Intrahousehold Bargaining and Agricultural Technology Adoption: Experimental Evidence from Zambia*

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Abstract

This study examines how technology adoption is determined in an intra-household bargaining process between spouses with different incentives. We develop a household bargaining model in which individual investments affect members' future bargaining position within the family, which can yield Pareto-inferior outcomes. To test for possible inefficiency, we introduce rice seeds to farmers in rural Zambia and randomly distribute vouchers for transportation from the village to a miller in town to husbands or wives. The results show that who receives the voucher matters for rice seed take-up when wives choose which crop to grow on suitable plots for rice production. Furthermore, intra-household information flows are distorted by the recipients. The heterogeneous effects and incomplete information sharing among spouses provide evidence against efficient resource pooling within the household. We present suggestive evidence that limited commitment to the production plan is a key mechanism behind strategic spousal behavior.

Keywords: Nonunitary model, productive efficiency, gender, targeting, Zambia

JEL Classification: D13, J12

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1 Introduction

Seemingly profitable technologies are being adopted slowly across a wide range of goods and contexts in developing countries. Typical examples include agricultural technologies (e.g., fertilizer), health products (e.g., mosquito nets), and financial products (e.g., microinsurance). This empirical puzzle has received much attention from economists, and an extensive literature has identified the factors acting as constraints preventing the adoption of new technologies among the poor.[1] Common explanations for the weak adoption include tight cash/credit constraints (Carter et al., 2013; Beaman et al., 2020), existing uninsurable risks (Karlan et al., 2014; Emerick et al., 2016), a lack of knowledge about how to use technology and what their private returns are (Bryan et al., 2014; Emerick and Dar, 2020), and the absence of supporting markets for consistent supply and maintenance (Hanna et al., 2016). However, these important impediments are all at the household level. In practice, each family member, with their own diverse preferences and resource constraints, is involved in household decision making. Relative bargaining positions among spouses within the household may have a significant impact on household-level technology adoption. In this study, we illustrate the importance of intrahousehold bargaining processes in technology adoption in rural sub-Saharan contexts.

At the individual level, the gender division of household responsibilities reflecting productivity differences implies that the benefits of adopting a new technology could be unequal among the spouses. For example, Pitt et al. (2010) find that women may bear a disproportionate share of health costs from indoor air pollution due to the unequal time burdens of food preparation and thus can reap greater benefits from the adoption of cleaner cookstoves. However, irrespective of females' higher demand for such a technology, their wishes may be overturned by their husbands due to their greater financial control, leading to an overall low demand (Miller and Mobarak, 2013). Thus, the targets of policy initiatives will differ depending on individuals' incentives to adopt a new technology and the binding constraints each faces.

This study investigates how incentives targeted to a particular spouse under gender-differentiated constraints on productive resources shape household technology adoption behavior. We start with a simple bargaining model with an internal noncooperative threat point, as in Lundberg and Pollak (1993). In the model, spouses cannot follow the Pareto-efficient production plan since they face different timings of specialized agricultural tasks and thus potential moral hazard problems in the future. For this reason, we extend the model with endogenous outside options by allowing strategic interactions between spouses. We impose the following assumptions in the framework: (1) each gender has a comparative advantage in different production activities (e.g., women are more productive in milling than men), and (2) individuals' agricultural investments determine not only total household income but also the relative future bargaining positions within the couple. Building upon these assumptions, the model predicts the possibility of sub-optimal outcomes in household equilibrium. In particular, the investment incentive targeted to an individual may not be effective for technology adoption when the other spouse controls a productive resource since he/she has little incentive to share it with that spouse. Thus, the effectiveness of policies aimed at encouraging adoption depends on the identities of the policy targets and the resource managers.

[1] See Jack (2013) and Magruder (2018) for an excellent review, with a focus on agricultural technology adoption.

African agriculture provides us a fruitful setting in which to examine this prediction. Agro-ecological conditions are fundamental determinants in agricultural technology adoption, such as crop choices. For instance, rice (our target crop) requires a great deal of water, making wetlands the most suitable areas for cultivation if there is no access to irrigation. Given that land rental markets are not active in many parts of sub-Saharan Africa, whether the household has access to suitable land for a particular crop would determine the level of agricultural investment made. Disparity in access to land can be observed not only across households but also within households. In particular, gender inequality in control over farm land in marriage is well-documented in the literature (Doss et al., 2015; Dillon and Voena, 2018). The literature has also found a misallocation of agricultural inputs between female and male plots (Udry, 1996). Given that relative contributions to household budgets are a determinant of marital bargaining power (Thomas, 1990; Hoddinott and Haddad, 1995), which family member controls agricultural plots relevant to a technology would affect household decisions through changes in their future power balance.

We test the validity of our theory by conducting a randomized controlled trial in which investment incentives to grow rice are offered to either males (husbands, who have greater control over household resources) or females (wives/female household heads) in rural Zambia. The important feature of the study area is that management rights over plots are individualized, and a good number of wives also have the authority to choose which crop to grow for agricultural fields. Specifically, female plot managers have greater control than their male counterparts over crop choice for shallow wetlands, locally called "dambo", which provide a productive environment for rice production. We introduced rice seeds, new to most of the local farmers, and gave randomly selected households vouchers covering the cost of transportation from their village to a miller in town, conditional on their milling rice there. In the intervention, we randomized the gender of the voucher recipient to test the theoretical prediction.

Empirical analyses using gender-disaggregated data on land management reveal that vouchers given to wives induce more demand for rice seeds than do vouchers given to husbands in households where the wife controls the dambo. This result indicates that the gender of the voucher recipient matters for technology adoption in this sub-population. We also find that plot managers' gender affects household decision making since the investment incentives given to husbands are effective in boosting household demand only when they control the dambo plot. Individual-level demand analyses show that the favorable impacts on total household demand come mostly from the high interest level of the dambo manager who received the transportation voucher. When the voucher recipient is different from the dambo manager within the household, the responses to the treatment look similar between the husband and wife. These heterogeneous effects can be accounted for by neither the canonical unitary household model nor the Pareto-efficient collective models. Rather, the empirical findings are consistent with the prediction of the inefficient bargaining model with feedback to future outside options.

Further analysis shows that the voucher recipient is less likely to communicate with his/her spouse about the voucher when the recipient and the dambo manager are different in the household. We interpret the observed incomplete information sharing among spouses as an outcome of the strategic behavior of the voucher recipients: They have no incentive to exploit the voucher for fear of improving their spouse's future say. This study also reports that purchase households are more likely to plant rice seeds when the voucher recipient takes responsibility for the management of the dambo plots. This result suggests the salience of limited commitment to future production plans in agricultural investment decisions. By contrast, gender differences regarding knowledge of rice cultivation and perceptions about the role of rice (food vs. cash crop/male vs. female crop) do not match well with the empirical patterns of demand for rice seeds among spouses.

Our findings contribute to three strands of the literature. First, this empirical examination is one of the first to study the role of intrahousehold bargaining in technology adoption among developing countries. Previous studies in this domain focus on gender differences in preferences as a key driver of low demand.[2] By contrast, our study underscores gender differences in resource management and presents empirical evidence that the effectiveness of policy interventions depends on who controls the relevant productive resources within the household. The study's model derives the important prediction that even if preferences are symmetric among spouses, second-best outcomes can be chosen as equilibrium through an intrahousehold bargaining process. In this vein, Lim et al. (2007) investigate the role of exit options available to each spouse as a threat point in household crop choice. While they treat livestock disposition upon divorce as an exogenous determinant of outside options, our model allows current investment decisions to affect future say in decisions within marriage. Other studies have found that the introduction of a new technology and subsequent agricultural commercialization can alter gender norms and hence power relationships within the household (von Braun and Webb, 1989; Fischer and Qaim, 2012; Carney and Carney, 2018). In our model, spouses take this possibility into consideration in their decision making.

Second, our work makes a direct contribution to the broad literature on intra-household allocation and targeting (Alderman et al., 1995; Doss, 2013). A vast literature has examined allocative and productive efficiency and highlighted the importance of modelling the household as a site of both cooperation and conflict among family members.[3] The unequal distribution of productive resources does not per se imply inefficient allocations for households, if it is a result of specialization among members (Doepke and Tertilt, 2019). However, this interpretation has been convincingly contested by many empirical studies on West Africa.[4] We add to the subset of this rich literature novel evidence that household technology

[2]See Miller and Mobarak (2013) and Mohapatra and Simon (2017) regarding cookstoves, Gulati et al. (2019) regarding agricultural machinery, Magnan et al. (2020) regarding improved maize seeds, Schaner (2015) regarding saving accounts, and Takahashi et al. (2016) and Bageant and Barrett (2017) regarding index insurance. Among them, Miller and Mobarak (2013) is a notable complementary study. In their demand experiment on improved cookstoves in Bangladesh, women showed higher demand initially but were less likely to adopt them in the end because they lacked the authority to make purchasing decisions. Magnan et al. (2020) test how spousal preferences influence the adoption of an improved maize seed in rural Tanzania. The results from one of two survey regions show that wives' risk preference parameters also have an explanatory power for household seed choice after controlling for the husbands' parameters.

[3]From the consumption side, Duflo (2003) finds that unearned income received by women is associated with greater improvements in the nutrition of girls than is that received by men in South Africa. A classic paper by Thomas (1990) also confirms that unearned income in the hands of wives is devoted more to expenditures on education, health care, and food using data from Brazil. Duflo and Udry (2004) show that harvest income shocks on male and female crops have different effects on the types of goods consumed in rural Cote d'Ivoire. From the production side, Udry (1996) reports the presence of agricultural input misallocation among male- and female-controlled plots, generating large productive inefficiencies. Similar production inefficiencies have been observed between Burkinabe's collectively and individually managed plots by Haider et al. (2018). Rangel and Thomas (2019) empirically test these two kinds of household efficiency based on the same dataset.

[4]See Udry (1996) for Burkina Faso, Duflo and Udry (2004) for Cote d'Ivoire, and Goldstein and Udry (2008) and Slootmaker (2014) for Ghana.

adoption decisions could be Pareto-inefficient. We also present suggestive evidence that spouses cannot stick to the efficient production plan and thus that individual agricultural investments determine future bargaining positions within the family. Walther (2018) is the closest to our study. She tests implications from a noncooperative collective model similar to ours in which spouses are unable to commit to a particular labor allocation ex ante. By exploiting the spatial distributions of descent rules in Malawi, her study reports that farmers with their own plots will overinvest labor in them to improve their future say within the household. Finally, the observed incomplete information sharing among spouses is consistent with strategic information withholding in various settings reported by the literature (e.g., Anderson and Baland, 2002; Ashraf, 2009).

Third, this study is also related to the literature on land inequalities between men and women and their economic consequences (e.g., Doss et al., 2015). For instance, Allendorf (2007) and Peterman (2011) show that women's land rights improve their say within the household, which leads to favorable impacts on their welfare and child outcomes. In line with those results, our analysis shows that pre-determined inequality in de facto land rights across genders within a household is an important factor contributing to the adoption of profitable technology.

The rest of this paper is structured as follows. Section 2 discusses the study's experimental setting, focusing on intra-household plot management, and the survey data used for the empirical analysis. Section 3 develops a bargaining model with no intertemporal commitment to establish a conceptual framework for empirical analyses. Empirical specifications and key results, as well as supporting evidence for the main findings, are presented in Section 4. Section 5 investigates the extent to which information is shared among spouses. An examination of the potential mechanisms behind the observed inefficiency follows in Section 6. Section 7 concludes the paper and discusses its implications for the design of effective programs aimed at technology diffusion.

2 Background

2.1 Experimental Context

Our survey area is located in Masaiti District of Copperbelt Province, Zambia (see Figure 1). People's livelihoods depend mainly on rain-fed agriculture, and the major crops for cultivation are maize, cassava, sweet potato, and groundnuts. The main agricultural season coincides with the rainy season (November–April). In the dry season (May–October), their agricultural activities are limited.

This district features shallow wetlands, which are inundated in the rainy season and become arid by the end of the dry season but retain some moisture throughout it, locally referred to as "dambo". Many dambo lands are left unexploited. Field interviews with local informants from 60 villages in 2013 showed that the proportion of cultivated areas out of the dambo was below 10%. The main reason for this low utilization is that maize, the staple food in Zambia, is not the best crop to plant on dambo, and no alternative crops were suitable for growing during the rainy season. Taking advantage of the remaining moisture in their soils, only a few farmers grow vegetables (e.g., rape and tomato) on dambo during the

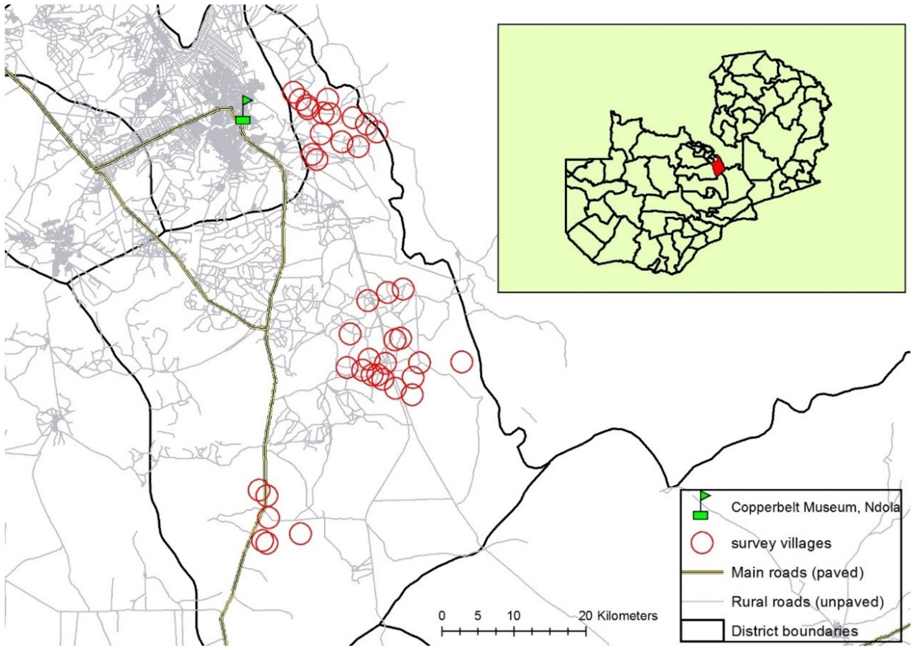

Figure 1: Project area

Notes: The top right panel shows administrative districts across Zambia and the red-colored one is Masaiti district in Copperbelt Province.

dry season. Hence, making full use of unexploited dambo could create alternative income sources.

Candidates include rice, such as New Rice for Africa (NERICA) variety, which is suitable for the African environment. The dissemination of rice cultivation will benefit people's livelihoods in many ways since rice will provide them with a new cash-earning opportunity and contribute to their diet. Rice for consumption is available for sales within villages and local people often purchase and consume it. However, rice seeds for production were not available at local markets, and their cultivation was completely new to most local farmers.[5] We collected information about potential interest in rice production by holding group discussions with farmers in March 2018. We noticed that reactions differed by gender: Female farmers showed great interest in rice cultivation, mainly for home consumption, but also expressed concerns relating to milling, whereas some male farmers were concerned about marketing rice after the harvest since there were no rice traders (unlike for maize).

In addition to such gender differences in reactions, intra-household inequality in land management rights make decision-making processes complicated in our context. In the survey area, land management rights are individualized, and a good number of women also practically choose which crop to grow for agricultural plots. This is culturally rooted in marriage practices.[6] Local communities in the survey area

[5]In 2013, we implemented training programs on rice production and gave NERICA rice seeds to agricultural camp extension officers in collaboration with the Japanese International Cooperation Agency. The training was conducted with officers from six different agricultural camps in Masaiti District. They were asked to conduct training sessions and distribute the seeds to local farmers for free. Despite this program, rice cultivation remained nonexistent in 2018 when we re-visited the survey communities. We found that farmers lost rice seeds due to poor harvests and could not buy more seeds because of the absence of rice seed markets in the survey region. As a result, rice was still a fairly new crop to our sample farmers at baseline.

[6]The survey data show that about 85% of household heads are Bemba, Lala, and Lamba. These ethnic groups follow a matrilineal lineage system, in which inheritances are passed down through the female line (Wotela, 2008).

follow a system of matrilocal residence in which the husband moves to the wife's village after the wedding. Her natal family will then allocate land to the daughter and her husband. The husband acquires only contingent rights during the uxorilocal marriage (Machina, 2002). The important empirical consideration is that the intrahousehold allocation of management rights over agricultural fields is pre-determined and fixed at marriage. Exploiting variations in this institutional factor, this study also investigates how a husband and wife with different roles in land management interact and jointly make important household decisions such as the adoption of a new crop.

Given the potential for disagreements regarding adoption among spouses with different land management roles, the issue of whether offering an opportunity to buy rice seeds leads to household rice adoption is an important empirical question. To answer this, we designed and conducted a demand experiment involving NERICA to quantify the actual demand for rice cultivation. To this end, we chose 30 villages from the 60 villages in which a community survey had been conducted in 2013. From each village, we randomly selected approximately 60% of the households to form our sample. This sample consists of 532 agricultural households, including single female-headed and single male-headed households.

2.2 Experiments and Data

To relax the potential constraints farmers face, we distributed printed vouchers to randomly selected individuals in July/August 2018. Voucher recipients could obtain the cost of transportation between their village and Ndola, where a collaborating rice miller was located.[7] Transportation costs range from K35 to K110 (USD 3 to 9), depending on the distance between the village and Ndola.[8] The voucher can be redeemed at the miller only for the purpose of milling rice in May 2019 (i.e., after the harvest season).[9] To avoid any exchange of vouchers among villagers, we informed recipients that the voucher could be redeemed only by the person whose name was on the voucher or his/her spouse.[10] Because strenuous manual milling is generally done by females, we expect that this treatment benefits women more than men by saving their energy and labor time.

The voucher recipients were randomized at the household level to test the differential reactions to the treatment by gender. Within a village, we randomly assigned sample households equally into (1) a treatment group of households in which women (wives/single female heads) received the transportation voucher (TF), (2) a group of households in which men (husbands/single male heads) received it (TM),

[7]As far as we know, this was the only rice miller in the study region when we conducted the experiment.

[8]In 2018, USD 1 was equal to K12 (12 Zambian Kwacha).

[9]The advantage of this treatment is that the transportation voucher does not affect household budget constraints at the time of rice seed purchase. As in Miller and Mobarak (2013), the free offer of rice seeds might have been another intervention that could have detected spousal differences in demand. However, resale to neighbors would have been a great concern, as it could reflect demand for immediate cash rather than demand for rice cultivation. For the same reason, we did not introduce randomly subsidized prices. Note that our treatment is not entirely free from this issue, although some precautions were implemented. See Footnote 10 for further details.

[10]As in Jensen and Miller (2008), the resale and counterfeit of vouchers is a major concern in the experimental design. To prevent them, (1) the vouchers were signed by the authors in Chinese characters with highlighters, (2) the recipients had pictures taken so that we could validate them at redemption, and (3) the recipients were explicitly told that the vouchers should not be transferred to any other household.

and (3) a control group of households that did not receive a voucher (C).[11] Given that female-headed households are common in the survey area, the sampling procedure was not restricted to couples. When single female-headed (single male-headed) households were assigned to the TM (TF) category at the first selection, such households were dropped and replaced with newly selected households since implementing the treatment was not feasible.

The baseline information was collected in July/August 2018. The survey questionnaire consisted of two sections. The first part collected household-level information on demographics, production activities, consumption expenditure, and asset ownership. To collect the information necessary for this study, the second part of the interviews were conducted separately with household heads and their spouses in turn in isolation from other family member.[12] At the very end of the interview, enumerators explained basic information on rice cultivation with a brochure. Irrespective of his/her treatment category, every respondent also received information on October rice seed sales with a price list and a location of the rice miller in Ndola. Finally, the transportation voucher was provided to women (men) for TF (TM) households, and interviewers took photos of the respondent with the voucher.

Although we included single male/female households in our sample, the analysis focuses on married couples since our primary interest is to understand intra-household decision making. Out of 532 households, the effective sample size is 384 households after excluding 106 single female households (20%), 27 single male households (5%), and 15 couples with missing information on either spouse (3%). The analysis sample includes only one polygamous household.

Table 1 reports the baseline household characteristics for the analysis sample. The average family size is 5.8, and only 6% of the households had experience in growing rice. In our analysis, the important empirical variable is the gender of plot managers in general and dambo fields in particular. The plot manager is defined based not on ownership but on who can make a decision regarding what to plant since our primary outcome is rice adoption.[13] As Table 1 shows, 39% of households own dambo fields[14]; wives are in charge of crop choice for dambo in 25% of them (10% of the whole sample), while husbands are responsible for crop selection on dambo plots in 75% of them (29% of the whole sample).

Table 1 also shows the balance of observable household characteristics across the treatment arms. No statistically significant differences across the categories are detected at the 5% level except for the ages of the wife and husband. Since age gaps between husband and wife are more relevant to bargaining positions than their absolute levels, we verified that the age gaps were not systematically different across the treatment categories (p-value = 0.73). We need to control for land size and age levels for both spouses in all the regressions below to assure the reliability of the treatment impact estimates; Table 1 indicates

[11]Since the randomization was done at the household level, information spillover is a concern, as it would contaminate the true treatment effects. However, the important information, such as the location of the miller in Ndola, was provided to both the control and treatment households. Thus, the voucher itself does not have any extra information.

[12]Since treatment in a presence of the spouse can cause a different impact, as Ashraf et al. (2014) found in Zambia, we strictly implemented the treatment in isolation so that information about the voucher was kept private at the intervention. However, we did not prohibit information sharing among spouses after the intervention.

[13]Further discussion about the definition of plot manager is provided in the next subsection.

[14]In addition to planting rice on dambo, rice can be grown in gardens with manual watering. However, where irrigation system is nonexistent, manual watering requires tremendous labor burdens.

Table 1: Baseline characteristics and balance check

Variable	(1) TF Mean/SD	(2) TM Mean/SD	(3) TC Mean/SD	(4) Total Mean/SD	F-test for joint orthogonality
Family size	5.80	5.80	5.77	5.79	0.99
	(2.12)	(2.06)	(2.31)	(2.15)	
Land size (ha)	2.39	3.33	2.91	2.92	0.05*
	(2.66)	(3.40)	(3.24)	(3.16)	
Value of assets (K1000)	2.73	3.77	3.83	3.47	0.25
	(3.60)	(5.29)	(7.84)	(5.77)	
=1 if has grown rice in last 10 years	0.09	0.06	0.04	0.06	0.28
	(0.28)	(0.23)	(0.19)	(0.24)	
=1 if household owns dambo	0.42	0.41	0.35	0.39	0.50
	(0.50)	(0.49)	(0.48)	(0.49)	
=1 if wife manages dambo	0.12	0.09	0.09	0.10	0.67
	(0.33)	(0.29)	(0.29)	(0.30)	
=1 if husband manages dambo	0.30	0.32	0.26	0.29	0.60
	(0.46)	(0.47)	(0.44)	(0.46)	
Age, wife	35.92	39.97	39.10	38.48	0.03**
	(11.95)	(13.36)	(12.99)	(12.92)	
Age, husband	41.63	46.08	45.20	44.47	0.03**
	(12.69)	(15.04)	(14.17)	(14.20)	
Years of education, wife	5.90	6.05	5.71	5.90	0.62
	(2.86)	(2.92)	(2.79)	(2.86)	
Years of education, husband	7.67	7.18	7.25	7.35	0.37
	(2.49)	(3.27)	(2.93)	(2.95)	
Financial autonomy (K100), wife	0.73	0.70	0.70	0.71	0.94
	(0.89)	(0.88)	(0.91)	(0.89)	
Financial autonomy (K100), husband	0.68	0.76	0.83	0.76	0.40
	(0.66)	(0.86)	(0.94)	(0.83)	
Non-farm income (K1000/year), wife	0.25	0.49	0.57	0.44	0.49
	(1.33)	(1.79)	(3.04)	(2.13)	
Non-farm income (K1000/year), husband	2.36	2.70	2.20	2.45	0.63
	(3.50)	(5.34)	(3.64)	(4.37)	
Risk preference, wife	0.70	0.73	0.68	0.71	0.25
	(0.28)	(0.25)	(0.28)	(0.27)	
Risk preference, husband	0.70	0.72	0.74	0.72	0.62
	(0.26)	(0.28)	(0.22)	(0.26)	
N	117	155	112	384	

Notes: The last column shows p-values from the F-test for the equality across treatment status. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The index for financial autonomy is created based on the following question "How much can you spend (e.g., purchasing some commodities) at one time without consulting your spouse?". The options are "less than K10", "K10-K30", "K30-K50", "K50-K100", "K100-K300", "K300-K500", and "more than K500". We use the intermediate value for each option as a proxy for financial autonomy. Risk preference parameters are elicited from a Binswanger (1980)-style hypothetical game. Six available options are (K5, K5), (K4, K12), (K3, K16), (K2, K19), (K1, K21), and (K0, K22). Risk parameters corresponding to each option are 1, 0.75, 0.6, 0.5, 0.33, and 0. The higher value indicates more risk averse.

Table 2: Demand for rice seeds by treatment group

Variable	N	(1) TF Mean/SD	N	(2) TM Mean/SD	N	(3) C Mean/SD
=1 if purchased	117	0.32	155	0.37	112	0.28
		(0.47)		(0.49)		(0.45)
Seeds purchased (kg)	117	0.89	155	1.11	112	0.58
		(1.87)		(2.00)		(1.36)
Seeds conditional on purchase (kg)	37	2.81	58	2.97	31	2.10
		(2.38)		(2.28)		(1.89)

that the randomization created fairly comparable groups.

In October 2018, we revisited the survey villages and held rice seed sales meetings for a week in agricultural extension areas. We select the locations of sales for every 4 to 5 village. Sample households were reminded of the sales meeting by the extension officers one week before the sales. We sold rice seeds (NERICA 4) with a fixed price list for every customer. After the consultation with an agro-input dealer and extension officers, we set prices at K20 for 1 kg, K35 for 2 kg, K80 for 5 kg, and K150 for 10 kg. For other quantities not on the list, we added K15 per 1 kg over and above the nearest base price. Although the sales were not restricted to the sample households, very few non-sample households showed up. Right after the sales, we conducted a short interview to collect additional data on topics such as whether they had exchanged information on rice cultivation, vouchers, and seed sales with spouses and friends. To those who had purchased seeds, we asked not only about the quantity of seeds purchased but also about whose demand was being met and who would mainly grow the rice.[15] We also followed up with households that did not come to the rice sales meeting and asked the same set of questions.

Table 2 reports the unadjusted purchase rate (share of households who purchased seeds at our rice sales meeting), the average quantity of seeds purchased in the whole sample, and the conditional quantity among those who had purchased seeds by treatment arm. As seen in Table 2, the demand was highest in the TM group, followed by TF and C. Even after conditioning on purchase, the average quantity of seeds purchased was only 2 to 3 kg per household. This implies that their purchase was mainly for self-consumption instead of marketing. Since most of the households had never grown rice before, we also speculate that they purchased seeds for experimentation. For the households that did not purchase rice seeds, the common reasons were (1) a lack of money and (2) a lack of suitable plots.

We also conducted a follow-up survey in May/June 2019. In this follow-up survey, enumerators collected information on agricultural production for the 2018/19 agricultural season and gathered knowledge on rice cultivation and perceptions vis-à-vis the role of rice (cash or food crop) from each spouse. We successfully collected data from 347 (90.4%) of the 384 original households.

[15] Since plot managers need to pay all the input costs, it was fairly easy to identify whose demand it was in this context.

2.3 Land Management within the Household

Before proceeding further, it is useful to take a closer look at intra-household land management patterns. Many women control agricultural plots in our study area, reflecting the cultural practices of matrilocality discussed earlier. To quantitatively confirm land allocation patterns among spouses within the household, we collected information on the owner and main decision maker about what to grow and whether to sell harvests for each plot at the baseline survey.[16] Since the decision making of interest is the selection of the new crop (i.e., rice), this study defines a wife (husband) plot as a field for which she (he) mainly decides what crop to grow. In other words, this study focuses on de facto plot managers rather than land owners. Those in charge of crop choice are usually also entitled to control the use of the revenue obtained from the sale of the harvested crops but also need to pay all relevant production costs.[17] Using this definition, 17% of the wives in our sample couples can make a decision regarding crop selection on any plot. At plot level, 99 (15%) out of 691 plots owned by 384 couple households were classified as fields mainly managed by the wife.

Table 3 compares characteristics between husband- and wife-managed plots for married couples. As reported in other parts of rural Africa (e.g., Udry, 1996), wife-managed plots are systematically different from husband-managed plots. For example, wife plots are smaller by 0.7 hectares on average. More importantly, wife plots are more likely to be dambo.[18] This observation is important, since dambo is considered the most suitable land for rice production in the survey area. The other characteristics of wife plots (in contrast to husband plots) are as follows: (1) maize is planted less often in the 2017/18 agricultural season; (2) chemical fertilizer is less heavily applied in the 2017/18 agricultural season, which partially reflects the differences in cropping patterns between male and female plots; (3) wife-managed plots are more likely to be under customary land tenure since plots have been obtained without market or formal institutional procedures; and (4) land title is less likely to be given. Overall, plot characteristics and usage patterns depend on the gender of the plot manager within the household.

In addition to heterogeneity regarding the gender of the voucher recipient, we also consider heterogeneous treatment effects depending on who manages the dambo fields. Such an investigation requires that the gender of dambo managers be balanced across the treatment arms. As Table 1 shows, this is the case for our analysis sample. The other validity condition is that the intra-household allocation of dambo plots must not capture the overall power balance between spouses per se. To check this condition, Table 4 compares baseline characteristics according to the gender of the dambo managers. As Table 4

[16] Joint ownership by a couple is possible. In fact, 45% of plots were classified by the respondents as jointly owned in the follow-up survey. However, as Doss et al. (2018) point out, joint ownership does not necessarily mean that management rights over the land are shared equally between the husband and wife. To capture differences in practical land management, we focus on the main person in charge of crop choice for agricultural field.

[17] Regarding labor sharing within the family, main crops like maize are grown by both genders in the survey region. In this sense, labor allocation patterns are completely different from those observed in West African countries where different members of the household simultaneously cultivate the same crop on different plots (e.g., Udry 1996).

[18] Appendix Table B1 checks this in the regression framework where the indicator variable for wife-managed plots is associated with plot characteristics. As Column 1 shows, the likelihood of a plot being one for which the wife makes crop choice decisions increases by 8 percentage points if the plot is categorized as dambo relative to highland fields. The results are more striking in the specification with household fixed-effects (see column 2), suggesting that wives have more control over dambo in households with multiple plots.

Table 3: Plot characteristics: husband- vs. wife-managed plots

Variable	N	(1) Husband Mean/SD	N	(2) Wife Mean/SD	T-test P-value (1)-(2)
Land size (ha)	592	1.68 (2.54)	99	1.00 (1.37)	0.01***
=1 if dambo	592	0.19 (0.39)	99	0.38 (0.49)	0.00***
=1 if garden	592	0.32 (0.47)	99	0.48 (0.50)	0.00***
=1 if soil is bad	592	0.13 (0.33)	99	0.05 (0.22)	0.03**
=1 if fallowed in 17/18 rainy season	592	0.16 (0.37)	99	0.19 (0.40)	0.46
=1 if planted maize in 17/18 rainy season	592	0.61 (0.49)	99	0.34 (0.48)	0.00***
Amount of fertilizer (kg/ha) applied in 17/18 rainy season	463	78.16 (58.80)	52	51.25 (65.86)	0.00***
=1 if purchased	539	0.24 (0.43)	90	0.13 (0.34)	0.02**
=1 if inherited	539	0.31 (0.46)	90	0.30 (0.46)	0.85
=1 if walked in	539	0.13 (0.33)	90	0.20 (0.40)	0.07*
=1 if customary and no title	539	0.59 (0.49)	90	0.74 (0.44)	0.00***

Notes: The unit of observation is plot. The last column shows p-values from the t-test for the equality between husband- and wife-managed plots. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The amount of fertilizer is conditional on cultivation in the 2017/18 rainy season.

shows, wives who manage dambo are less educated and less risk-averse than are those with husbands who manage dambo. However, there are no significant differences between male and female dambo plot managers in variables related to the marital bargaining positions, such as financial autonomy and non-farm income. This shows that any heterogeneous treatment effects according to who manages the dambo will come through the gender division of land management rather than through gender differences in overall bargaining power within the couple.

3 Theoretical Framework

This section provides a conceptual framework with which to derive theoretical guidance for the subsequent empirical examination of the experimental data. First, we discuss what the standard unitary household model and Pareto-efficient collective model predict. According to both models, the identity of neither the voucher recipient nor the plot manager should affect household demand for agricultural

Table 4: Household and spousal characteristics by dambo management pattern

Variable	(1) Wife manager Mean/SD	(2) Husband manager Mean/SD	(3) No dambo Mean/SD	(1)-(2)	T-test P-value (1)-(3)	(2)-(3)	F-test for joint orthogonality
Family size	5.97	6.35	5.49	0.39	0.16	0.00***	0.00***
	(1.97)	(2.47)	(1.95)				
Land size (ha)	4.27	3.10	2.62	0.02**	0.00***	0.18	0.01***
	(3.15)	(2.57)	(3.36)				
Value of assets (K1000)	3.84	3.40	3.45	0.60	0.73	0.94	0.92
	(5.61)	(4.01)	(6.49)				
=1 if has grown rice in last 10 years	0.13	0.09	0.03	0.45	0.01***	0.03**	0.02**
	(0.34)	(0.29)	(0.18)				
Age, wife	43.03	39.22	37.39	0.10	0.01**	0.22	0.03**
	(12.40)	(12.41)	(13.11)				
Age, husband	50.34	44.38	43.55	0.02**	0.01***	0.61	0.02**
	(13.80)	(13.25)	(14.53)				
Years of education, wife	5.03	6.55	5.73	0.00***	0.18	0.01**	0.01***
	(2.89)	(2.32)	(3.04)				
Years of education, husband	7.50	7.39	7.30	0.84	0.71	0.81	0.92
	(2.60)	(2.97)	(3.01)				
Financial autonomy (K100), wife	0.78	0.72	0.69	0.71	0.56	0.76	0.83
	(0.81)	(0.86)	(0.92)				
Financial autonomy (K100), husband	0.98	0.77	0.71	0.18	0.08*	0.53	0.19
	(1.01)	(0.73)	(0.84)				
Non-farm income (K1000/year), wife	0.92	0.51	0.33	0.45	0.03**	0.46	0.25
	(2.16)	(3.12)	(1.40)				
Non-farm income (K1000/year), husband	3.62	2.26	2.35	0.15	0.10*	0.84	0.21
	(6.76)	(4.38)	(3.83)				
Risk preference, wife	0.69	0.79	0.67	0.02**	0.69	0.00***	0.00***
	(0.29)	(0.22)	(0.28)				
Risk preference, husband	0.72	0.75	0.70	0.49	0.77	0.10*	0.26
	(0.28)	(0.27)	(0.25)				
N	38	113	233				

Notes: The unit of observation is household. *** denotes significance at 1% level, ** at 5% level, and * at 10% level.

inputs. Then, we present a bargaining model with endogenous outside options to understand why Pareto inefficiencies could be observed in agricultural production contexts.

Crop choice is intrinsically an inter-temporal decision due to the sequential nature of agriculture: farmers decide what crop to grow before the start of the agricultural season and need to stick to the production plan (e.g., how many hours to be spent on a specific activity) until harvesting time. However, achieving intertemporal efficiency may be difficult for several practical reasons. First, the burdens of farm activities tend to differ among family members. For example, the time costs of milling rice are incurred largely by wives because of their comparative advantage, while land preparation tasks mainly fall within the husband's sphere. Since the timing of agricultural practices also differ, farmers have an incentive to deviate from an initial agreement with their spouse. Second, plot managers are also in charge of selling the harvest, and their spouses are often unaware of the exact amount of output sales. Because such information asymmetry restricts the spouses' capacity to punish, rooms for the plot manager to renege on the previous agreement of compensation are left. It can thus be difficult to achieve commitment to an efficient joint production and a previously agreed-upon division of surplus in this dynamic setting.

Reflecting this potential commitment problem, our model incorporates ex post renegotiation after investments are sunk. We assume that agricultural investments in the first period will affect not only household's full income but also the marital bargaining position in the future period. The bargaining model with endogenized outside options reflects the possibility that who receives the investment incentive matters for the take-up of new technology depending on who controls the relevant productive resources.

3.1 Unitary Model

The unitary household model has served as the standard approach in economics for analyzing household responses to policy intervention. This model treats household behavior as an outcome of optimization by a single decision maker. The unitary model implicitly hinges on two fundamental assumptions: (1) Individuals' preferences can be aggregated to only one set of preferences;[19] and (2) all household resources—including income, family labor, and land—are pooled into a single common fund to which any family member has access without incurring any costs. Under these assumptions, the unitary model predicts that all that matters for program evaluation is the total amount of the benefits the household receives, not the identity of the targeted recipient within the household.

In the experimental setting, what does the unitary model predict about the impact of our voucher treatment on the household demand for rice seed? The main mechanism through which our treatment affects the outcome is a reduction in time costs involving removing husks from paddy, conditional on harvested rice being brought to the designated miller.[20] This would lead to an uptake of rice seeds through a relaxation of the participation constraints for rice cultivation if cash constraints were not binding at the time of purchase. In addition, if the cost function is convex with the quantity produced, the voucher would make it more profitable to purchase a larger quantity of seeds and process rice harvests at the miller than to obtain a small quantity of seeds and mill them manually. Overall, the voucher is likely to increase household demand for rice seeds on both the extensive and intensive margins if farm households are able to finance the upfront input costs. However, the recipient's gender should not alter the treatment effect on household-level demand under the unitary model in which investment incentives are pooled in a joint budget. Thus, the transportation voucher should have the same effect on household demand for rice seeds regardless of who receives it.

3.2 Pareto-efficient Collective Models

The income pooling assumption of the unitary model has been challenged by empirical studies from both developing and developed countries (Doss, 2013). In practice, household members make decisions

[19] This could happen either when all the family members share the same homothetic preferences (Samuelson's consensus model) or when one altruistic individual makes a positive transfer to each member of the family (Becker's Rotten Kid Theorem).

[20] When not using a milling machine, farmers have to pound paddy with mortar and pestle, which takes time and may break grains. Having access to milling machine saves labor time and energy even for home consumption purposes. Milling harvested rice by machine is also crucial for selling rice at the market.

collectively. The literature on intrahousehold allocation has proposed two broad types of collective model to explicitly account for the sharing process within the family: One relies on cooperative solutions and the other builds on noncooperative solutions.

One branch of the former theoretical model does not assume a specific bargaining process by which resources are shared across different individuals within the family (e.g., Browning and Chiappori, 1998). Given the Pareto-weight reflecting the balance of power in the family, the household maximizes a weighted sum of utilities from the different family members. The other cooperative model involves household bargaining. This type of the model puts some structures on the marital sharing rule with exogenous threat points, determined by environmental factors such as the sex ratios in marriage markets and alimony upon divorce (e.g., Manser and Brown, 1980; McElroy and Horney, 1981; McElroy, 1990). The common axiom embedded in both cooperative collective models is that household decisions are always Pareto-efficient: There should be no alternative allocation that makes one person better off without making the other worse off. A plausible rationale for the Pareto-efficiency axiom flows from the idea that household members interact repeatedly and thus there is no room for wasting limited resources. The other important assumption common to both types is that changes in environmental factors and hence marital bargaining powers are exogenous to the household and foreseeable at the start.

According to these cooperative collective models, the production decisions of the household will be independent of its consumption decisions if the relevant markets are all complete (Bardhan and Udry, 1999). With complete markets, households simply choose the level of agricultural inputs to maximize profits from production. Because individual farm revenues are aggregated into a single pool, the identities of neither the transportation voucher recipient nor the plot manager will affect the agricultural production decisions in our experimental setting.

However, influential papers from rural sub-Saharan Africa have reported that inputs are rarely allocated efficiently on the production side (Udry, 1996; Goldstein and Udry, 2008; Haider et al., 2018; Walther, 2018). The absence of static efficiency across individual producers within the household violates a necessary condition for Pareto-efficient decisions. In addition, empirical evidence also reject perfect risk sharing among family members (Dercon and Krishnan, 2000; Duflo and Udry, 2004; Robinson, 2012). These observations contradict not only the income pooling hypothesis required by the unitary model but also the assumption of Pareto efficiency that the cooperative collective models impose.

The Pareto-efficiency axiom requires spouses to commit to all future allocations. Renegotiation or the revision of resource shares never happen even after changes in the environmental. However, it is difficult to commit to the original sharing rule when household members face different incentives and hence at least one of the spouses has an incentive to renege on the initial agreement (Rasul, 2008; Baland and Ziparo, 2018). Commitment problems also arise in another dynamic setting where unpredictable shocks are salient (e.g., Mazzocco, 2007). In those cases of limited commitment, the sub-optimal decisions will be chosen, rather than the first-best solution, in equilibrium. Furthermore, imperfections in rural input and financial markets would make individuals unable to take advantage of trade opportunities, exacerbating internal inefficiency (Fafchamps, 2001). Thus, non-cooperative collective models that allow for Pareto-inferior results would be a better match for the reality faced by agricultural households in rural Africa

(Doss and Quisumbing, 2020). The model developed in the next section provides a theoretical basis for Pareto-inefficiency and claims that the targeting of investment incentives to specific individuals can result in different impacts in the context of agricultural technology adoption.

3.3 A Nash Bargaining Model with Endogenous Outside Options

Extending the separate spheres model developed by Lundberg and Pollak (1993), we present a bargaining model of a household comprising two spouses with different productivities and resource constraints.[21] To incorporate the assumption of the limited commitment to an efficient production plan into the setup, the model consists of two periods: noncooperative investment stage and cooperative bargaining stage. Our two-period model assumes that individual farm revenues determined by agricultural investments in the first period act as the fallback position when members negotiate over interspousal transfers in the second period. We also introduce both the comparative advantage of males in one agricultural task and the comparative advantage of females in the other task. Although any contributions to production are rewarded through interspousal transfer, the numerical example based on this model shows that the inefficient negotiation process within marriage can generate implications different from what the unitary model and efficient collective models predict.[22]

3.3.1 Set-up

The household consists of a husband (h) and a wife (w) who live for two periods: investment and negotiation stages. First, each spouse individually allocates their income endowments between the investments in rice production and first-period consumption to maximize their own lifetime utility. The return to the agricultural investment will be realized in the next period. Key to the analysis is that the first-period investment will affect the final shares of the total household resources in the second period from which they can extract. Thus, both spouses invest in a forward-looking way: They take into account how their investments increase not only the size of the household pie that will be allocated in the second period but also the outside option representing what each spouse would get in within-household noncooperation. In addition, they decide whether to use the transportation voucher in the future if it is available by comparing the lifetime utilities between when it is utilized and when it is not. We assume that the recipient needs to pre-commit to the decision to use the voucher, which allows the spouse of the recipient to utilize it even in autarchy.

In the second negotiation stage, rice production consists of land preparation and milling activities. We assume that wives have a comparative advantage in milling activities, while husbands have a comparative

[21]The separate spheres model originates from the cooperative Nash bargaining model with the divorce threat point (Manser and Brown, 1980; McElroy and Horney, 1981). Applications of the Lundberg and Pollak (1993) model are found in Carter and Katz (1997), Chen and Woolley (2001), Rasul (2008), and Slootmaker (2014).

[22]Related non-cooperative collective models that also allow for Pareto-inefficient outcomes have been developed by Basu (2006), Iyigun and Walsh (2007), and Walther (2018) to analyze joint household decision making such as human capital investments and the labor supply of adults. Their models explicitly assume the endogenous Pareto weights determined by relative spousal contributions to the household budget. The importance of relative spousal earnings in sharing household resources has been empirically recognized by Thomas (1990) and Hoddinott and Haddad (1995).

advantage in land preparation. Then, the household jointly decides on consumption for each family member by negotiating over interspousal transfers. In the negotiation, the outside options are individual farm revenues accrued to the plot manager in within-household noncooperation.

Each spouse receives utility from consumption and home leisure. The lifetime utility for the wife U_w is specified as:

$$U_w = c_1^w + \ln(T - l_w - m_w) + c_2^w$$

where c_t^i represents the level of private consumption of gender i in period t, T is constant time endowment, and l_i (m_i) is time spent on land preparation (threshing and milling) by gender i. The lifetime utility for the husband U_h takes a similar form:

$$U_h = c_1^h + \ln(T - l_h - m_h) + c_2^h$$

We allow for neither different preferences nor altruism to underscore the roles of gender gaps in labor productivity and access to land resources. For the same reason, we do not incorporate uncertainty in agricultural production.

The illustration starts with the autarchy case, in which each spouse needs to do all the agricultural tasks, including land preparation and milling. In autarchy, the spouses face first-period budget constraints, specified as

$$c_1^w + d^w p x_1^w = y_1^w$$

and

$$c_1^h + d^h p x_1^h = y_1^h$$

where d^w (d^h) is an indicator variable equal to 1 if the wife (husband) manages a plot for rice production, p is the unit price of rice seeds, x_1^w (x_1^h) is the amount of rice seeds purchased by the wife (husband), and y_1^w (y_1^h) is income endowment given to the wife (husband) available in period 1. The price of a private consumption good is normalized to 1 and is constant across the two periods for simplicity.

The second period budget constraints in autarchy are formatted as

$$c_2^w = y_2^w + d^w q \theta x_1^w$$

and

$$c_2^h = y_2^h + d^h q \theta x_1^h$$

where q stands for the output price of rice, and θ is a measure of land productivity. This specification assumes no differences in soil quality between wife- and husband-managed plots.

The utility levels in the within-household noncooperation case serve as the reservation utility in the negotiation among the spouses. To calculate the utility levels in autarchy, we impose the following assumptions on the time cost function: (1) Men get the same workload of ploughing land done in less time than women; (2) women get the same workload of threshing and milling done in less time than men; (3) vouchers provide a discount on milling time; and (4) the time required for both agricultural tasks increases proportionally along with the quantity produced. The times for land preparation are defined as $l_w = \pi x_1^w$ and $l_h = \gamma x_1^h$ with $\pi > \gamma$, reflecting the first assumption about labor efficiency. With the last three assumptions, we specify the time required for threshing and milling as $m_w = \mu v_w x_1^w$ and $m_h = v_h x_1^h$ with parameters $\mu < 1$, which represents the comparative advantage of females in milling tasks, and $v \leq 1$ which indicates a discount on time via the transportation voucher. $v = 1$ represents the case wherein the voucher is not available. Substituting the budget constraints and the time costs into the lifetime utility functions produces the following utility levels from autarchy:

$$V_w^A \equiv y_1^w - d^w p x_1^w + \ln(T - d^w \pi x_1^w - d^f \mu v_w x_1^w) + y_2^w + d^w q \theta x_1^w$$

and

$$V_h^A \equiv y_1^h - d^h p x_1^h + \ln(T - d^h \gamma x_1^h - d^h v_h x_1^h) + y_2^h + d^h q \theta x_1^h$$

Next, we consider the case of cooperation within marriage. If the husband and wife agree on joint production, the household can exploit efficiency gains from gender specialization. Note that the assumption of transferable utility ensures the efficient provision of public goods (e.g., land preparation and milling activities in this model) in the ex post sense. In particular, the wife will do all the threshing and milling because of her comparative advantage, and her efforts are fully compensated by appropriate inter-spousal transfers. Similarly, only the husband will contribute his time to land preparation. Such a task specialization generates marital gains. However, cooperative outcomes can be inefficient in the ex ante sense even if the bargaining succeeds because of the absence of spousal coordination and credible commitment to the efficient joint production.

Given the local contexts, we assume that the plot manager pays all the monetary costs for rice cultivation, except the time costs for land preparation incurred by the husband and those for milling incurred by the wife.[23] The introduction of income transfer t changes the second-period budget constraint to:

$$c_2^w = y_2^w + d^w q \theta x_1^w + t$$

and

$$c_2^h = y_2^h + d^h q \theta x_1^h - t$$

[23]To focus on household-level demand, we do not allow for the possibility of cross-investments by each spouse. Only plot managers will buy rice seeds if they want.

The transfer is positive if it is from husband to wife. Under this setup, the utility levels for each spouse can be written as

$$V_w^J \equiv y_1^w - d^w p x_1^w + \ln(T - d^h \mu v_w x_1^h - d^w \mu v_w x_1^w) + y_2^w + d^w q\theta x_1^w + t$$

and

$$V_h^J \equiv y_1^h - d^h p x_1^h + \ln(T - d^h \gamma x_1^h - d^w \gamma x_1^w) + y_2^h + d^h q\theta x_1^h - t$$

The wife's time for leisure reduces to $T - d^h \mu v_w x_1^h - d^w \mu v_w x_1^w$ because she needs to spend her time on threshing and milling even on the husband's plot as long as he decides to produce rice. In the same way, the husband's leisure time is expressed as $T - d^h \gamma x_1^h - d^w \gamma x_1^w$ because of his specialization in land preparation.

In the case of joint production, two spouses bargain over cash transfer t made between them. With the concept of Nash bargaining, the solution is the one that maximizes the product of the gains to cooperation between the wife and husband, defined as the increase in utility from the threat points representing the utility that each spouse would achieve in autarchy. In this bargaining stage, the Nash product N is formalized as

$$N \equiv (V_f^J - V_f^A)(V_m^J - V_m^A)$$

where the relative weights of cooperative gains (i.e., the distribution of bargaining power) are assumed to be symmetry.[24] The household chooses the equilibrium transfer to maximize the above Nash product N in the second stage.

3.3.2 Optimization

We solve this model backwards from the second bargaining stage in which, at a given level of investment in rice production (x_1^f and x_1^m) chosen in the first investment stage, the two spouses are negotiating over interspousal transfer. Differentiating the Nash product N with respect to transfer t, we obtain a closed-form expression of the optimal spousal transfer from the husband h to the wife w, denoted by t^*, as a function of x_1^w and x_1^h:

$$\begin{aligned} t^* = \frac{1}{2} \times [& - \ln(T - (d^w x_1^w + d^h x_1^h)\mu v) + \ln(T - d^w(\mu v_w + \pi)x_1^w) \\ & + \ln(T - (d^w x_1^w + d^h x_1^h)\gamma) - \ln(T - d^h(v_h + \gamma)x_1^h)] \end{aligned}$$

Then, each spouse individually solves the first-period problem by choosing the level of investments

[24] A higher weight, which may reflect a better outside option, allows the member to extract a higher payoff from the household bargaining process. Pareto-inefficient outcomes of the key prediction are robust to the asymmetric weights of marital gains. Rather, results show that inefficient behavior is more common in households with unequal weights. As shown in Table 1, no spousal gaps in financial autonomy would assure the symmetric assumption in the study context.

x_1^w and x_1^h taking the Nash bargaining solution transfer t^* as given. The problem structure depends on plot ownership. The field data show that no household has multiple dambo fields. Thus, there is no case when both d^w and d^h take 1 for the same household. We thus consider the following three cases:

Case 1: ($d^w = 1$, $d^h = 0$), where the wife manages a suitable plot for rice
Case 2: ($d^w = 0$, $d^h = 1$), where the husband manages a suitable plot for rice
Case 3: ($d^w = 0$, $d^h = 0$), where the household does not have a suitable plot for rice

For each case, substituting t^* back into V_w^J and V_h^J and then differentiating them with respect to x_1^w and x_1^h yields the spouse's best response to the other's action. Solving the system of two equations for x_1^w and x_1^h will generate a combination of optimal investment levels in the noncooperative first stage. Finally, the recipient decides whether to make use of the transportation voucher in the second stage by comparing the lifetime utilities when it is utilized and when it is not if the voucher is available. This is done by substituting the optimal investment levels back into the lifetime utilities.

Although the equilibrium levels of x_1^f and x_1^m cannot be analytically solved for, the numerical experiment in the next subsection presents examples for the case when the identities of both voucher recipients and plot managers matter for household rice seed demand. The spouses' strategic actions are the result of optimal forward-looking behavior because they anticipate renegotiation later. Limited commitment, coupled with the division of tasks by gender, will yield sub-optimal equilibrium for some cases.

3.3.3 Numerical Exercise

Table 5: Parameter values for the numerical model

θ	q	v_w	v_h	π	γ	T	p	$y_1^w = y_2^w$	$y_1^h = y_2^h$
50	10	0.2	0.4	1.2	1	1	20	100	500

We conduct a numerical exercise to demonstrate how demand for rice seeds changes along with the identities of both the voucher recipients and plot managers. Table 5 presents the parameter values used for this exercise. These values are chosen so that the numerical example reflects the reality of the surveyed couple households. We allow time discounts by vouchers to differ between the husband and wife.[25] With these parameters, Figure 2 illustrates total household demand for rice seeds with various values of the parameter μ representing the wife's comparative advantage in threshing and milling tasks.[26] As Figure 2

[25] Giving the voucher to the husband may vanish the wife's comparative advantage in milling. While the assumption of equal time discounts also leads to inefficient investment patterns, the gender of recipients will always affect demand for rice seeds when the husband manages dambo. For this, our preferable assumption is the unequal time discounts of vouchers.

[26] Using $\mu = 0.5$ and the parameters in Table 5, Appendix Figure A1 graphically shows the combinations of utilities in equilibrium by voucher availability. Irrespective of the gender of the voucher recipients, the voucher improves the recipient's utility when the voucher recipient and plot manager are coincided. This would not be the case when the voucher recipients have no control over the dambo plot. In Appendix Figure A1, the utility of the husband whose wife controls the dambo is higher when the voucher is not utilized.

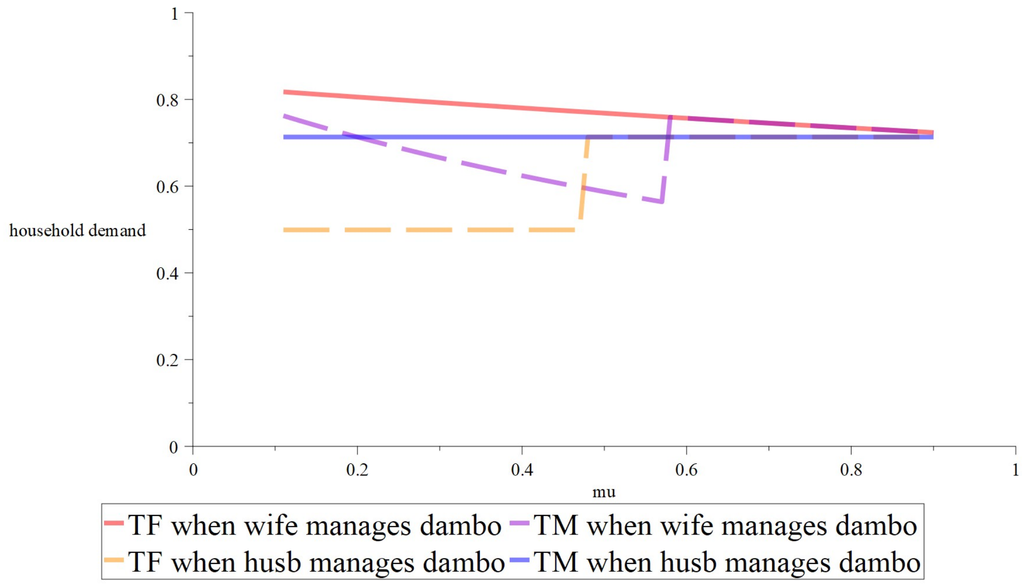

Figure 2: Optimal household demand for rice seeds

Notes: "husb" stands for husband. The parameter values for this Figure are presented in Table 5.

shows, the recipient always utilizes the voucher when he or she manages dambo (red and blue lines). As a result, demand in such households is high and relatively stable across μ.

The purple and yellow lines in Figure 2 show household demand when the voucher recipient differs from the plot manager within the household. At higher values of μ (i.e., when the husband and wife have comparable levels of milling productivity), the voucher will increase the recipient's utility irrespective of his/her gender. As a consequence, the voucher given to the wife has the same impact as the voucher given to the husband. On the other hand, we find discrete jumps at lower values of μ (i.e., a higher comparative advantage of the wife in milling) when the voucher recipient is not a plot manager. This happens because the disutility from the improvement in the plot manager's position outweighs the potential gains from the increase in total household surplus. Consequently, the voucher recipient prefers not to use the voucher. Thus, we should not observe any treatment effects in such cases.

Figure 2 also suggests that the responses to our treatment may be asymmetric. In the region of μ between 0.47 and 0.57, the treatment impact will be zero only when the husband receives the voucher and the wife manages the dambo (purple line). The wife's outside option will improve in this case, while the husband's bargaining position will not change after the use of the voucher. As a result, the husband has no incentive to exploit the voucher for fear of improving the wife's future say. Combining these results, the following testable hypotheses can be derived:

Hypothesis 1:

(1) The voucher increases household demand for rice seeds no matter who receives it when the dambo manager receives the voucher

(2) The voucher may have no impact on household demand for rice seeds when the dambo manager is different from the voucher recipient

This behavior cannot be accounted for by the collective model with fixed outside options, and the current model indicates the possibility of inefficiency within the family. As Carter and Katz (1997) point out, the impact of the voucher can be decomposed into (1) the reallocation effect and (2) the bargaining power effect. While the first effect is also captured by the unitary household model, the second effect is unique to this noncooperative collective model in the sense that the voucher given to a spouse will enhance his/her bargaining position in our context.

The absence of credible commitment also suggests that the voucher recipients have no incentive to share voucher information with spouses who manage a plot suitable for rice production, because revealing the information would improve the spouse's bargaining position in the future period. The voucher recipient's incentives to strategically withhold the information can be expressed as follows:

Hypothesis 2:
When the spouse of the voucher recipient manages dambo, the voucher reduces the likelihood of communication about the voucher between the spouses

Thus, in contrast to the traditional household models, this simple bargaining model with the endogenous outside option can provide a theoretical basis for the claim that the identity of the beneficiary within the household matters for technology adoption. These theoretical results suggest that investment incentives directed to a specific individual will help improve their bargaining position within the couple through changes in fallback position. We test these theoretical predictions using experimental data from the field in the next section.

4 Empirical Specifications and Results

This section exploits experimental variations in the provision of the transportation voucher to present the intention to treat (ITT) estimates of the treatment effects. We first estimate the effect of the voucher on household purchase behavior on the extensive and intensive margins for the whole sample. Next, we investigate whether intrahousehold land management patterns alter the take-up of rice seeds by estimating treatment effects for each subpopulation divided by who controls a suitable land for rice production. Finally, evidence on related outcomes is reported to support the main empirical findings.

4.1 Empirical Specifications

The random assignment of treatment allows us to sidestep the standard endogeneity issues and estimate its impact in a relatively straightforward way. Specifically, we run the following household-level regression equations to estimate the overall impact of our treatment:

$$Y_i = \beta T_i + X_i^H \gamma_H + X_i^h \gamma_h + X_i^w \gamma_w + \varepsilon_i \quad (1)$$

or by separately adding treatment dummies,

$$Y_i = \beta_F TF_i + \beta_M TM_i + X_i^H \gamma_H + X_i^h \gamma_h + X_i^w \gamma_w + \varepsilon_i \tag{2}$$

where Y_i is either the total quantity of seeds purchased by household i in kilograms or an indicator variable reflecting take-up by household i, T is an indicator for the households categorized as treatment, TF_i (TM_i) takes one if a wife (husband) in household i received transportation voucher and zero otherwise, and ε_i is an error term. Because the randomized distribution of vouchers ensures that the treatment indicators TF and TM, and ε_i are orthogonal in theory, the OLS regression will provide us an unbiased estimator for the ITT effect. In this specification, the ITT effect of the voucher given to the wife (husband) is captured by β_F (β_M). X_i^H is a set of baseline household characteristics that may predict the take-up of rice seeds. These covariates include household size, total area of land owned, and total value of household assets such as livestock and durables. To capture information constraints, the indicator for previous experience in rice cultivation is also included in a vector of household characteristics. Finally, as the survey villages were spread across five agricultural extension camps, we include camp fixed effects.[27]

X_i^h is a set of pre-treatment characteristics of the husband in household i, while X_i^w is the exact same set of controls but for the wife in household i. In particular, we assess whether household demand is the same between the households where the wife manages dambo and those where the husband does so. To control for other important gender differences in preferences and resource constraints, we separately include both spouses' ages, education levels, an index for financial autonomy[28], annual non-farm income, and risk preference parameters elicited by the methodology of Binswanger (1980). See the footnote of Table 1 for more details on the index for financial autonomy and risk parameters.

We test whether $\beta_F = \beta_M$ holds to evaluate the income pooling assumption of the unitary household model. Since land transactions are inactive in the survey area, current access to productive lands for rice cultivation (i.e., dambo) is a critical condition for taking up rice seeds. The theoretical model in Section 3.3 predicts that the impact of the voucher holder depends on who manages the dambo plots within the household. By including the interaction terms between our treatment and the gender of the dambo plot manager, we also examine if the equality of β_F and β_M holds for each subpopulation classified based on who selects what to grow on dambo within the couple.

Since statistical inferences based on conventional robust covariance estimates rely on asymptotic properties, they have a risk of force discoveries for treatment effects if there are a few available observations in sub-group analyses (Young, 2019). In our case, the effective size of the analysis sample is limited for households in which the wife manages the dambo. To address this issue, we also report the results from hypothesis tests based on bootstrapping and randomization inference (Heß, 2017).

[27] Although our randomization was stratified by village, we add only five camp fixed effects to circumvent the reduction in degrees of freedom. Note that point estimates should be the same even if stratification is ignored, since we set equal proportions of treatment and control households within strata at randomization.

[28] This variable is an empirical proxy for the relative weights of marital gains at the baseline (e.g., Heath and Tan, 2020). Table 4 shows that this financial autonomy index is not correlated with the gender of dambo managers; thus, our index for financial autonomy would partially reflect the initial bargaining positions within the household but would not capture outside options driven by agricultural investments.

4.2 Main Results

Table 6 reports the regression results of Equations (1) and (2). Column 1 shows that the treatment households who had received the transportation voucher purchased an additional 0.46 kg of rice seeds relative to control households. Given that the average purchase amount among control households is 0.58 kg, the voucher has a significant impact on the household demand for rice seeds among local farmers with little prior experience in its cultivation. The treatment impact is also derived on the extensive margin in column 4, though the detected statistical significance level is marginal.[29]

We next assess whether the gender of dambo field managers matters in household purchase behavior. The results indicate that when the husband decides what to grow on the dambo plot, households are more likely (all else being equal) to adopt rice by about 20 percentage points relative to households where the wife controls the dambo (with a difference in coefficients of 0.128- [-0.076] in column 4). This finding contradicts the resource pooling assumption of the unitary model. However, this inferred relationship should not be interpreted as a causal one because these two kinds of households might systematically differ in unobserved ways. For instance, dambo fields may be more likely to be allocated to husbands upon marriage if they are interested in crop production for market sales rather than for consumption purposes.[30]

Our primary interest is to test whether the gender of the voucher recipient matters for technology adoption decisions. Columns (2) and (5) in Table 6 shows the estimation results from a specification adding TF and TM treatment dummies separately. We find no evidence that the voucher holder has different impacts on the quantity of rice seeds purchased, indicating that the resource pooling assumption of the unitary household model is not rejected at first glance. The result does not change even when we run the Tobit model to take into account the fact that a significant number of households ended up with no purchase (see column 3). This result is not surprising, since these null results are based on the full sample, which consists of households with land suitable for rice as well as those without at the time of the sales meeting. Our theoretical framework posits that the voucher recipient's gender has an impact when the wife or husband controls land resources relevant to the technology in question. To understand the role of intrahousehold decision making in technology adoption, we thus need to test the equality of

[29] One potential explanation for the non-significance results for binary purchase decisions might be that bringing harvests to town for milling is relatively costly when production is small-scale (e.g., planting only 1 kg for home consumption). The voucher would be more appealing to farmers who are willing to plant rice at a certain scale. In fact, Appendix Table B2 confirms that the voucher significantly affects the binary decision to purchase more than or equal to 2 kg of seeds.

[30] Coefficients on other spousal characteristics also provide informative patterns to see if the husband's preference is more reflected in observed household behavior than the wife's (or vice versa). Table 6 shows that the wife's characteristics per se have an explanatory power for household demand for rice seeds. Specifically, one of the robust findings across all the specifications is that the wife's financial autonomy has a negative impact. A possible explanation for this finding is that, since rice is locally available for consumption even within a survey village and rice production incurs time costs for females because of milling, wives with a degree of financial autonomy have no incentive to plant rice. Furthermore, keeping the wife's age constant, an additional year in the husband's age increases the probability of household take-up by 1.2 percentage points, and the estimated impact is significantly different from that of the wife's age. These results suggest the importance of taking into account not only the household head's characteristics but also his/her spouse's characteristics in explaining technology adoption. This finding is consistent with results in the small but growing literature on heterogeneous preferences within households (e.g., Miller and Mobarak, 2013; Magnan et al., 2020).

Table 6: Effect of transportation voucher on household demand for rice seeds

	(1) Seeds (kg)	(2) Seeds (kg)	(3) Seeds (kg)	(4) Take-up	(5) Take-up	(6) Take-up
TF/TM	0.463***			0.079		
	(0.156)			(0.048)		
TF		0.456**	1.102*		0.069	0.066
		(0.189)	(0.575)		(0.056)	(0.057)
TM		0.468**	1.314**		0.085	0.088*
		(0.186)	(0.540)		(0.055)	(0.053)
Wife manages dambo=1	-0.423*	-0.422*	-1.057	-0.076	-0.074	-0.070
	(0.218)	(0.217)	(0.762)	(0.073)	(0.073)	(0.075)
Husband manages dambo=1	0.273	0.273	0.982**	0.128**	0.128**	0.118**
	(0.205)	(0.206)	(0.462)	(0.054)	(0.054)	(0.047)
Age, wife	-0.007	-0.007	-0.053	-0.009*	-0.009*	-0.009**
	(0.017)	(0.017)	(0.041)	(0.005)	(0.005)	(0.005)
Age, husband	0.013	0.013	0.078*	0.012***	0.012***	0.012***
	(0.017)	(0.017)	(0.040)	(0.004)	(0.004)	(0.004)
Years of education, wife	0.047*	0.047*	0.118	0.011	0.011	0.009
	(0.027)	(0.028)	(0.083)	(0.008)	(0.009)	(0.008)
Years of education, husband	0.003	0.004	-0.001	-0.004	-0.004	-0.003
	(0.030)	(0.031)	(0.084)	(0.009)	(0.009)	(0.008)
Financial autonomy (K100), wife	-0.292***	-0.291***	-0.891***	-0.085***	-0.084***	-0.086***
	(0.076)	(0.077)	(0.252)	(0.023)	(0.023)	(0.027)
Financial autonomy (K100), husband	-0.030	-0.030	0.202	0.039	0.039	0.038
	(0.108)	(0.109)	(0.243)	(0.029)	(0.029)	(0.026)
Non-farm income (K1000/year), wife	0.039	0.039	0.033	0.003	0.003	0.004
	(0.040)	(0.040)	(0.056)	(0.008)	(0.008)	(0.010)
Non-farm income (K1000/year), husband	0.005	0.005	-0.002	0.000	-0.000	-0.001
	(0.019)	(0.019)	(0.045)	(0.005)	(0.005)	(0.005)
Risk preference, wife	-0.073	-0.074	-0.788	-0.117	-0.118	-0.119
	(0.259)	(0.264)	(0.752)	(0.082)	(0.083)	(0.081)
Risk preference, husband	-0.444	-0.445	-1.262	-0.097	-0.097	-0.110
	(0.336)	(0.336)	(0.855)	(0.085)	(0.085)	(0.081)
Test: TF=TM (p-value)	.	0.95	0.67	.	0.76	0.66
Test: Wife manages=Husband manages (p-value)	0.01	0.01	0.01	0.01	0.01	0.02
Model	OLS	OLS	Tobit	OLS	OLS	Probit
HH controls	Yes	Yes	Yes	Yes	Yes	Yes
Camp FE	Yes	Yes	Yes	Yes	Yes	Yes
Control HH's mean of dependent variable	0.58	0.58	0.58	0.28	0.28	0.28
R squared	0.30	0.30		0.22	0.22	
N	384	384	384	384	384	384

Notes: Robust standard errors in parentheses. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The dependent variables are the quantity of seeds purchased in kg for columns 1-3 and a binary variable for purchase for columns 4-6. The values in column 6 are marginal effects obtained from the Probit model estimation. Household controls include family size, total area of land owned, total value of household assets, and a dummy for past experience of rice cultivation.

impacts between the vouchers given to the wife and husband separately according to the identity of the person who controls the dambo fields.

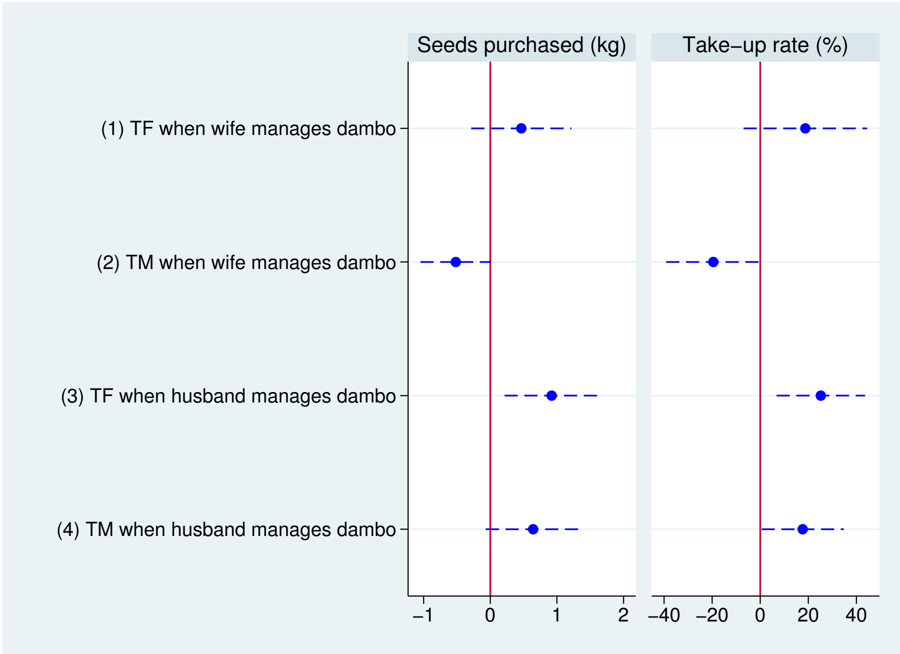

Figure 3: Heterogeneous treatment effects on household demands by the gender of dambo manager

Notes: Figure shows point estimates for the impact of transportation voucher on household demand and their 95% confidence intervals by household category based on the genders of the dambo plot managers and voucher recipients. The statistical differences are found for the following hypothesis testing. p-values (randomization inference p-values) for H0:(1)=(2) are 0.02 (0.02) in the left panel and 0.01 (0.02) in the right panel. p-values values (randomization inference p-values) for H0:(2)=(4) are 0.00 (0.08) in the left panel and 0.00 (0.02) in the right panel. See Appendix Table B3 for the full estimation results.

We do so by estimating heterogeneous ITT effects by incorporating the interaction terms between the treatment indicators and the dambo manager's gender dummies into the empirical specification of Equation (2). Figure 3 summarizes the treatment impacts by household category based on the genders of the dambo plot managers and voucher recipients.[31] There are three key findings. First, if the wife controls a dambo field, the voucher given to her (rather than her husband) induces higher household demand, and the impacts are different at the 5% statistical level at both the intensive and extensive margins (household categories [1] and [2]). By contrast, when the husband selects what to grow on a dambo plot, the voucher increases household demand regardless of the gender of the voucher receiver (household categories [3] and [4]). Second, vouchers given to the wife increase household demand regardless of the gender of the dambo plot manager. On the contrary, vouchers given to husbands increase demand only when they control dambo fields while it decreases the demand when their wives manage the dambo plot. Finally, for households owing no dambo fields at baseline, take-up rates are higher when the voucher is given to the husband than when it is given to the wife (see row "Test: TF = TM (p-value)" of Appendix Table B3).[32]

[31] Appendix Table B3 reports the full estimation and hypothesis testing results based on bootstrapping and randomization inference methods as well as conventional robust standard errors.

[32] These households have to look for agricultural land with enough moisture in its soil for rice planting before the onset of

To sum up, Figure 3 and Appendix Table B3 show that (1) when households have no dambo at the baseline survey, vouchers given to husbands induce more rice demand on the extensive margin than do vouchers given to wives, and (2) if the wife chooses what to cultivate on the dambo, the vouchers given to wives have greater impacts on household demand for rice seeds than those given to husbands. These empirical findings that the gender of the voucher recipients matters indicate that economic incentives generated by the voucher are not shared within the marriage. Figure 3 also reports interesting evidence that (3) the voucher given to husbands is effective only when they control the dambo fields. This suggest that households' productive resources relevant to agricultural technology are also not pooled within the household. The observed significant differences in household demand for the new crop between the treatment assignments and the intrahousehold land management patterns are hard to reconcile with the unitary household model and Pareto-efficient collective models, both of which predict that their identities should not matter for production decisions. Rather, these observations are more consistent with the household bargaining model that allows for Pareto-inferior outcomes. In particular, the negative impact of the voucher given to husbands when their wives control dambo implies the presence of tensions between spouses.

4.3 Treatment Effects on Spousal Demands

Individual-level results of our treatment would provide more direct evidence on the role of intrahousehold bargaining in technology adoption. In addition to the total purchase amount of rice seeds at the household level, we asked respondents whose demand was being met and the quantity of seeds demanded by each spouse. Since plot managers need to pay all the input costs, it was fairly easy to identify whose demand it was in this context. Such self-reported information allows us to estimate heterogeneous treatment effects on each spousal rice demand separately by treatment status and intra-household land management pattern. If spouses have different motivations to adopt rice, we expect that reactions to the voucher will also be different, as proposed by our theoretical model.

Figure 4 presents the estimated treatment impacts for the wife's and husband's demand by household category.[33] As shown in Figure 4, the wife shows higher interest in rice seeds for production when she receives the transportation voucher (household categories [1] and [3] vs. [2] and [4] in Figure). In addition to the comparison between household categories [1] and [2], the difference in the wife's demand is significant between household categories [3] and [4]. Unlike the wife's responses, the husband's demand does not react significantly to the transportation voucher when his spouse controls a dambo plot. Thus, who receives the voucher matters for the wife's demand but not for the husband's.

Another important finding is that the positive impacts on total household demand come mostly from the high demand of the voucher recipient when he or she also controls dambo. When the wife is a dambo

the rainy season or need to pay more labor costs for cultivation (e.g., manual watering on a normal field) during the season. The results may imply that only husbands, who usually have more control over normal fields, can make such an arrangement (and thus a decision) to start producing rice in the setting where land markets are not active.

[33] Appendix Table B4 reports the full estimation results.

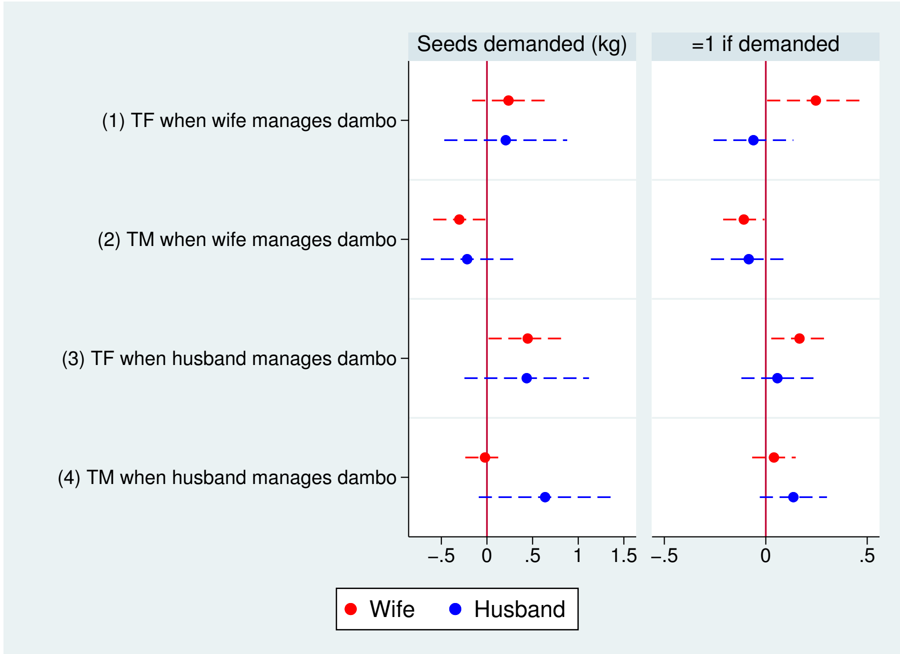

Figure 4: Heterogeneous treatment effects on spouses' demands by the gender of dambo manager

Notes: Figure shows point estimates for the impact of transportation voucher on spouses' demands for rice seeds and their 95% confidence intervals by household category based on the genders of the dambo plot managers and voucher recipients. The statistical differences are found for the following hypothesis testing. For the wife's demands, p-values (randomization inference p-values) for H0:(1)=(2) are 0.02 (0.02) in the left panel and 0.00 (0.01) in the right panel. p-values (randomization inference p-values) for H0:(3)=(4) are 0.05 (0.02) in the left panel and 0.11 (0.10) in the right panel. p-values (randomization inference p-values) for H0:(2)=(4) are 0.03 (0.29) in the left panel and 0.00 (0.05) in the right panel. For the husband's demands, p-values (randomization inference p-values) for H0:(2)=(4) are 0.02 (0.14) in the left panel and 0.04 (0.27) in the right panel. See Appendix Table B4 for the full estimation results.

plot manager, the voucher given to her has a greater impact on the fraction of the wives who showed interest in rice production than that given to husbands by 36 percentage points (0.271– [-0.094]; see column 3 of Appendix Table B4). Moreover, the demand of the husband is higher at the intensive margin than that of the wife when he receives the voucher and manages dambo. In the hypothesis tests across the regression models, these two different responses by the wife and husband were found to be statistically significant at the 10% level (not reported). This result is consistent with the household bargaining model with endogenous outside option: The dambo manager who receives the voucher has a strong incentive to produce rice, since it will improve his or her future bargaining position within the marriage. On the flip side, when the voucher recipient is a different person from the dambo manager, the responses to the treatment look similar between the spouses. This may indicate that such households purchase rice seeds only if the husband and wife reach an agreement over rice production. Thus, similar responses among spouses can be a sign of cooperation within the household. Overall, the analysis with individual-level demand data finds results consistent with the idea that household technology adoption is an outcome of intrahousehold bargaining.[34]

[34] We also asked respondents which spouse had wanted rice directly. Appendix Figure A2 reports heterogeneous treatment impact estimates on the answer to this direct question. The results show that the gender of the voucher recipient matters for the preferences of both spouses when wives manage the dambo. However, this direct question was asked only to purchase

4.4 Additional Evidence

We have so far presented evidence that observed rice demand reflects not only the patterns of voucher distributions within the household but also those of intrahousehold land management. These findings suggest the presence of inefficiency. This subsection presents supporting evidence for the main results.

4.4.1 Gender of Customers and Production Plan

Another interesting issue is which spouse came to the rice seed sales meetings. In our experimental design, both spouses received the same information on when and where the sales meetings were happening, while the voucher distribution was implemented privately. Since opportunity costs for showing up at the venue may differ between males and females, it would make sense if we observed that, for example, the wives were more likely to come. However, the gender of the recipient cannot be a determinant of who showed up to buy seeds unless the recipients revealed higher demand than non-recipients from the same household. As a related outcome, we will also use self-reported answers to the question "Who will mainly grow rice?" as the other outcome variable. This question was asked at the sales meeting.

Figure 5 graphically summarizes the reduced-form results for each household category.[35] The left panel in Figure 5 shows the treatment impacts of the voucher on the probability of the wife (husband) coming to our sales meeting in red (blue). The results show that, when the wife controls the dambo, the wife's receipt of the voucher increases the likelihood of the wife showing up at the meeting. This is also true for the households in which the husband manages the dambo. In addition, the husband who receives the voucher is less likely to come when his spouse manages the dambo than when he controls the dambo. In this case, husbands seem to show no interest in the purchase, probably because they cannot reap benefits from rice production due to their lack of control over suitable plots for rice.

The other outcome is the answer to the question about who would cultivate rice according to the respondent's initial plan. The right-hand panel of Figure 5 illustrates the estimation results. In line with the previous argument, wives who control the dambo are more likely to be involved in rice production when they receive the voucher than they are when their husbands receive it. Furthermore, the propensity of husbands to participate in rice cultivation depends both on who gets the voucher and who manages the dambo.

In summary, both panels show non-random patterns depending on the genders of the voucher recipients and dambo managers. The additional evidence presented here is consistent with the main finding that the gender of the voucher recipients matters for household technology adoption, especially when wives manage the lands most suitable for rice cultivation. In this case, husbands from TF households are less likely to show up on the rice sales day than are husbands from TM households. Similarly, wives from TF households are more involved in rice production during the upcoming rainy season than are wives from

households, and thus the estimates are based on a small sample and may suffer from sample selection bias. Despite this caveat, the auxiliary exercise also supports the main empirical findings.

[35] Appendix Table B5 reports the full estimation results. Because there were only 12 cases (out of 126 purchase households) in which both spouses showed up, we simply create dummy variables taking 1 if each spouse came and use them separately as dependent variables.

Figure 5: Heterogeneous treatment effects on other outcomes by the gender of dambo manager

Notes: The left panel shows point estimates for the impact of transportation voucher on the probability that wife (husband) came to the rice sales meeting with red (blue) symbol and their 95% confidence intervals by household category. The right panel shows point estimates for the impact of transportation voucher on the probability of answering wife (husband) in response to the question of "Who mainly grow rice?" with red (blue) symbol and their 95% confidence intervals by category. The statistical differences are found for the following hypothesis testing. For the wife, p-values (randomization inference p-values) for H0:(1)=(2) are 0.07 (0.09) in the left panel and 0.01 (0.02) in the right panel. p-value (RI p-value) for H0:(3)=(4) is 0.08 (0.07) in the left panel. p-value (RI p-value) for H0:(2)=(4) is 0.02 (0.02) in the right panel. For the husband, p-value (RI p-value) for H0:(1)=(2) is 0.06 (0.09) in the right panel. p-values (RI p-value) for H0:(2)=(4) is 0.05 (0.26) in the left panel and 0.00 (0.13) in the right panel. See Appendix Table B5 for the full estimation results.

TM households. Overall, the empirical evidence supports the key predictions of our theoretical model, indicating that spouses face different incentives.

4.4.2 Comparison with Single Female-headed Households

We also check whether intrahousehold bargaining plays a significant role in technology adoption decisions by comparing the impacts of vouchers given to the wife in a married couple with those of vouchers given to the single female heads of the household. The motivating hypothesis is that, because the female heads are free from intrahousehold bargaining, they may simply choose optimal investment levels to maximize profits. By contrast, as shown in the theoretical model, married wives who can choose what to grow on dambo have an incentive to overinvest in rice seeds to improve their future bargaining positions. Thus, the voucher given to wives in couple households should have a greater impact on technology take-up if intrahousehold bargaining plays a key role in household investment decisions.

To test this hypothesis, we add 106 observations from single female-headed households and drop TM households since single female households cannot be considered part of the TM category according to our assignment rule. We control for the individual characteristics of females, either wife or female head.

Specifically, a set of explanatory variables in the regression equation includes age, years of education, non-farm income, and risk preferences, but not financial autonomy since that variable was not elicited from the single female household heads.

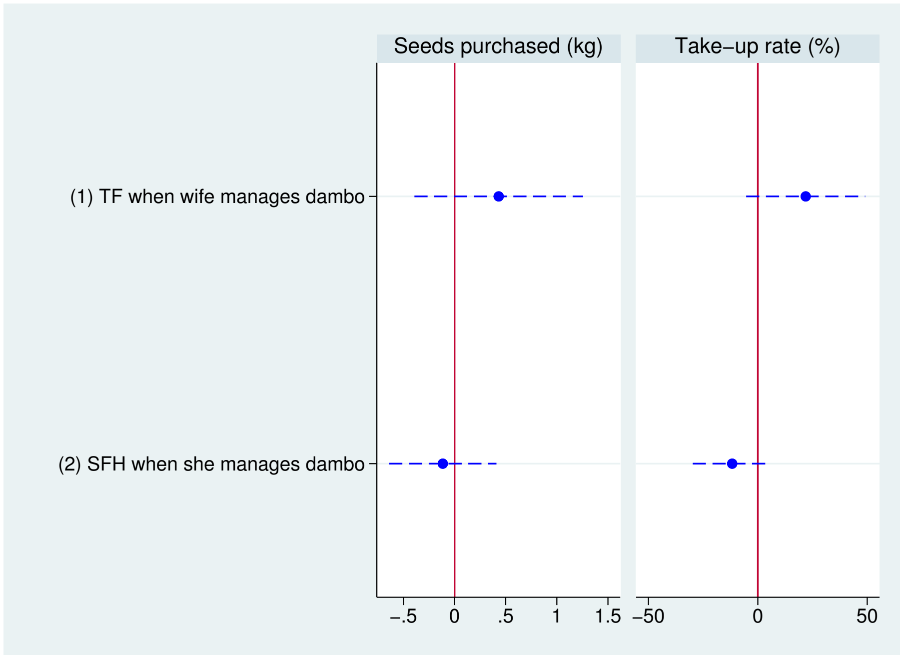

Figure 6: Heterogeneous treatment effects among married and single female-headed households

Notes: SFH stands for single female-headed households that received the voucher. Figure shows point estimates for the impact of transportation voucher on household demand and their 95% confidence intervals by category. The statistical differences are found for the following hypothesis testing. p-value (randomization inference p-values) for H0:(1)=(2) is 0.03 (0.13) in the right panel. See Appendix Table B6 for the full estimation results.

Figure 6 presents the estimation results in which the reference category is couple households in the control group that own no dambo fields.[36] The voucher given to female spouses in married couples increases participation in rice production when they manage dambo fields, although the estimate is not precise much. Contrariwise, the voucher given to single females has no impact on demand for rice seeds. The difference in the response to our treatment between the two household types is significantly different, though the hypothesis test based on randomization inference suggests a marginal result. Although the analysis here is descriptive[37], this result is consistent with the prediction that female spouses have an extra incentive to invest in their own fields to enhance their bargaining position within the household.

[36] Appendix Table B6 presents the full estimation results.

[37] There may be systematic differences that drive different patterns of adoption between married and single households. For example, family labor is more likely to be in short supply in single households than in couple households. This may account for the null effect of our treatment for single female-headed households.

5 Information Sharing within the Household

This section investigates the role of household bargaining in technology take-up from a different angle. If information flows within the marriage are not perfect, this can be a direct source of inefficiencies.[38] Our bargaining model predicts that information asymmetries between spouses can be interpreted as an outcome of their strategic behavior (hypothesis 2). In our experimental context, recipients may not share information on transportation vouchers with their spouses for (un)intended purposes, even though we did not prohibit such information sharing.[39]

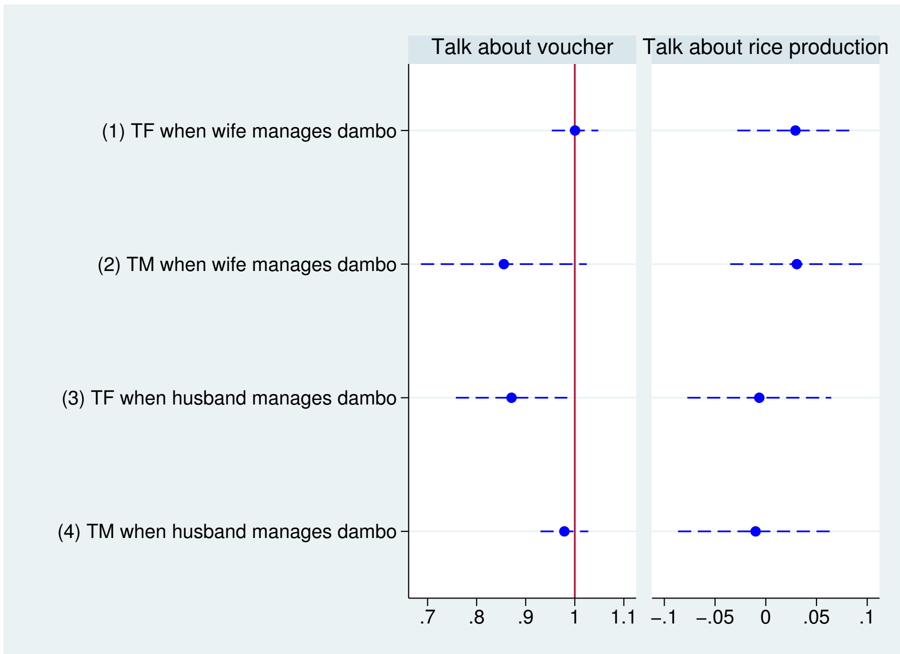

Figure 7: Heterogeneous treatment effects on communication among spouses

Notes: Figure shows point estimates for the impact of transportation voucher on the likelihood of spousal communication about voucher (left) and rice production (right) and their 95% confidence intervals by household category based on the genders of the dambo plot managers and voucher recipients. The statistical differences are found for the following hypothesis testing. For the left panel, p-values (randomization inference p-values) are 0.12 (0.18) for H0:(1)=(2), 0.07 (0.05) for H0:(3)=(4), and 0.03 (0.05) for H0:(1)=(3). No statistical significance was detected in the right panel. See Appendix Table B8 for the full estimation results.

To directly test hypothesis 2 postulated in Section 3, we utilize the data on spousal communication about the voucher before the rice sales. The results are presented in Figure 7 (left-hand panel).[40] We found a striking pattern regarding spousal communication about vouchers. If the dambo manager receives

[38]Some studies have reported the presence of misinformation among spouses and strong incentives to conceal resources such as income from other family members (e.g., Anderson and Baland, 2002; Ashraf, 2009). These suggest that individuals are often willing to pay additional costs to keep information private. Such asymmetric information problems automatically lead to Pareto-inefficient outcomes, since there is room for an increase in total household surplus through information sharing between husband and wife.

[39]Appendix Table B7 confirms the lack of significant differences between the genders of voucher recipients in term of the probability of acknowledging the rule of voucher usage (i.e., wherein spouses, in addition to voucher recipients, can redeem the voucher).

[40]See Appendix Table B8 for the full estimation results.

the transportation voucher, most talk about them to their spouses before the sales. When the voucher recipient is different from the dambo manager within the household, however, the likelihood of spousal communication falls by about 15 percentage points. This interesting result is consistent with the idea that voucher recipients have less incentive to share information if they have no authority to select the crops for dambo fields, since their bargaining positions will not improve through rice cultivation. As shown in the right-hand panel of Figure 7, we asked the respondents if they had talked about rice cultivation with his/her spouse and found no evidence that the voucher affected spousal communication about rice production in general. These results suggest that spouses have an incentive to hide useful resources when the voucher does not improve their allocations, which can increase the household's total surplus.

6 Mechanisms behind Inefficient Production Choices

6.1 Limited Commitment

The previous sections indicate the importance of intrahousehold bargaining in the context of technology adoption. Since the gender division of labor makes it difficult to satisfy incentive compatibility faced by at least one of the spouses in a dynamic setting, household members cannot make an enforceable contract regarding future actions with their spouses and choose the first-best production plan. The theoretical framework in Section 3 illustrates the possibility of selecting the suboptimal choice as household equilibrium because of this commitment problem. The empirical results in Sections 4 and 5 are coherent with the prediction of the bargaining model with no intertemporal commitment.

Although it is hard to present direct evidence on the difficulty of commitment among spouses, the data on how many households who purchased rice seeds actually grow rice provide suggestive evidence on limited commitment to future production plans. Our follow-up survey in June 2019 collected information on agricultural activities, including rice production, during the 2018/19 rainy season. Interestingly, out of 119 households who purchased seeds in October 2018, only 28 households actually cultivated rice.[41] This may be because new information obtained after the seed sales meeting forced the households to revise their initial production plan. If the future plan was fully committed to and if information shocks are purely random, however, we should not observe different patterns in the likelihood of actual rice cultivation across household categories defined by treatment assignment and land management pattern.

To test this conjecture, we regress the dummy variable reflecting actual rice planting on the identities of the voucher recipients and dambo managers. To deal with a small number of "success" observations with actual planting, treatment households are categorized into matched households (i.e., wherein the voucher recipient and the dambo manager are matched) and unmatched households. Because planting follows rice seed purchase, it would be ideal to correct for self-selection into purchasing rice in the regression framework. In particular, the selection equation should have identifying variables that affect the likelihood that the household will decide to purchase rice seeds but do not affect the likelihood of planting

[41] The most common reasons for not conducting rice planting were that (1) they did not know how to grow rice and (2) they were busy planting other crops like maize.

Table 7: Effects on actual rice planting of correspondence between voucher recipient and dambo manager

	(1)	(2)
Matched HHs=1	0.106	0.316*
	(0.077)	(0.190)
Unmatched HHs=1	-0.005	-0.026
	(0.068)	(0.194)
TF	0.064	0.204
	(0.045)	(0.143)
TM	0.030	0.008
	(0.043)	(0.122)
Wife manages dambo=1	-0.066	-0.254
	(0.060)	(0.197)
Husband manages dambo=1	-0.000	-0.103
	(0.053)	(0.149)
Sample	Full sample	Purchase HHs
Test: Matched HHs=Unmatched HHs (p-value)	0.08	0.05
Test: Matched HHs=Unmatched HHs (bootstrap p-value)	0.08	0.09
Test: Matched HHs=Unmatched HHs (RI p-value)	0.00	0.00
Test: TF=TM (p-value)	0.40	0.11
Test: TF=TM (bootstrap p-value)	0.40	0.14
Test: TF=TM (RI p-value)	0.41	0.08
Control HH's mean of dependent variable	0.06	0.22
R squared	0.10	0.17
N	347	119

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The dependent variables are an indicator variable for rice planting in the 2018/19 rainy season. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

except through purchase. Unfortunately, such excludable variables are not available. Instead, we present simple OLS estimation results for the full sample and the sample comprising only purchase households. These provide us the lower bound of estimates, since some households might give up purchasing rice seeds because of the severe commitment problem.

Table 7 shows the estimated impacts on the likelihood of rice planting during the 2018/19 agricultural season. The results show that our sample households are more likely to plant rice, especially when the voucher recipient manages dambo fields.[42] The equality in the coefficients between the matched and unmatched households is rejected at the 5% level for the restricted sample. These conservative estimates provide suggestive evidence that the difficulty in intertemporal commitment among spouses is a key mechanism behind the observed household inefficiency.

[42] Appendix Figure A3 also confirms the non-random patterns of rice planting across the four household categories, although the statistical levels are not high due to the small sample size. The empirical results reveal that (1) TF households are more likely to grow rice than TM households when the wife controls the dambo and that (2) the voucher given to the husband increases the probability that rice will actually be planted when he chooses what to grow on the dambo relative to when his wife does so. Both results are consistent with the observed patterns for household demand for rice seeds as shown in Figure 3. In particular, committing to a production plan was found to be most difficult when the husband received the voucher and the wife managed the dambo plot.

6.2 Alternative Explanations

One of our main results is that the favorable impacts of our voucher can be explained solely by the high interest of the plot manager who also received the voucher (Figure 4). This also implies that the effects of the voucher did not spill over onto their spouses' demand. One may argue that this difference in the responses to our treatment between spouses flows not from differences in incentives reflected by the gender division of plot managements but from other gender differences, such as in knowledge of rice cultivation and perceptions about rice. To answer this question, we investigate the spousal difference patterns in these two factors.

6.2.1 Gender Differences in Knowledge of Rice Cultivation

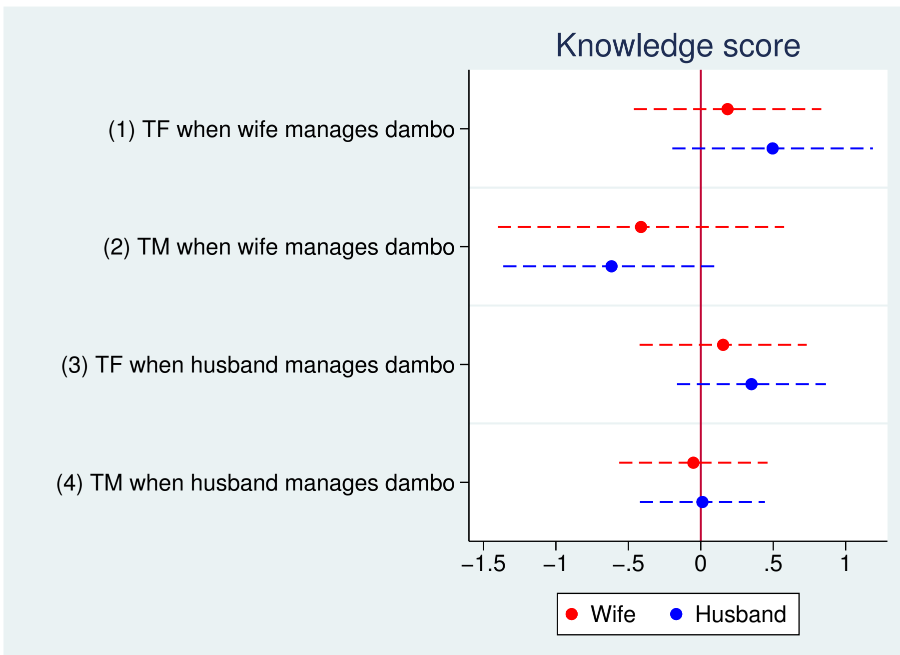

Figure 8: Heterogeneous treatment effects on knowledge gaps

Notes: Figure shows point estimates for the treatment effect of transportation voucher on the total number of the correct responses to five multiple-choice questions about rice cultivation and their 95% confidence intervals by household category based on the genders of the dambo plot managers and voucher recipients. See the footnote of Appendix Table B11 for the detail on the questions. No statistical differences are detected for the wife's responses. For the husband's knowledge score, statistical difference is found for the following hypothesis testing: p-value (randomization inference p-values) is 0.02 (0.05) for H0:(1)=(2). See Appendix Table B11 for the full estimation results.

Before the study's intervention, rice production was new to most of the local farmers. Our enumerators provided information on rice cultivation techniques via a brochure to both the treatment and control households and to both spouses in the baseline survey. Nevertheless, gender differences in knowledge might help explain the differences in rice demand between the spouses. To address this possibility, we asked five multiple-choice questions during the follow-up survey in May/June 2019.[43] As a measure of

[43] See the footnote of Appendix Table B11 for more details on the questions.

knowledge about rice cultivation, we calculate a knowledge score that aggregates together the correct answers to the five questions. Figure 8 reports the treatment effects on the knowledge score according to the gender of the recipients interacted with the gender of the dambo plot managers.[44] We find no significant differences in knowledge scores between the spouses across the four household categories, which rules out this channel. Instead, the order of the household-level average score is highest in group 1 (TF when the wife manages the dambo) and is lowest in group 2 (TM when the wife manages the dambo), the same as the observed pattern of total household demand shown in Figure 3. Thus, knowledge about rice cultivation as measured here may reflect individuals' efforts to acquire knowledge on how to grow rice after its purchase.

6.2.2 Gender Differences in Perceptions of Rice

Cultural distinctions between female and male crops are often observed in the African context, though the typical categorization does not often fit the reality (Doss, 2002). This concept is associated with the distinction between crops for market sales (cash crops) and crops for home consumption (food crops). The general observation is that cash crops are mainly a male task domain, while food crops are a female domain. In addition, the literature points out that the distinctions between men's and women's crops are affected by changes in the environment and crop profitability (e.g., von Braun and Webb, 1989; Fischer and Qaim, 2012; Carney and Carney, 2018).

In our context, the pattern of intrahousehold land management might reflect spousal differences in perceptions about rice whereby women may consider rice as a food crop while men may think of it as a cash crop. In addition, our treatment could alter the status-quo perceptions of rice among the survey farmers since the treatment households are encouraged to bring harvested rice to the town for milling. Selling rice at market requires one to mill the rice using a milling machine because doing so manually using a mortar can result in grain breakage, leading to poor-quality rice. Accordingly, the initial perception of rice as a food crop might have changed to a perception of it as a cash crop after the vouchers were received. If the pattern of changes in the perceptions differ by gender, this might explain the observed patterns of spousal demand and hence of total household demand.

The follow-up survey elicited perceptions by asking respondents whether they agreed to the statement "rice is a cash crop".[45] Figure 9 summarizes the heterogeneous treatment effects on the perception of rice by household category based on the genders of the dambo plot managers and voucher recipients. Because we detect no significant gap among spouses about perceptions of rice as a cash crop in the first and fourth

[44]To validate our empirical exercise, we need to assume no gender differences in knowledge before the intervention. To test this assumption, we regress the knowledge score on a gender dummy variable interacted with the management status of dambo with another sample of households from neighboring villages. In these villages, no one received the voucher or any information on rice production and the sales meeting. Estimation results confirm that there were no significant knowledge gaps between the sexes (Appendix Table B10).

[45]Perceptions were elicited after the 2018/19 crop season. To test whether changes in perceptions caused by the receipt of the voucher affected household demand for rice seeds at the time of purchase in October 2018, we hypothesize here that they were constant until the time of the follow-up survey when we collected the information. Although the perceived role of rice might have changed, the small number of households that actually planted rice would mitigate this concern. In fact, the inclusion of the dummy for the actual rice cultivation did not change results.

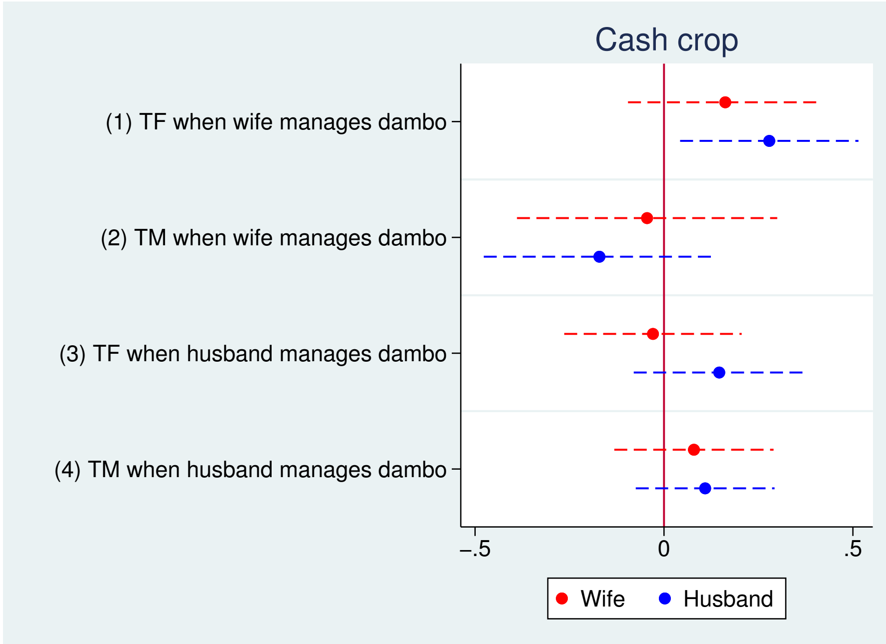

Figure 9: Heterogeneous treatment effects on perceptions about rice as cash crop

Notes: Figure shows point estimates for the treatment impact of transportation voucher on the dummy taking 1 if the respondent agree with the statement "rice is a cash crop" and their 95% confidence intervals by household category based on the genders of the dambo plot managers and voucher recipients. Estimates about wife (husband)'s answers are shown in red (blue). See Appendix Table B12 for the full estimation results.

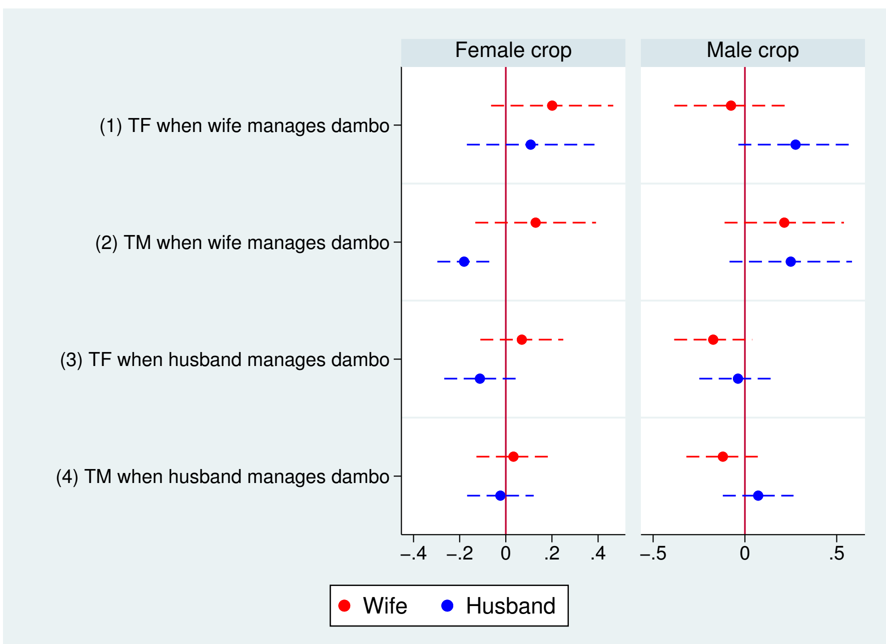

Figure 10: Heterogeneous treatment effects on perceptions about rice as female/male crop

Notes: Figure shows point estimates for the treatment effect of transportation voucher on the agreement to the statement "rice is a female crop" (left) and "rice is a male crop" (right) and their 95% confidence intervals by household category based on the genders of the dambo plot managers and voucher recipients. Estimates about wife (husband)'s answers are shown in red (blue). The omitted category is gender-neutral crop. See Appendix Table B12 for the full estimation results.

categories, it is reasonable to conclude that gender differences in such perceptions did not drive the pattern of household demand for rice seeds. Figure 10 shows the heterogeneous treatment impacts when we regress a dummy variable taking 1 if respondents considered rice as a male crop or female crop. The results show that wives (husbands) are more likely than husbands (wives) to consider rice as a female (male) crop irrespective of the treatment and land management category. Thus, we find no evidence that any differences in perceptions between spouses drive our main results.

Overall, gender differences in both knowledge of rice cultivation and perceptions do not explain the observed patterns of spousal differences in demand for rice seeds.

7 Conclusions

This study exploits experimental variations in the gender specific targeting of investment incentives intended to enhance the adoption of a new crop to understand the role of intrahousehold bargaining in technology adoption. We find that the impact of transportation vouchers, which are expected to benefit more female than male farmers, on household demand for rice seeds differs according to the genders of the voucher recipient and plot manager. The vouchers given to the husbands increase household demand for rice seeds only when they manage a field suitable for rice production. When the wives choose what to grow in such fields, the impact of the voucher given to the wives is significantly different from that given to the husbands. We also find that the voucher recipient is less likely to communicate with his/her spouse about the voucher when the recipient and the plot manager are different in the household. The differential impacts on technology take-up and information sharing by targeted individual are consistent neither with the standard unitary model nor with the collective model with exogenous outside options. Rather, a full set of empirical results is well-explained by a household bargaining model with feedback to future bargaining positions.

Evidence that productive resources are poorly pooled within the household indicates the presence of productive inefficiency. For the efficient use of productive resources, it would be desirable to identify who manages the resources critical for adopting the technology of interest and to design interventions effectively targeted to those who manage the resource, rather than to household heads, as is commonly done. As Haider et al. (2018) have pointed out, however, such individual targeting is not implemented in the current agricultural programs aimed at technology diffusion. Lastly, a growing literature is investigating who is the best seed person for technology diffusion (e.g., Beaman et al., 2018). It would be worthwhile evaluating the relative importance of targeting across households and targeting within households in the context of technology adoption.

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A Appendix figures

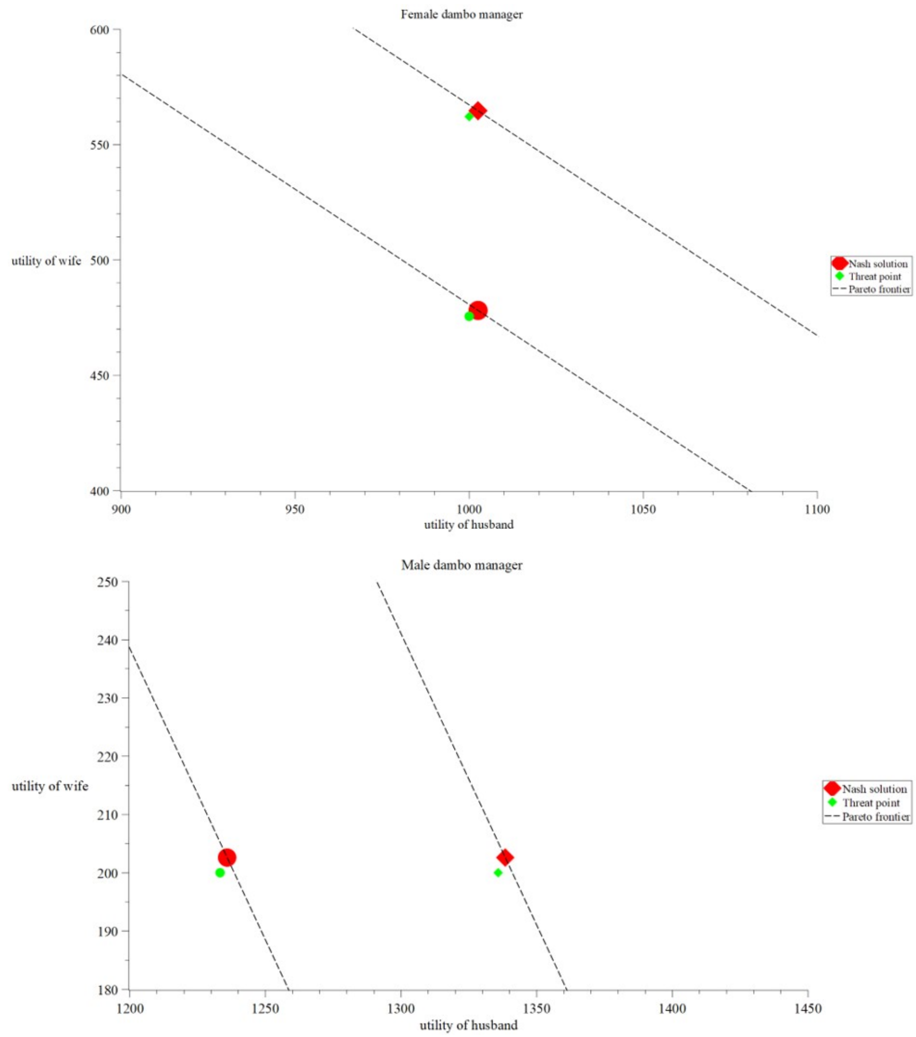

Figure A1: Possibility of joint production by the availability of voucher

Notes: This figure is drawn with the parameters presented in Table 5 and $\mu = 0.5$. The top panel shows the combination of Nash solutions and threat points when the wife manages a suitable plot for rice production. The bottom panel shows the combination of Nash solutions and threat points when the husband manages a suitable plot for rice production. In both panels, the outer (inner) Pareto frontier represents the case when the voucher is available (not available).

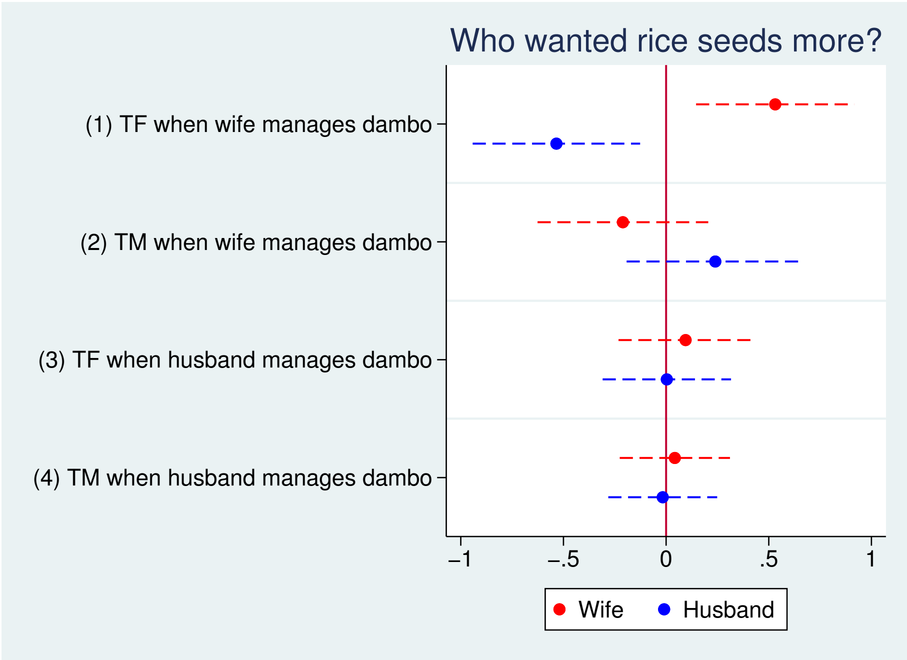

Figure A2: Heterogeneous treatment effects on spousal preferences

Notes: The panel shows point estimates for the impact of transportation voucher on the probability of answering wife (husband) in response to the question of "Who wanted rice seeds more?" with red (blue) symbol and their confidence intervals by category. The full estimation results are available upon request.

Figure A3: Heterogeneous treatment effects on actual rice planting

Notes: Figure shows point estimates for the impact of transportation voucher on actual rice planting and their 95% confidence intervals by category. Estimates in the left panel are based on the whole sample, while those in the right panel are based on the sample limited to 119 purchase households. The statistical differences are found for the following hypothesis testing. p-value (RI p-value) for H0:(1)=(2) is 0.05 (0.04) in the left panel. p-values (RI p-value) for H0:(2)=(4) are 0.00 (0.02) in the left panel and 0.08 (0.10) in the right panel. See Appendix Table B9 for the full estimation results.

B Appendix tables

Table B1: Determinants of plot managed by wife

	(1)	(2)
=1 if dambo	0.079*	0.171***
	(0.042)	(0.058)
=1 if lowland	-0.127***	0.157***
	(0.025)	(0.049)
=1 if soil is good	-0.012	0.052
	(0.028)	(0.055)
=1 if soil is bad	-0.103***	-0.063
	(0.035)	(0.075)
Land size (ha)	-0.010***	-0.022**
	(0.004)	(0.010)
Camp FE	Yes	No
HH FE	No	Yes
Mean of dependent variable	0.14	0.14
R squared	0.08	0.73
N	691	691

Notes: Robust standard errors in parentheses. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The unit of observation is plot. The dependent variables are an indicator variable for wife-managed plot. The reference category for dambo and lowland dummies is highland. OLS is used for the estimation.

Table B2: Effect of transportation voucher on household demand for rice seeds: alternative definition

	(1)	(2)	(3)
TF/TM	0.131***		
	(0.039)		
TF		0.115**	0.147***
		(0.047)	(0.054)
TM		0.143***	0.169***
		(0.046)	(0.049)
Wife manages dambo=1	-0.045	-0.042	-0.028
	(0.064)	(0.064)	(0.063)
Husband manages dambo=1	0.086*	0.086*	0.074*
	(0.051)	(0.051)	(0.042)
Test: TF=TM (p-value)	.	0.57	0.60
Test: Wife manages=Husband manages (p-value)	0.08	0.08	0.12
Model	OLS	OLS	Probit
HH controls	Yes	Yes	Yes
Camp FE	Yes	Yes	Yes
Control HH's mean of dependent variable	0.13	0.13	0.13
R squared	0.23	0.24	
N	384	384	384

Notes: Robust standard errors in parentheses. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The dependent variables are a binary variable equal to 1 if household purchases more than or equal to 2kg of rice seeds. The values in column 3 are marginal effects obtained from the Probit model estimation. The same set of household controls as in Table 6 are included but not reported.

Table B3: Heterogeneous treatment effects on household demands by the gender of dambo manager

	(1) Seeds (kg)	(2) Take-up
TF	0.260	-0.014
	(0.238)	(0.069)
TF × Wife manages dambo=1	0.491	0.296*
	(0.565)	(0.177)
TF × Husband manages dambo=1	0.497	0.182
	(0.451)	(0.131)
TM	0.581**	0.116
	(0.243)	(0.071)
TM × Wife manages dambo=1	-0.813	-0.217
	(0.501)	(0.160)
TM × Husband manages dambo=1	-0.102	-0.024
	(0.472)	(0.134)
Wife manages dambo=1	-0.285	-0.094
	(0.380)	(0.120)
Husband manages dambo=1	0.165	0.084
	(0.274)	(0.101)
Test:TF=TM (p-value)	0.18	0.05
Test:TF=TM (bootstrap p-value)	0.17	0.04
Test:TF=TM (RI p-value)	0.17	0.04
(1) TF when wife manages dambo	0.47	0.19
p-value	0.23	0.15
(2) TM when wife manages dambo	-0.52	-0.20
p-value	0.06	0.05
(3) TF when husband manages dambo	0.92	0.25
p-value	0.01	0.01
(4) TM when husband manages dambo	0.64	0.18
p-value	0.08	0.04
Test:(1)=(2) (p-value)	0.02	0.01
Test:(1)=(2) (bootstrap p-value)	0.03	0.02
Test:(1)=(2) (RI p-value)	0.02	0.02
Test:(3)=(4) (p-value)	0.54	0.46
Test:(3)=(4) (bootstrap p-value)	0.53	0.47
Test:(3)=(4) (RI p-value)	0.53	0.46
Test:(1)=(3) (p-value)	0.33	0.64
Test:(1)=(3) (bootstrap p-value)	0.34	0.66
Test:(1)=(3) (RI p-value)	0.85	0.94
Test:(2)=(4) (p-value)	0.00	0.00
Test:(2)=(4) (bootstrap p-value)	0.00	0.00
Test:(2)=(4) (RI p-value)	0.08	0.02
Control HH's mean of dependent variable	0.55	0.25
R squared	0.31	0.24
N	384	384

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

Table B4: Heterogeneous treatment effects on spouses' demands by the gender of dambo manager

	(1) Wife's demand (kg)	(2) Husband's demand (kg)	(3) =1 if wife demands	(4) =1 if husband demands
TF	0.073	0.186	0.041	-0.041
	(0.101)	(0.230)	(0.042)	(0.064)
TF × Wife manages dambo=1	0.341	0.129	0.271**	0.010
	(0.269)	(0.506)	(0.136)	(0.159)
TF × Husband manages dambo=1	0.266	0.205	-0.033	0.173
	(0.275)	(0.422)	(0.106)	(0.115)
TM	0.055	0.525**	0.052	0.077
	(0.113)	(0.233)	(0.042)	(0.067)
TM × Wife manages dambo=1	-0.181	-0.632	-0.094	-0.130
	(0.195)	(0.468)	(0.077)	(0.156)
TM × Husband manages dambo=1	-0.184	0.068	-0.170*	0.134
	(0.190)	(0.466)	(0.096)	(0.115)
Wife manages dambo=1	-0.178	-0.110	-0.065	-0.030
	(0.151)	(0.336)	(0.057)	(0.118)
Husband manages dambo=1	0.108	0.044	0.158**	-0.075
	(0.144)	(0.258)	(0.078)	(0.080)
Test:TF=TM (p-value)	0.86	0.15	0.81	0.05
Test:TF=TM (bootstrap p-value)	0.87	0.14	0.81	0.05
Test:TF=TM (RI p-value)	0.87	0.16	0.83	0.06
(1) TF when wife manages dambo	0.24	0.21	0.25	-0.06
p-value	0.25	0.55	0.04	0.55
(2) TM when wife manages dambo	-0.30	-0.22	-0.11	-0.08
p-value	0.04	0.40	0.04	0.38
(3) TF when husband manages dambo	0.45	0.44	0.17	0.06
p-value	0.04	0.21	0.02	0.53
(4) TM when husband manages dambo	-0.02	0.64	0.04	0.14
p-value	0.85	0.09	0.46	0.11
Test:(1)=(2) (p-value)	0.02	0.28	0.00	0.85
Test:(1)=(2) (bootstrap p-value)	0.03	0.31	0.01	0.86
Test:(1)=(2) (RI p-value)	0.02	0.31	0.01	0.86
Test:(3)=(4) (p-value)	0.05	0.65	0.11	0.43
Test:(3)=(4) (bootstrap p-value)	0.05	0.64	0.11	0.42
Test:(3)=(4) (RI p-value)	0.02	0.67	0.10	0.44
Test:(1)=(3) (p-value)	0.47	0.59	0.55	0.30
Test:(1)=(3) (bootstrap p-value)	0.47	0.59	0.56	0.31
Test:(1)=(3) (RI p-value)	0.50	0.84	0.42	0.74
Test:(2)=(4) (p-value)	0.03	0.02	0.00	0.04
Test:(2)=(4) (bootstrap p-value)	0.05	0.03	0.01	0.05
Test:(2)=(4) (RI p-value)	0.29	0.14	0.05	0.27
Control HH's mean of dependent variable	0.14	0.41	0.05	0.19
R squared	0.23	0.26	0.17	0.17
N	384	384	384	384

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

Table B5: Heterogeneous treatment effects on other outcomes by the gender of dambo manager

	(1) Wife came	(2) Husband came	(3) Wife grow	(4) Husband grow
TF	0.048	-0.023	0.062	-0.048
	(0.050)	(0.063)	(0.047)	(0.063)
TF × Wife manages dambo=1	0.128	0.005	0.286*	0.136
	(0.149)	(0.161)	(0.153)	(0.177)
TF × Husband manages dambo=1	0.014	0.148	-0.005	0.239*
	(0.110)	(0.114)	(0.105)	(0.127)
TM	0.039	0.082	0.087*	0.093
	(0.046)	(0.066)	(0.048)	(0.067)
TM × Wife manages dambo=1	-0.123	-0.138	-0.127	-0.246
	(0.109)	(0.160)	(0.106)	(0.153)
TM × Husband manages dambo=1	-0.119	0.114	-0.026	0.023
	(0.099)	(0.113)	(0.104)	(0.125)
Wife manages dambo=1	-0.001	-0.028	-0.018	-0.005
	(0.076)	(0.120)	(0.073)	(0.126)
Husband manages dambo=1	0.084	-0.054	0.096	0.034
	(0.082)	(0.077)	(0.075)	(0.093)
Test:TF=TM (p-value)	0.85	0.09	0.63	0.02
Test:TF=TM (bootstrap p-value)	0.85	0.08	0.64	0.01
Test:TF=TM (RI p-value)	0.85	0.10	0.67	0.02
(1) TF when wife manages dambo	0.18	-0.05	0.33	0.08
p-value	0.17	0.65	0.01	0.50
(2) TM when wife manages dambo	-0.09	-0.08	-0.06	-0.16
p-value	0.27	0.40	0.42	0.06
(3) TF when husband manages dambo	0.15	0.07	0.15	0.23
p-value	0.06	0.42	0.05	0.02
(4) TM when husband manages dambo	0.00	0.14	0.16	0.15
p-value	0.95	0.09	0.04	0.08
Test:(1)=(2) (p-value)	0.07	0.77	0.01	0.06
Test:(1)=(2) (bootstrap p-value)	0.07	0.78	0.01	0.08
Test:(1)=(2) (RI p-value)	0.09	0.78	0.02	0.09
Test:(3)=(4) (p-value)	0.08	0.48	0.96	0.47
Test:(3)=(4) (bootstrap p-value)	0.08	0.47	0.96	0.47
Test:(3)=(4) (RI p-value)	0.07	0.48	0.96	0.48
Test:(1)=(3) (p-value)	0.83	0.30	0.22	0.29
Test:(1)=(3) (bootstrap p-value)	0.83	0.32	0.23	0.31
Test:(1)=(3) (RI p-value)	0.78	0.75	0.12	0.79
Test:(2)=(4) (p-value)	0.27	0.05	0.02	0.00
Test:(2)=(4) (bootstrap p-value)	0.30	0.05	0.02	0.00
Test:(2)=(4) (RI p-value)	0.24	0.26	0.02	0.13
Control HH's mean of dependent variable	0.08	0.19	0.07	0.19
R squared	0.19	0.17	0.16	0.17
N	384	384	384	384

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

Table B6: Heterogeneous treatment effects among married and single female-headed households

	(1) Seeds (kg)	(2) Take-up
TF	0.408**	0.036
	(0.206)	(0.059)
TF × Single female HH=1	-0.069	0.032
	(0.363)	(0.106)
TF × Single female HH=1 × Female manages dambo=1	-0.533	-0.366
	(0.700)	(0.265)
TF × Female manages dambo=1	0.124	0.205
	(0.525)	(0.182)
Single female HH=1 × Female manages dambo=1	-0.107	-0.033
	(0.488)	(0.206)
Female manages dambo=1	-0.100	-0.022
	(0.297)	(0.121)
Single female HH=1	0.162	0.031
	(0.176)	(0.076)
Other family member manages dambo=1	0.267	0.135**
	(0.214)	(0.065)
(1) TF for married HH with dambo	0.43	0.22
p-value	0.31	0.12
(2) TF for single female HH without dambo	0.50	0.10
p-value	0.12	0.25
(3) TF for single female HH with dambo	-0.12	-0.12
p-value	0.67	0.20
Test:(1)=(3) (p-value)	0.22	0.03
Test:(1)=(3) (bootstrap p-value)	0.25	0.03
Test:(1)=(3) (RI p-value)	0.22	0.13
Sample	TF and C households	TF and C households
Control HH's mean of dependent variable	0.49	0.25
R squared	0.25	0.20
N	335	335

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported. The following characteristics of females (i.e., wives or female heads) are also controlled but not reported: age, education level, non-farm income, and risk preferences.

Table B7: Understanding of voucher rule among treatment households

	(1) Rule1	(2) Rule2
Female=1	0.039	0.097
	(0.096)	(0.101)
Dambo manager=1 × Female=1	-0.050	-0.299
	(0.173)	(0.195)
Spouse manages dambo=1 × Female=1	0.163	-0.365**
	(0.183)	(0.182)
Dambo manager=1	0.112	0.291***
	(0.093)	(0.108)
Spouse manages dambo=1	0.020	0.322**
	(0.151)	(0.149)
Sample	Voucher recepients	Non-recepients
(1) Wife when she manages dambo	0.10	0.09
p-value	0.50	0.61
(2) Husband when spouse manages dambo	0.02	0.32
p-value	0.89	0.03
(3) Wife when spouse manages dambo	0.22	0.05
p-value	0.04	0.66
(4) Husband when he manages dambo	0.11	0.29
p-value	0.23	0.01
Test: (1)=(2) (p-value)	0.68	0.24
Test: (3)=(4) (p-value)	0.31	0.05
Test: (1)=(3) (p-value)	0.41	0.84
Test: (2)=(4) (p-value)	0.56	0.84
Camp FE	Yes	Yes
Husbands' mean of dependent variable	0.62	0.50
R squared	0.08	0.07
N	229	212

Notes: Robust standard errors clustered by household in parentheses. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The unit of observation is individual. The estimation sample is restricted to voucher recipients in column (1) and non-recipients in column (2). The dependent variable for column 1 is a dummy equal to 1 if the recipient knows that the transportation voucher can also be utilized by the spouse. The dependent variable for column 2 is a dummy equal to 1 if the non-recipient knows that the transportation voucher can also be utilized by them as well as recipients. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

Table B8: Heterogeneous treatment effects on communication among spouses

	(1) Talked about voucher	(2) Talked about rice production
TF	0.893***	-0.033
	(0.040)	(0.040)
TF × Female manages dambo=1	0.103**	0.135
	(0.052)	(0.113)
TF × Husband manages dambo=1	-0.015	0.074
	(0.070)	(0.072)
TM	0.925***	-0.009
	(0.029)	(0.029)
TM × Female manages dambo=1	-0.073	0.112
	(0.092)	(0.110)
TM × Husband manages dambo=1	0.061*	0.047
	(0.035)	(0.066)
Female manages dambo=1	0.004	-0.072
	(0.021)	(0.116)
Husband manages dambo=1	-0.007	-0.047
	(0.022)	(0.059)
Test:TF=TM (p-value)	0.51	0.52
Test:TF=TM (bootstrap p-value)	0.51	0.52
Test:TF=TM (RI p-value)	0.50	0.52
(1) TF when wife manages dambo	1.00	0.03
p-value	0.00	0.32
(2) TM when wife manages dambo	0.86	0.03
p-value	0.00	0.36
(3) TF when husband manages dambo	0.87	-0.01
p-value	0.00	0.86
(4) TM when husband manages dambo	0.98	-0.01
p-value	0.00	0.80
Test:(1)=(2) (p-value)	0.12	0.96
Test:(1)=(2) (bootstrap p-value)	0.14	0.97
Test:(1)=(2) (RI p-value)	0.18	0.94
Test:(3)=(4) (p-value)	0.07	0.93
Test:(3)=(4) (bootstrap p-value)	0.07	0.93
Test:(3)=(4) (RI p-value)	0.05	0.95
Test:(1)=(3) (p-value)	0.03	0.23
Test:(1)=(3) (bootstrap p-value)	0.03	0.29
Test:(1)=(3) (RI p-value)	0.05	0.51
Test:(2)=(4) (p-value)	0.18	0.25
Test:(2)=(4) (bootstrap p-value)	0.19	0.28
Test:(2)=(4) (RI p-value)	0.01	0.48
Control HH's mean of dependent variable	0.00	0.97
R squared	0.80	0.05
N	371	371

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The dependent variables are a dummy equal to 1 if the respondent talks with his/her spouse about what is indicated in the header of each column. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

Table B9: Heterogeneous treatment effects on rice planting during the 2018/19 rainy season

	(1)	(2)
TF	0.050	0.231
	(0.048)	(0.161)
TF × Wife manages dambo=1	0.134	0.185
	(0.118)	(0.360)
TF × Husband manages dambo=1	0.029	-0.048
	(0.084)	(0.219)
TM	0.041	-0.006
	(0.045)	(0.128)
TM × Wife manages dambo=1	-0.068	0.065
	(0.069)	(0.291)
TM × Husband manages dambo=1	0.090	0.358*
	(0.088)	(0.202)
Wife manages dambo=1	-0.052	-0.196
	(0.053)	(0.230)
Husband manages dambo=1	-0.004	-0.119
	(0.057)	(0.149)
Sample	Full sample	Purchase HHs
Test: TF=TM (p-value)	0.86	0.15
Test: TF=TM (bootstrap p-value)	0.85	0.15
Test: TF=TM (RI p-value)	0.86	0.12
(1) TF when wife manages dambo	0.13	0.22
p-value	0.22	0.40
(2) TM when wife manages dambo	-0.08	-0.14
p-value	0.09	0.49
(3) TF when husband manages dambo	0.08	0.06
p-value	0.21	0.71
(4) TM when husband manages dambo	0.13	0.23
p-value	0.06	0.14
Test: (1)=(2) (p-value)	0.05	0.15
Test: (1)=(2) (bootstrap p-value)	0.06	0.22
Test: (1)=(2) (RI p-value)	0.04	0.55
Test: (3)=(4) (p-value)	0.49	0.31
Test: (3)=(4) (bootstrap p-value)	0.49	0.35
Test: (3)=(4) (RI p-value)	0.53	0.35
Test: (1)=(3) (p-value)	0.61	0.59
Test: (1)=(3) (bootstrap p-value)	0.62	0.63
Test: (1)=(3) (RI p-value)	0.66	0.66
Test: (2)=(4) (p-value)	0.00	0.08
Test: (2)=(4) (bootstrap p-value)	0.00	0.10
Test: (2)=(4) (RI p-value)	0.02	0.10
Control HH's mean of dep. var.	0.06	0.22
R squared	0.10	0.17
N	347	119

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The dependent variables are an indicator variable for rice planting in the 2018/19 rainy season. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

Table B10: Effect of gender and dambo management on knowledge of rice cultivation: neighboring villages

	(1)	(2)	(3)	(4)	(5)	(6)
	Q1	Q2	Q3	Q4	Q5	Score
Female=1	-0.044	0.104	-0.150	0.012	0.082	0.005
	(0.091)	(0.098)	(0.157)	(0.127)	(0.114)	(0.311)
Dambo manager=1 × Female=1	0.482**	0.045	0.082	0.243	-0.227	0.624
	(0.199)	(0.389)	(0.351)	(0.180)	(0.311)	(0.726)
Spouse manages dambo=1 × Female=1	-0.421**	0.026	-0.029	-0.196	0.105	-0.515
	(0.198)	(0.269)	(0.203)	(0.206)	(0.284)	(0.680)
Dambo manager=1	-0.025	-0.308*	0.130	-0.096	-0.069	-0.367
	(0.157)	(0.157)	(0.118)	(0.129)	(0.143)	(0.348)
Spouse manages dambo=1	0.370**	-0.375	0.393**	0.133	-0.360	0.161
	(0.166)	(0.267)	(0.165)	(0.155)	(0.246)	(0.566)
(1) Female when she manages dambo	0.41	-0.16	0.06	0.16	-0.21	0.26
p-value	0.03	0.65	0.85	0.29	0.46	0.69
(2) Male when spouse manages dambo	0.37	-0.37	0.39	0.13	-0.36	0.16
p-value	0.03	0.17	0.02	0.40	0.15	0.78
(3) Female when spouse manages dambo	-0.10	-0.24	0.21	-0.05	-0.17	-0.35
p-value	0.59	0.10	0.08	0.71	0.27	0.42
(4) Male when he manages dambo	-0.02	-0.31	0.13	-0.10	-0.07	-0.37
p-value	0.88	0.05	0.28	0.46	0.63	0.30
Test: (1)=(2) (p-value)	0.69	0.05	0.22	0.72	0.10	0.73
Test: (3)=(4) (p-value)	0.62	0.62	0.31	0.66	0.35	0.96
Test: (1)=(3) (p-value)	0.01	0.81	0.62	0.18	0.89	0.40
Test: (2)=(4) (p-value)	0.03	0.82	0.07	0.14	0.26	0.37
Camp FE	Yes	Yes	Yes	Yes	Yes	Yes
Males' mean of dependent variable	0.65	0.85	0.77	0.85	0.85	3.96
R squared	0.17	0.24	0.14	0.12	0.17	0.15
N	107	107	107	107	107	107

Notes: Robust standard errors clustered by household in parentheses. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The unit of observation is individual. The sample comes from neighboring villages in which no one received the voucher or any information on rice production and the sales meeting. The dependent variables in columns (1)-(5) are a dummy equal to 1 if the respondent got the right answer to the following multiple-choice questions about rice cultivation. Q1 is "Can upland rice be grown in maize plots?" and options are (1) Yes and (2) No. Q2 is "How many kgs of rice seeds are needed for cultivating 1 lima?" and options are (1) 5kg, (2) 12.5 kg and (3) 25kg. Q3 is "How many seeds are needed for planting for 1 meter?" and options are (1) 50-60 seeds, (2) 100-120 seeds, and (3) 200-250 seeds. Q4 is "When is the best time for weeding (how many weeks after germination)?" and options are (1) no need for weeding, (2) after 1 week, and (3) after 3 weeks. Q5 was "How many days does it take for NERICA4 variety to be matured?" and options are (1) about 90 days, (2) about 120 days, and (3) about 150 days. The dependent variable for column (6) is the total number of the correct answers out of the five questions. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

Table B11: Effect of voucher on knowledge about rice cultivation by spouse

	(1) Wife's score	(2) Husband's score
TF	0.020	0.065
	(0.235)	(0.209)
TF $\times$ Wife manages dambo=1	0.077	0.043
	(0.485)	(0.479)
TF $\times$ Husband manages dambo=1	0.443	0.731**
	(0.372)	(0.334)
TM	-0.165	-0.119
	(0.216)	(0.183)
TM $\times$ Wife manages dambo=1	-0.335	-0.885*
	(0.629)	(0.501)
TM $\times$ Husband manages dambo=1	0.423	0.576*
	(0.361)	(0.307)
Wife manages dambo=1	0.088	0.388
	(0.396)	(0.334)
Husband manages dambo=1	-0.309	-0.446*
	(0.279)	(0.232)
Test: TF=TM (p-value)	0.38	0.37
Test: TF=TM (bootstrap p-value)	0.38	0.37
Test: TF=TM (RI p-value)	0.37	0.34
(1) TF when wife manages dambo	0.18	0.50
p-value	0.58	0.16
(2) TM when wife manages dambo	-0.41	-0.62
p-value	0.41	0.11
(3) TF when husband manages dambo	0.15	0.35
p-value	0.60	0.18
(4) TM when husband manages dambo	-0.05	0.01
p-value	0.85	0.96
Test: (1)=(2) (p-value)	0.26	0.02
Test: (1)=(2) (bootstrap p-value)	0.27	0.03
Test: (1)=(2) (RI p-value)	0.28	0.05
Test: (3)=(4) (p-value)	0.49	0.21
Test: (3)=(4) (bootstrap p-value)	0.49	0.21
Test: (3)=(4) (RI p-value)	0.52	0.21
Test: (1)=(3) (p-value)	0.93	0.71
Test: (1)=(3) (bootstrap p-value)	0.93	0.72
Test: (1)=(3) (RI p-value)	0.94	0.72
Test: (2)=(4) (p-value)	0.48	0.11
Test: (2)=(4) (bootstrap p-value)	0.48	0.13
Test: (2)=(4) (RI p-value)	0.23	0.05
Control HH's mean of dependent variable	3.61	3.47
R squared	0.12	0.13
N	291	329

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The dependent variables are the total number of the correct answers out of the following five multiple-choice questions about rice cultivation. Q1 is "Can upland rice be grown in maize plots?" and options are (1) Yes and (2) No. Q2 is "How many kgs of rice seeds are needed for cultivating 1 lima?" and options are (1) 5kg, (2) 12.5 kg and (3) 25kg. Q3 is "How many seeds are needed for planting for 1 meter?" and options are (1) 50-60 seeds, (2) 100-120 seeds, and (3) 200-250 seeds. Q4 is "When is the best time for weeding (how many weeks after germination)?" and options are (1) no need for weeding, (2) after 1 week, and (3) after 3 weeks. Q5 was "How many days does it take for NERICA4 variety to be matured?" and options are (1) about 90 days, (2) about 120 days, and (3) about 150 days. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.

Table B12: Effect of voucher on perceptions of rice

	(1) Cash crop/wife	(2) Cash crop/husb	(3) Female crop/wife	(4) Female crop/husb	(5) Male crop/wife	(6) Male crop/husb
TF	0.043	-0.022	-0.012	0.005	-0.067	0.127
	(0.098)	(0.092)	(0.070)	(0.071)	(0.097)	(0.093)
TF × Wife manages dambo=1	0.176	0.434**	-0.135	-0.032	0.164	0.023
	(0.225)	(0.220)	(0.231)	(0.198)	(0.211)	(0.246)
TF × Husband manages dambo=1	-0.117	0.297*	0.096	-0.054	-0.021	-0.230
	(0.172)	(0.165)	(0.128)	(0.120)	(0.161)	(0.164)
TM	0.039	-0.023	-0.041	-0.074	-0.102	0.017
	(0.094)	(0.086)	(0.058)	(0.059)	(0.089)	(0.083)
TM × Wife manages dambo=1	-0.028	-0.014	-0.177	-0.241*	0.488**	0.107
	(0.248)	(0.241)	(0.228)	(0.145)	(0.214)	(0.251)
TM × Husband manages dambo=1	-0.006	0.261*	0.089	0.114	0.067	-0.009
	(0.160)	(0.150)	(0.111)	(0.116)	(0.164)	(0.154)
Wife manages dambo=1	-0.056	-0.134	0.348*	0.134	-0.172	0.126
	(0.184)	(0.186)	(0.183)	(0.138)	(0.149)	(0.190)
Husband manages dambo=1	0.046	-0.129	-0.014	-0.064	-0.085	0.065
	(0.127)	(0.122)	(0.090)	(0.099)	(0.133)	(0.123)
Test: TF=TM (p-value)	0.97	0.99	0.64	0.21	0.69	0.21
Test: TF=TM (bootstrap p-value)	0.97	0.99	0.64	0.21	0.69	0.21
Test: TF=TM (RI p-value)	0.98	0.99	0.65	0.18	0.69	0.21
(1) TF when wife manages dambo	0.16	0.28	0.20	0.11	-0.08	0.28
p-value	0.22	0.02	0.14	0.45	0.63	0.08
(2) TM when wife manages dambo	-0.04	-0.17	0.13	-0.18	0.21	0.25
p-value	0.80	0.27	0.33	0.00	0.20	0.14
(3) TF when husband manages dambo	-0.03	0.15	0.07	-0.11	-0.17	-0.04
p-value	0.81	0.21	0.45	0.16	0.11	0.73
(4) TM when husband manages dambo	0.08	0.11	0.03	-0.02	-0.12	0.07
p-value	0.46	0.25	0.69	0.75	0.24	0.46
Test: (1)=(2) (p-value)	0.28	0.01	0.69	0.03	0.15	0.90
Test: (1)=(2) (bootstrap p-value)	0.31	0.02	0.70	0.04	0.16	0.91
Test: (1)=(2) (RI p-value)	0.30	0.02	0.70	0.06	0.19	0.91
Test: (3)=(4) (p-value)	0.39	0.75	0.72	0.26	0.62	0.34
Test: (3)=(4) (bootstrap p-value)	0.39	0.75	0.73	0.27	0.62	0.34
Test: (3)=(4) (RI p-value)	0.38	0.74	0.71	0.26	0.62	0.33
Test: (1)=(3) (p-value)	0.18	0.34	0.37	0.12	0.53	0.06
Test: (1)=(3) (bootstrap p-value)	0.20	0.35	0.38	0.13	0.54	0.07
Test: (1)=(3) (RI p-value)	0.17	0.35	0.49	0.03	0.80	0.30
Test: (2)=(4) (p-value)	0.49	0.08	0.50	0.01	0.04	0.31
Test: (2)=(4) (bootstrap p-value)	0.50	0.09	0.51	0.02	0.05	0.33
Test: (2)=(4) (RI p-value)	0.25	0.01	0.61	0.05	0.11	0.71
Control HH's mean of dependent variable	0.63	0.56	0.12	0.16	0.35	0.32
R squared	0.06	0.12	0.10	0.09	0.08	0.07
N	291	329	291	329	291	329

Notes: Robust standard errors in parentheses. Bootstrap and randomization inference p-values are estimated based on 5000 replications. *** denotes significance at 1% level, ** at 5% level, and * at 10% level. The dependent variables are a dummy equal to 1 if the respondent agreed to what is shown in the header of each column as the description of rice. While the odd columns show results for the wives' answers, the even columns show results for the husbands' answers. OLS was used for the estimation. The same set of household controls as in Table 6 are included but not reported.