(x)dx$$

.
Since $\int_{k^4}^{\overline{k}} \frac{1}{q_A^H+q_A^W(x)} F(x)dx < \int_{k^4}^{\overline{k}} \frac{1}{q_A^H} F(x)dx$. It follows that in T_4, with II, $q_A^{**H} < q_A^{*H}$. So the level at which q_A^W starts to be 0 is lower than T_4.
Symmetrically, we want to see what happens on the other edge of the interval, when the (actual) relative income is equal to T3. Here, we compare the marginal return of consumption and public good when $q_A^H =$ (the optimal value in T3 with CI). Since we know that $u'(.)$ is convex in q_A^H it follows that:

$$\frac{1}{Y^H+B-t-q_B^H} > \int_{\underline{k}}^{\overline{k}} \frac{1}{q_A^W(x)} F(x)dx$$

. It follows that in T_3, with II, $q_A^{**H} > 0$. So the level at which q_A^H starts to be 0 is lower than T_3. The two thresholds are thus pushed towards the left.
We now analyse optimal transfers. When $[\frac{R^H}{R^H+R^W(\underline{k}B)} - \frac{R^H}{R^H+R^W(\overline{k}B)}] \in [T4-1] \to t^{**}=0$, when $[\frac{R^H}{R^H+R^W(\underline{k}B)} - \frac{R^H}{R^H+R^W(\overline{k}B)}] \in [T3-T4] \to t^{**}=B$ and when $\frac{R^H}{R^H+R^W(0)} < T3$ then $t^{**}=0$. It is easy to show that $t^{**}=B$ as long as $q_A^{**H}>0$ even when $T3 \in [\frac{R^H}{R^H+R^W(\underline{k}B)} - \frac{R^H}{R^H+R^W(\overline{k}B)}]$.
When , instead $T3 \in [\frac{R^H}{R^H+R^W(\underline{k}B)} - \frac{R^H}{R^H+R^W(\overline{k}B)}]$ and $q_A^{**H}=0$; or,
$T3 \in [\frac{R^H}{R^H+R^W(\underline{k}B)} - \frac{R^H}{R^H+R^W(\underline{k}B)}]$, $t^{**}<t^*$ because of $RRA=1$.
Finally, for all the realization of productivity, within a certain interval of relative income (that

is perfectly observed by the wife, all the types prefer to declare the same message, no communication is possible in equilibrium (Crawford and Sobel, 1982).