Married Couple's Rice Varietal Choice:

Evidence from in Eastern India

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1. Introduction

Increased crop productivity through the adoption of modern technologies (improved seeds, synthetic fertilizer, irrigation, and mechanization) is considered one of the greatest legacies of the Green Revolution in South and Southeast Asia (Tsusaka and Otsuka, 2013). The introduction of modern technologies has increased food security and reduced poverty in developing and emerging economies worldwide (de Graft-Johnson et al., 2014). Rice is one of the crops that benefited from genetic improvement and resulted in estimated economic gains between US$ 296 million-US$ 9.9 billion (Raitzer et al., 2015). In India alone, there are more than 900 modern rice varieties (1975-2010) and around 47 hybrid rice varieties[1] (1994-2010) were released by the government of India (DRD, 2020).

Rice plays a vital role in Indian agriculture not only as a major supplier of calories[2] in the Indian diet but also covers approximately 35% of the total area under food grains (GOI, 2015). Despite the rice varietal developments, there is noticeable slow productivity growth in food grains in recent decades, compared to the early decade of the Green Revolution (Khush, 1999). Eastern India[3] is one region that experienced slow rice productivity. Two possible reasons that may contribute to low growth - lack of desirable traits of high-yielding varieties (Hossain et al., 2003) and adverse effects of climatic conditions (e.g., drought, flood, submergence, salinity, toxicity, and nutrient deficiencies) are the common causes for slowing the productivity (Tsusaka and Otsuka, 2013). For example, Pandey et al. (2007) estimated that drought events between 1970 and

[1] Hybrid rice varieties (HRV) refer to all first-generation offspring of crossbred rice varieties between two genetically diverse parents resulting in higher yields (Barclay, 2007).
[2] Rice supplies 28% of calories to the Indian diet (IRRI, 2019).
[3] Eastern India is composed of the following states: Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, West Bengal, and Uttar Pradesh.

2000 resulted in an average loss in rice production of 5.4 million tonnes or $162 million. This low yield growth will substantially impact the region since rice farming is characterized by the dominance of fragmented and smaller holdings, lack of irrigation facilities, and frequent occurrence of adverse climatic conditions. Given the rice farming status in eastern India, this may trigger the continuing vicious circle of low input-low output agriculture (Pandey et al., 2012).

To reduce the variability in farm income and precarious livelihood, male heads of households have sought off-farm employment or dual employment to increase family income. The booming non-farming sectors (such as construction, service, manufacturing, and industrial) have pulled both hired labor and family labor out of the agricultural sector. The labor movement from agriculture has led to an increase in the daily nominal wage rate for various farm activities, including plowing, sowing, and rice transplanting[4]. A report by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) shows that the nominal wage rate increased 3.6 to 4.2 times during the 2004-2014 period (Bhattarai et al., 2014). The movement to non-rural sector was further enhanced by government programs like the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)[5] that have led to labor shortages in agricultural production.

However, low productivity affects household income structure and the gender roles within the households. Datta and Mishra (2011) and Maharjan et al. (2012) reveal that the Indian rice farmers' income sources have become more diversified in recent years, which has led to significant changes in gender roles within the households. Recall that in most societies, farming decisions (such as the

[4] During the 2004- 2014 period, the cultivation cost of major crops (paddy and wheat) increased at an annual rate of 10% due to the rise in labor costs. Labor costs account for up to 50% of the total production cost of paddy cultivation.
[5] Enacted as the National Rural Employment Guarantee Act of India (2005) is a public policy in India that pays people to seek employment. The wage rate is higher than the daily wages of agricultural workers.

selection of crops, technology, and labor) traditionally have been made by the male household heads, who represented the whole household (Orr et al., 2016). However, in the absence of male decision-makers, spouses are increasingly responsible for making farming-related decisions. The new responsibilities to women also pose significant constraints, particularly in accessing productive resources and services compared to their male counterparts. Thus, resulting in inappropriate farming decisions. Existing studies tend to rely on household heads' information in analyzing the adoption of technologies (Mehar et al., 2017; Quisumbing and Kumar, 2014). The characteristics of women who are not household heads are essential in understanding the decision-making processes within households (Doss, 2001; Orr et al., 2016).

Moreover, with the increased educational attainment of spouses, it is more likely today than in the past that farming-related decisions are made jointly. Joint decision-making is gaining significant traction in the literature (Ibrahim et al., 2011; Aregu et al., 2011; Damisa and Yohanna, 2007). To this end, studies investigating the adoption of technologies with a focus on male decision-makers may lead to biased estimates (Agarwal, 2013; Quisumbing and Pandolfelli, 2009). However, there is a paucity of studies on the married couple's participation in decision-making regarding farming-related activities, especially rice seed varieties in India.

Thus, the objective of this study is twofold. First, to investigate the factors affecting married couples' participation in the joint decision-making of rice varieties. Second, to assess the impact of the joint decision-making strategy on rice productivity. We use a nationally representative household-level survey data from India. Our study contributes to the literature in several ways. First, the study focuses on the factors why married couples chooses joint decision-making regarding the choice of rice varieties. Since this study is based on observational data, the decision-making strategy choices are not distributed randomly, making the two groups systematically different. The study employs endogenous switching regression (ESR) to account for selection bias and endogeneity (Pitt, 1983; Fuglie and Bosch, 1995; Alene and Manyong, 2007; Di Falco et al., 2011). Second, the impact of joint decision-making strategy on rice productivity is generated using the counterfactual estimation. Findings from this study will provide a clearer picture if the married couple's decision-making strategies is beneficial for smallholder households. Results will guide policymakers regarding implementing different agricultural development strategies for farming activities that would lead to the development of outreach materials appropriate for spouses and their involvement in farming to increase rice productivity in the region.

2. Women participation in farm decision-making

Women's participation in rice farming is often associated with their share in production labor. In eastern India, women provide labor in nurseries, transplanting, weeding, and harvesting, comprising at least 60% of total rice labor requirements (Pandey et al., 2010). However, it is not always guaranteed that women significantly influence decision-making regarding critical issues about farming and household matters. Behura et al. (2012) and Bagchi and Bool-Emerick (2012) found that while women in eastern India contribute substantial labor, the household's male head is still the one who makes decisions on which technology or agronomic practices to adopt, while women are responsible for decisions about the selling of rice production. However, in the absence of male decision-makers, spouses are increasingly responsible for making farming-related decisions. Most of the literature tends to rely on household heads' information to analyze the adoption behavior and exclude women who are not household heads. Focusing on the household head is a standard method used in most existing literature, particularly in the South Asian setting, due to its simplicity. However, with the changes in the sources of income to nonfarm rural sources among rice farming households, there is evidence in the changing roles within the household which result to a high participation of women in decision-making not only regarding household but also farming decisions (Paris et al., 2005; Paris et al., 2010).

Most of the studies that examine intrahousehold decision-making are from sub-Saharan Africa and Latin America. There is little evidence on the joint decision-making process between married couples in determining rice varietal choice in India. Though the Indian government has implemented several programs to improve women's status, it is still necessary to know women's involvement, particularly in making agricultural decisions. Thus, investigating who are decision-makers constraints is an effective way of understanding technology adoption by households (Deerie, 2005).

3. Conceptual Framework and Econometric Specification

The rice variety that the farmer adopts is an important factor in increasing rice productivity. A Probit model is used to estimate the factors affecting the decision strategy. The decision strategy will depend if the couple has joint participates in selecting rice variety selection or the operator (husband) is the decision-maker. Since the survey queried married couples on seven farm production-related decisions [6], we only consider the joint decision-making regarding the selection of rice seed varieties. Each of the couples were asked about their involvement in decision-making. Only couples who answered the question are included in the analysis. We categorized decision-making into the following categories: (1) husband only decides in the presence of the wife; (2) wife only decides in the presence of the husband; (3) both husband and wife participated in determining the choice of a rice variety to be used in the coming season. In our data category, 2 is non-existent. Thus, the joint decision-making regarding rice variety takes a value of 1 when both husbands and spouses choose the rice variety and 0 if the husband solely decides the rice variety.

[6] We use the operator interchangeably with husband and spouse as a wife.

Several factors are included in estimating the Probit model in which the data description is presented in Appendix Table A1. The choice of decision-making strategy follows a random utility maximization framework where the latent variable J_i^*, describes the i^{th} household decision strategy on whether the couple jointly participate or only the husband solely decides the rice variety. The latent variable, J_i^*, captures the expected benefits that household i receives by jointly participating and can be determined by the observed attributes X, and unobserved characteristics, ε and expressed as:

$$J_i^* = \alpha X_i + \mu_i \qquad with \;\; J_i = \begin{cases} 1 \; if \; J_i^* > 0 \\ 0 \;\; Otherwise \end{cases} \qquad (1)$$

The household i will choose a joint participation strategy in deciding rice variety if $J_i^* > 0$, or 0 otherwise. The error term is μ_i with mean zero and variance σ^2.

The endogenous switching regression (ESR) is used to analyze the impact of the couple's joint decision-making strategy on rice yield. This method was developed by Lee (1978) and later applied in agriculture by Pitt (1983). Since then, this method was used in several empirical studies (Fuglie and Bosch, 1995; Alene and Manyong, 2006; Di Falco et al., 2011). Separate outcome equations are specified if the couple has joint decision-making and husband sole decision-making as:

$$Y_{1i} = \alpha_1 Z_{1i} + \varepsilon_{1i} \qquad if \;\; J_i = 1 \qquad (2)$$

$$Y_{2i} = \alpha_2 Z_{2i} + \varepsilon_{2i} \qquad if \;\; J_i = 0 \qquad (3)$$

where Y_i is the outcome variable (yield) of the i^{th} household when using couple's participation strategy (1= joint decision-making; 0= husband sole decision-making), Z is a vector of explanatory variables (farmer and plot characteristics), and α are parameters to be estimated. The outcome variable Y_{1i} when the couple jointly decide the rice variety while Y_{2i} is observed when the husband solely decide the rice variety. In using OLS, the estimates α_1 and α_2 in Equations 1 and 2 will suffer selection bias since the choice of strategy is endogenous. This implies that error terms in Equation 2 and 3 will have non-zero expected value (Lee, 1978; Madala, 1983). The error terms in Probit model (first stage), 1, and 2 are assumed to have tri-variate normal distribution with mean zero and non-singular covariance matrix which given as

$$Cov\ (\varepsilon_{1i}, \varepsilon_{2i}, \mu_i) = \begin{bmatrix} \sigma_{\varepsilon 2}^2 & . & \sigma_{\varepsilon 2\mu} \\ . & \sigma_{\varepsilon 1}^2 & \sigma_{\varepsilon 1\mu} \\ . & . & \sigma_{\mu}^2 \end{bmatrix} \tag{4}$$

where σ_{μ}^2 is the variance of error term of the selection equation; $\sigma_{\varepsilon 1}^2$and $\sigma_{\varepsilon 2}^2$ are variances of the error terms of the outcome functions in 1 and 2; $\sigma_{\varepsilon 1\mu}$ and $\sigma_{\varepsilon 2\mu}$are the covariance of μ_i, ε_{1i}, and ε_{2i}. According to Madala (1983), since Y_{1i} and Y_{2i} are not simultaneously observed, the covariance between μ_{1i} and μ_{2i} are not defined. Based on the given assumptions, the expected values of ε_{1i} and ε_{2i} conditional on sample selection are non-zero:

$$E[\varepsilon_{1i} | J_i = 1] = \sigma_{\varepsilon 1\mu} \frac{\phi\ (\alpha X_i)}{\Phi(\alpha X_i)} = \sigma_{\varepsilon 1\mu} \lambda_{1i} \tag{5}$$

$$E[\varepsilon_{2i} | J_i = 0] = \sigma_{\varepsilon 2\mu} \frac{\phi\ (\alpha X_i)}{1-\Phi(\alpha X_i)} = \sigma_{\varepsilon 2\mu} \lambda_{2i} \tag{6}$$

where ϕ is a standard normal probability density function and Φ standard normal cumulative functions. The ratio between ϕ and Φ evaluated at αX_i is the inverse Mills ratio (λ_{1i} and λ_{2i} in Equations 5 and 6). Substituting $\lambda_{1i} = \frac{\phi\ (\alpha X_i)}{\Phi(\alpha X_i)}$ and $\lambda_{2i} = \frac{\phi\ (\alpha X_i)}{1-\Phi(\alpha X_i)}$ in Equations 2 and 3, then the outcome equations can be expressed as

$$Y_{1i} = \alpha_1 Z_{1i} + \sigma_{\varepsilon 1\mu} \lambda_{1i} + \varepsilon_{1i} \qquad if\ \ J_i = 1 \tag{7}$$

$$Y_{2i} = \alpha_2 Z_{2i} + \sigma_{\varepsilon 2\mu} \lambda_{2i} + \varepsilon_{2i} \qquad if\ \ J_i = 0 \tag{8}$$

where ε_{1i} and ε_{2i} have zero conditional means. If the estimated $\sigma_{\varepsilon 1\mu}$ and $\sigma_{\varepsilon 2\mu}$ are statistically significant, then we can reject the null hypothesis that there is an absence of sample selectivity bias which suggests that there is an evidence of endogenous switching. Since the generated regressors arising from two-stage estimation often results to heteroscedastic error terms ε_{1i} and ε_{2i} , OLS estimates for Equations 7 and 8 will be inefficient (Antle 1983; Khonje et al., 2019). An efficient method in estimating endogenous switching models is using the full information maximum likelihood ([FIML] Alene and Manyong, 2006; Di Falco et al., 2011; Loskin and Sajaia, 2004). The FIML simultaneously estimates the selection equation and the outcome equation in order to have consistent standard errors. The FMIL estimates are obtained using *movestay* command in STATA (Lokshin and Sajaia, 2004). On the other hand, for the model to be identified, exclusion restrictions need to be included. Thus, at least one variable in X which is not included Z.

The choice of instruments is considered valid if they can influence the selection (joint decision-making strategy) equation but not the outcome (yield). The instruments include access to credit, differences of the couple's age (husband-wife); and distance to the nearest market. Access to credit among women has been proven to benefit women by increasing household assets and savings (Amin et al., 1998). Thus, resulting in the development of her self-confidence and recognition of her role in the household (Sharma and Varna, 2008). Kabeer (1998) found that access to credit among households in Bangladesh impacted women's participation in the household decision-making processes. Though not all credit loans were allocated for the improvement in production. Chavas et al. (2005) found that Gambian farmers who availed loans from *Osusu*[7] often use the funds for non-farming related activities and only few were used to purchase inputs and equipment. In this case, only few have existing agricultural loans and most of the loans were used to for medical and school expenses. Thus, this can be use as instrument since may influence participation in decision-making but may not have a direct link to rice productivity.

[7] *Osusu* is local rotating saving and credit association in Gambia (Chavas et al., 2005).

The second instrument, the difference in the couples' age, affects how decisions are made—joint or solo. This represents the power relation between the couple. For instance, Kantor (2003) examines Indian female participants under home-based garment sector found that a couple with a large age difference would place more power to the husband. In addition, Schneebaum and Mader (2013) found that smaller age differences initiate a joint decision-making process among married couples rather than one person making critical decisions. The age difference may affect women's participation in deciding rice variety but not necessarily the outcome variables (yield).

Lastly, the distance to the nearest market could be a barrier for women to participate in selecting a rice variety. For example, Nakazi et al. (2017), found that women in Uganda who spend more time walking to the market tend to participate minimally in bean production. Additionally, cultural norms prohibit women from riding a bicycle (major transportation) that prevents accessing the market. In eastern India, few women own assets used for transportation (e.g., bicycle, motorbike, and vehicle). Thus, if the spouse (woman) is going to spend time traveling to the market, it is less likely that the spouse would participate in the farming decision-making. Any additional time for the spouse would be spent in household production (cooking, child-rearing, and feeding and caring for livestock). We hypothesize that the farther the market location, the less likely that a woman participates in decision-making. The validity of the instruments is presented in Appendix Table A2. Results confirm that the instrumental variables jointly affect participation in joint-decision making or husband solely decides ($\chi^2 = 39.88; p = 0.000$) but do not affect the outcome variable (yield).

The above results are used to estimate the counterfactuals and average adoption effects using cross-sectional. The conditionally expected outcome (yield) was computed to generate the average treatment effect on treated (ATT) and average treatment effect on untreated (ATU) with joint decision-making (treated group) and husband decision-making (base group) in actual and counterfactual scenarios (Di Falco et al., 2011; Shiferaw et al., 2014). The conditional expectations for each outcome expectations are the following:

Household with joint decision-making (adopters) (actual):

$$E(Y_{1i}|J=1)=\alpha_1 Z_{1i}+\sigma_{\varepsilon 1\mu}\lambda_{1i} \quad (9)$$

Households with husband (or male operator) decision-making (non-adopters) (actual):

$$E(Y_{2i}|J=0)=\alpha_2 Z_{2i}+\sigma_{\varepsilon 2\mu}\lambda_{2i} \quad (10)$$

Households with husband decision-maker that decided to make decisions jointly (counterfactual):

$$E(Y_{2i}|J=1)=\alpha_2 Z_{1i}+\sigma_{\varepsilon 2\mu}\lambda_{1i} \quad (11)$$

A household with joint decision-makers that decided for a husband to make decisions regarding the choice of rice varieties (counterfactual):

$$E(Y_{1i}|J=0)=\alpha_1 Z_{2i}+\sigma_{\varepsilon 1\mu}\lambda_{2i} \quad (12)$$

Recall that the ATT estimates the effect of participation strategy on the actual yield of households that make decisions jointly. Specifically, it is the difference between Eq. (10) and Eq. (12):

$$ATT_{JD}=E(Y_{1i}|J=1)-E(Y_{2i}|J=1)=Z_{1i}(\alpha_2-\alpha_1)+\lambda_{1i}(\sigma_{\varepsilon 1\mu}-\sigma_{\varepsilon 2\mu} \quad (13)$$

The impact on yield for husband decision-makers had they jointly made decisions is estimated using the average treatment effect on the untreated (ATU) is the difference between Eq. (12) and Eq. (10) specifically:

$$ATU_{MD}=E(Y_{1i}|J=0)-E(Y_{2i}|J=0)=Z_{2i}(\alpha_1-\alpha_2)+\lambda_{2i}(\sigma_{\varepsilon 1\mu}-\sigma_{\varepsilon 2\mu}) \quad (14)$$

The treatment effects can be further identified through heterogeneity effects (Carter and Milon, 2005). A household with joint decision-makers (actual) may have a higher outcome (yield) than those households with husband decision-makers regardless of their strategic decision but due to other unobservable characteristics. This effect is termed as the “effect base heterogeneity” (BH) and is defined as:

$$BH_{JD} = E(Y_{1i}|J = 1) - E(Y_{1i}|J = 0) \quad (15)$$

$$BH_{MD} = E(Y_{2i}|J = 1) - E(Y_{2i}|J = 0) \quad (16)$$

Therefore, the BH for a household with a joint decision-maker is the difference between Eq. (9) and Eq. (11), while BH for husband (male) decision-maker is the difference between Eq. (10) and Eq. (12).

3. Survey Data

The study focuses rice farms in eastern India. A rice-producing household is defined as a household that produced rice during the past 12 months. The survey targeted the rural population of eastern India by randomly selecting rural areas based on the 2011 Census of India. Four states in the eastern part of India are considered in the study: eastern Uttar Pradesh, Odisha, Bihar, and West Bengal (Figure 1). A multi-stage sampling technique was adopted in selecting the respondents. In the first stage, the number of districts was randomly selected in each state using the Census of 2011[8]. On the other hand, the second stage involves determining the number of villages based on the proportion of each state’s total rice area, keeping the total number of villages at 720. Among the selected villages, household samples are randomly selected using the household census village data. A total of 101 districts and 2,471 rice-producing households are included in the survey (Table 1). All respondents are considered as male-headed households.

A structured questionnaire was used to interview two household members, namely the husband and wife. Only families that reported with husband and wife are included in the study. Information regarding rice production and farm-related decision-making were collected from

[8] This data set contains information about all the districts, villages, towns, and cities in urban and rural India.

husbands, and information regarding livestock, household assets, and decision regarding farming were also collected from the spouse. In order to elicit unbiased responses, the survey employed male and female enumerators in the interview process. The male enumerator interviewed the operator while the female enumerator interviewed the spouse. The study focused on information regarding the 2015 wet season, the primary rice-growing season in eastern India. Table 2 provides definitions and summary statistics of the variables used in the analysis. Due to space and brevity, the description of each variable is provided in Appendix Table A1.

4. Results and Discussion

The results of the ESR model are presented in Appendix tables A3. Due to brevity and space constraints, we only discuss the results of the impact model. Table 3 shows the expected quantity of rice produced (kg/ha) under actual and counterfactual conditions. For instance, the cells (A) and (B) represent the expected rice yields (kg/ha) observed in the sample. Cells (C) and (D) represent the expected rice yields (kg/ha) in the counterfactual case. Since there is no selection effect[9] for husband as decision-maker, we only focus on the expected rice yield of the joint decision-maker and its counterfactual. In the case of "all rice varieties," results show that the expected rice yield of households under joint decision-making was about 844 kg/ha and 1,049 kg/ha for husband sole decision-making households. However, this simple comparison could be misleading in attributing the different values of expected yields for both groups to joint decision-making. Columns 5 and 6 of Table 3 report the treatment effects of participation in joint decision-making about variety selection. In the counterfactual case (C), joint decision-making households would have produced

[9] The estimated correlation coefficient terms (ρ_i) are presented in Appendix Table 3. Results show that there is positive and significant self-selection only in joint decision-making participation, which suggests that observed and unobserved factors affect the joint decision-making strategy choice and rice yield. On the other hand, correlation coefficient for husband decision-maker is not statistically significant, which means that households under joint decision-makers and husband decision-makers will have the same rice yield using the old decision-making strategy.

less (about 125 kg/ha, or 17%) if they had not adopted a joint decision-making strategy. Similarly, in the counterfactual case (D) that rice farmers that did not adopt joint decision-making adopted (or male decision-maker households), they would have produced about 81% less if they had adopted joint decision-making.

In terms of adopted rice varieties, Table 3 shows that yield advantage differs depending on rice varieties. Most rice smallholder households show a yield disadvantage when adopting joint decision-making in all rice variety types except MRV2 (1977-1985). In other words, joint decision-making on rice variety selection results in a positive impact on rice yields for MRV2 generation of rice variety. Results in Table 3 (Panel 4) shows that the expected rice yield of households under joint decision-making was about 827 kg/ha and 509 kg/ha for husband sole decision-making households. In the counterfactual case, joint decision-making households would have produced less (about 317kg/ha, or 62%) if they had not adopted a joint decision-making strategy. Similarly, in the counterfactual case (D) that rice farmers that did not adopt joint decision-making adopted (or husband decision-maker households), they would have produced about 71% less if they had adopted joint decision-making. This an exciting finding. In the study by Paris et al. (2008), they found that male and female farmers in eastern Uttar Pradesh have sets of preferred traits in choosing a particular variety based on varying factors (e.g. environmental, socio-economic and cultural, and gender roles). Results show that men prefer varieties based on agronomical traits (e.g., tolerance to submergence, resistant to pest, and responsive to fertilizer) while women prefer more on the intrinsic qualities of varieties (e.g., taste, cooking qualities, and shape of grain). However, both men and women farmers prefer high yielding, good taste and aroma, and postharvest quality. One of the popular mega-variety is Swarna, covers almost 30% of the total rice area in eastern India in 2015 (Tsusaka et al., 2015), belongs to MRV2 category. The high productivity and consumer preference may be driving factors. MRV2 contains attributes that are attractive to both farmers and spouses. For instance, studies (Tsusaka et al., 2015; Mehar et al., 2017) have shown that most of the mega-varieties are preferred by farmers due to its higher yield and good eating quality. A sensory evaluation analysis done by Champagne et al. (2010) shows that Swarna has a rough after cooking surface that is suited with the thick sauce that is prominent in Indian cuisine. Thus, it is no surprise that the study found positive effects of joint decision-making on rice yields in MRV2—rice varieties that were bred for grain yields and consumer preference attributes.

Finally, results in Table 3 (see, for example, rows "all varieties" category) reveal transitional heterogeneity effects in adopting joint decision-making strategy. Findings indicate that smallholder rice producers with joint decision-makers produced significantly less than households in the counterfactual case (c). The result highlights some important heterogeneity sources that make the household under joint decision-makers worse off producing rice regardless of the variety. However, in the case of MRV2, results in Table 3 show that joint decision-maker farming households produced significantly more rice than households in the counterfactual case (c). Thus, in the MRV2 case, findings show some essential heterogeneity sources that make the rice farming smallholders under joint decision-makers better producers than their counterparts.

5. Conclusions and Implications

The objectives of this study were to analyze the factors affecting the joint decision-making in the selection of rice varieties and to investigate the impact of joint decision-making on rice yields. The study used ESR method to assess the objectives. The choice of rice varieties is critical and often is assumed to be the male household head's task. However, with the household head frequently absent from the farm and engaging in off-farm work or dual employment, women are increasingly taking charge of jointly participating in decision-making related farming activities.

In general, this study showed that farming households under joint decision-making tend to have higher rice yields than their counterparts. Farmers who adopted joint decision-making have some attributes, for example, extension information and skills, that makes them more productive with implementing joint decision-making strategy. Further, the joint decision-making strategy has positively impacted the rice yield of MRV2 (rice varieties released between 1977-85). Rice farmers who adopted joint decision-making tend to produce more MRV2 rice variety than farmers who did not adopt joint decision-making strategy in the counterfactual. Adoption of MRV2 rice variety among joint decision-making households increases rice yield due to familiarity with the variety.

It is a preconceived notion that women's participation in rice farming is limited only to farm labor. Since joint decision-making households perform well in producing MRV2, which is commonly composed of mega varieties like Swarna, increasing awareness about the flood-tolerant version of Swarna (Swarna-Sub1)[10] should be targeted in this group. Studies (Sarkar et al. 2006; Neeraja et al. 2007) show no significant difference between Swarna and Swarna-Sub1 in agronomical, grain quality, taste, grain length, and grain yield under normal conditions.

There are two ways of increasing a spouse's participation in rice production activities. First is the involvement in varietal development. One way of verifying newly developed rice variety lines' acceptability is through the Participatory Varietal Selection (PVS). In this method, men and their spouses can participate in the initial screening before varieties are released (Paris et al., 2011). Usually, participants are selected based on the proportion of the male-headed and female-headed

[10] For the past decades, scientists at IRRI have developed Swarna-Sub1, a flood-tolerant rice, by introgression SUB1 QTL to mega-varieties (Swarna) through marker-assisted crossing (Neeraja et al., 2007; Septiningsih et al., 2009).

in the area who are the main responsible for making farming decisions in the household. Since our sample shows that eastern India is mainly composed of male-headed households, there is a possibility that women can also participate in choosing rice varieties. For example, Manzanilla et al. (2013) show that female farmers are as knowledgeable as the male farmers in evaluating the lines/variety of visible characteristics. To incorporate women participation, PVS strategies for submergence tolerant varieties in Southeast Asia, researchers involved the participating households' wife by selecting only a sub-sample of the farmer participants (Paris et al., 2011). In India, where most are male-headed households, it is interesting to explore the individual and the couple's preference when selecting new variety lines.

Second, targeting a woman's self-help group (WSHG) is one of the most natural pathways in reaching spouses. WSHGs serve as channels in disseminating information, particularly in areas that are hard for extension workers to enter. Since MRVs are composed of specific agronomical characteristics (e.g., potential yield, grain size, resistance to pest and diseases), information can be disseminated through farmer's field school or demonstration plots. The demonstration trials would enable women to be exposed to new rice varieties, labor-saving technologies, and proper farm management practices that would lead to higher adoption rates. This study examined the impact of joint decision-making on rice yields, but it has a caveat. The study used cross-sectional data for one rice season, suggesting that the findings are applicable only on a short-run basis and should be interpreted accordingly. To capture long-term adoption impacts, one needs to investigate this issue with panel data. The degree of the spouse's control within the joint decision-making framework is worth exploring in future studies.

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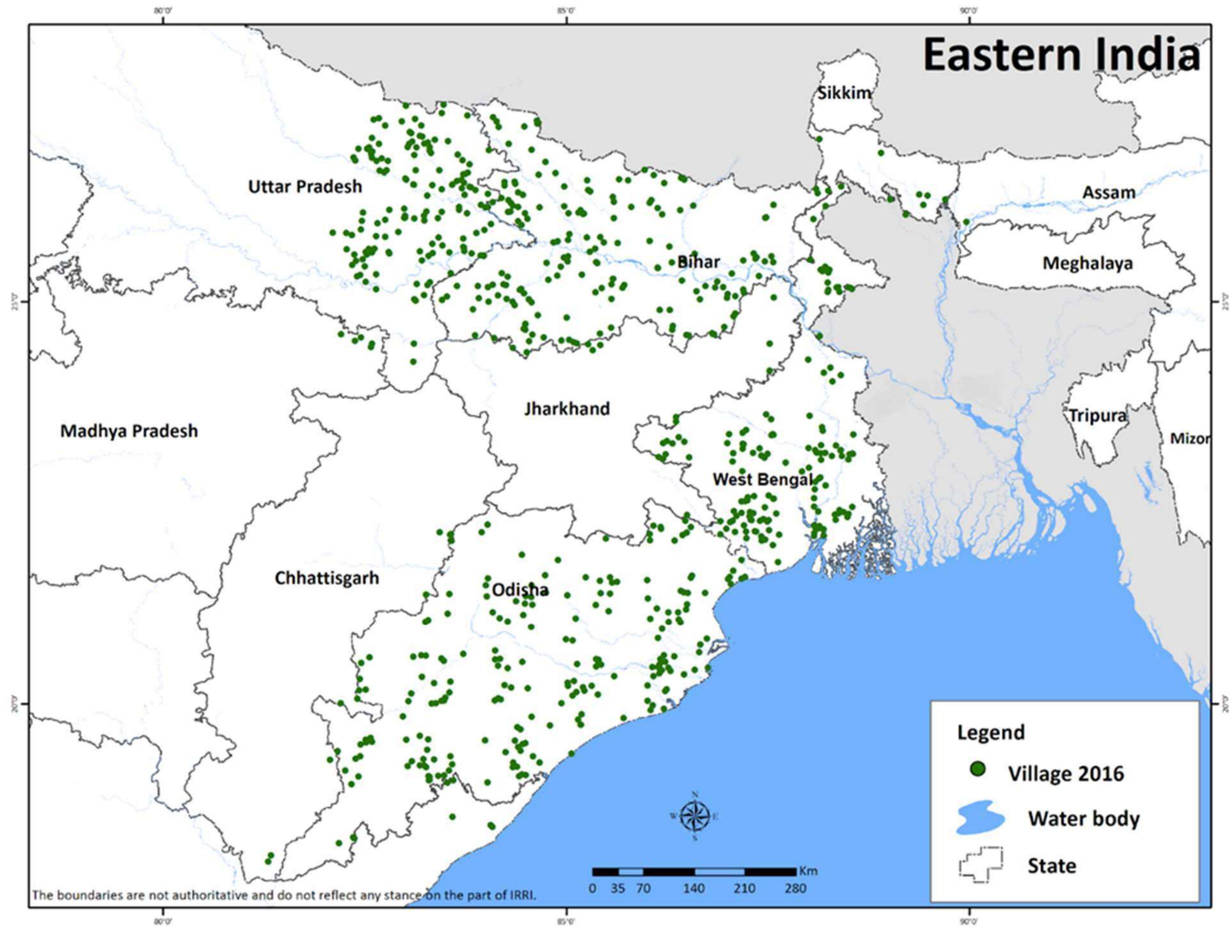

Figure 1. Sample sites in eastern India

Table 1. Sample districts and smallholder households in eastern India, 2016.

State	Number of districts	Number of households
Eastern Uttar Pradesh	37	617
Odisha	30	827
Bihar	16	413
West Bengal	18	614
Total	101	2,471

Table 2. Summary statistics of the variables used in the rice variety selection model, Eastern India, 2016.

	Joint decision-maker[1] (n=1,197)	Male decision-maker (n=1,274)	All households (n=2,471)	Difference	
Dependent variables					
Yield (kg/ha)	1,545.608	1,679.701	1,614.744	$t =$	134.093***
	(10.008)	(1,547.090)	(1,591.461)		
Explanatory variables					
Age of the respondent[2] (years), log	47.867	48.467	48.176	$t =$	0.600
	(11.619)	(11.938)	(11.786)		
Years of education respondent (years), log	5.236	6.119	5.691	$t =$	0.883***
	(4.228)	(4.779)	(4.541)		
Total number household members, log	3.515	3.872	3.699	$t =$	0.357***
	(1.484)	(1.750)	(1.636)		
Scheduled caste/tribe[3] (=1 if yes; 0 otherwise)	0.355	0.221	0.286	$\chi^2 =$	54.697***
	(0.479)	(0.415)	(0.452)		
Other backward caste[4] (=1 if yes; 0 otherwise)	0.426	0.396	0.410	$\chi^2 =$	2.367
	(0.495)	(0.489)	(0.492)		
General caste (=1 if yes; 0 otherwise)	0.219	0.384	0.304	$\chi^2 =$	79.373***
	(0.414)	(0.487)	(0.460)		
Farm location, Bihar state (=1 if yes; 0 otherwise)	0.121	0.370	0.250	$\chi^2 =$	204.815
	(0.326)	(0.483)	(0.433)		
Farm location, Odisha state (=1 if yes; 0 otherwise)	0.577	0.107	0.335	$\chi^2 =$	613.616***
	(0.494)	(0.309)	(0.472)		
Farm location, West Bengal state (=1 if yes; 0 otherwise)	0.257	0.240	0.248	$\chi^2 =$	0.969
	(0.437)	(0.427)	(0.432)		
Farm location, Uttar Pradesh state (=1 if yes; 0 otherwise)	0.283	0.044	0.167	$\chi^2 =$	251.755***
	(0.450)	(0.206)	(0.373)		
With off-farm employment[5] (=1 if yes; 0 otherwise)	1.224	0.914	1.064	$t =$	-0.309***
	(0.995)	(0.915)	(0.947)		
Share of assets owned by women[6]	22.200	25.755	24.033	$t =$	3.555***

	(25.092)	(27.552)	(26.443)		
With migrants[7] (=1 if yes; 0 otherwise)	0.165	0.191	0.178	$\chi^2 =$	2.987
	(0.462)	(0.499)	(0.481)		
Experienced flood/drought 2015 (=1 if yes; 0 otherwise)	0.508	0.632	0.572	$\chi^2 =$	38.714***
	(0.500)	(0.482)	(0.495)		
Uses machine (1=yes; 0 otherwise)	0.795	0.953	0.877	$\chi^2 =$	141.643***
	(0.404)	(0.212)	(0.329)		
Uses pesticide (1=yes; 0 otherwise)	0.444	0.503	0.474	$\chi^2 =$	8.772***
	(0.497)	(0.500)	(0.499)		
Transplanted rice (=1 if yes; 0 otherwise)	0.869	0.966	0.919	$\chi^2 =$	78.721***
	(0.338)	(0.181)	(0.273)		
Total number of rice plots	1.490	1.301	1.393	t=	-0.190***
	(0.778)	(0.625)	(0.709)		
Share of irrigated area (%)	40.421	74.520	58.001	$t =$	34.099***
	(48.095)	(41.012)	(47.723)		
Proportion of medium land	0.522	0.537	0.530	$t =$	0.015
	(0.488)	(0.492)	(0.490)		
Seeds usage (kg/ha)	40.490	36.069	38.211	$t =$	-4.421***
	(38.681)	(38.689)	(38.740)		
Total fertilizer (kg/ha)[8]	248.419	294.102	271.972	$t =$	45.684***
	(164.251)	(183.184)	(175.725)		
Family labor (person-days/ha) [9]	30.558	30.981	30.776	$t =$	0.423
	(33.704)	(41.224)	(37.762)		
Hired labor (person-days/ha)	16.614	15.631	16.107	$t =$	-0.982
	(20.517)	(21.252)	(20.901)		
Contract labor (person-days/ha)	10.828	17.981	14.516	$t =$	7.154***
	(23.677)	(26.899)	(25.635)		
Rice varieties					
Traditional varieties (TV)	0.129	0.130	0.130	$t =$	0.015
	(0.335)	(0.337)	(0.336)		
MRV1 (before 1977) (=1 if yes; 0 otherwise)	0.077	0.126	0.102	$t =$	16.002***
	(0.266)	(0.332)	(0.303)		
MRV2 (1977-85) (=1 if yes; 0 otherwise)	0.236	0.219	0.227	$t =$	0.968

	(0.425)	(0.414)	(0.419)	
MRV3 (1986-1995) (=1 if yes; 0 otherwise)	0.077	0.113	0.096	$t =$ 9.347***
	(0.266)	(0.317)	(0.294)	
MRV4(1996 or later) (=1 if yes; 0 otherwise)	0.104	0.061	0.082	$t =$ 15.277***
	(0.306)	(0.240)	(0.275)	
MRV5 (hybrid rice 1995 and later) (=1 if yes; 0 otherwise)	0.028	0.120	0.075	$t =$ 75.903***
	(0.164)	(0.325)	(0.264)	
MRV6 (mixed generation) (=1 if yes; 0 otherwise)	0.350	0.231	0.289	$t =$ 42.767***
	(0.477)	(0.421)	(0.453)	
Instrumental variables				
With credit[10]	0.297	0.203	0.248	$t =$ -0.094***
	(0.457)	(0.402)	(0.432)	
(for farm credit)	0.183	0.108	0.145	$t =$ -0.075***
	(0.011)	(0.009)	(0.352)	
Difference age (Husband-wife)	6.045	5.555	5.792	$t =$ -0.490***
	(3.420)	(3.802)	(3.630)	
Distance to nearest market (km), log	4.403	4.117	4.255	$t =$ -0.286
	(4.341)	(4.060)	(4.200)	

Standard deviations in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

[1] Husband and spouse making farming-related decisions jointly.

[2] Respondents are husband.

[3] Includes designated groups of historically disadvantaged indigenous people in India. The terms are recognized in the Constitution of India (GoI), and the various groups are designated in one of the categories. Since independence, the scheduled castes and scheduled tribes were given reservation status, guaranteeing political representation.

[4] Includes castes that are socially and educationally discriminated.

[5] At least one of the household members with off-farm labor like salaried job, business, and works in service industry.

[6] Share productive assets solely owned by women.

[7] At least of one the member is a migrant.

[8] Total chemical fertilizer used in rice production: NPK- nitrogen, phosphorus and potassium (15-15-15); DAP - diammonium phosphate (18-44-0); and Urea (46-0-0) (http:\www.yara.com).

[9] This includes family labor, hired labor, and contract labor. Person-days/ha is same as person-days/ ha in which 6 hours =1 day.

[11] Credit are for farm and nonfarm purposes.

Table 3. Average treatment effect on treated/untreated and heterogeneity effects for rice yield (kg/ha), by rice variety.

Rice seed variety/ generation		Joint decision-making yield (kg/ ha)	Male solely deciding yield (kg/ ha)	ATE/ATU	
				Change	%
All Varieties	Joint	843.96[A]	718.56[C]	125.40***	17.45
		(21.97)	(15.37)	(26.82)	
	Male solely	196.70[D]	1,049.24[B]	-852.54***	-81.25
		(4.87)	(21.29)	(21.84)	
	Heterogeneity	647.26***	-330.68***	977.94***	
		21.89	26.54	27.98	
Local varieties	Joint	767.82	603.33	164.49***	27.26
		(50.89)	(23.10)	(55.88)	
	Male solely	218.40	839.63	-621.22***	-73.99
		(14.75)	(34.18)	(37.22)	
	Heterogeneity	549.42***	-236.30***	785.72***	
		(51.34)	(41.89)	(54.68)	
MRV1 (before 1977)	Joint	581.24	852.12	-270.88***	-31.79
		(70.34)	(44.16)	(83.05)	
	Male solely	149.04	1179.56	-1,030.52***	-87.36
		(11.81)	(47.42)	(48.87)	
	Heterogeneity	149.04***	1,179.56***	-1,030.52***	
		(11.81)	(47.42)	(48.87)	
MRV2 (1977-85)	Joint	826.56	509.10	317.45***	62.36
		(36.31)	(18.15)	(40.60)	
	Male solely	175.34	599.51	-424.17***	-70.75
		(8.73)	(19.94)	(21.77)	
	Heterogeneity	651.21	-90.41	741.62***	
		(37.53)	(26.95)	(39.71)	
MRV3 (1986-1995)	Joint	1,013.84	757.71	256.13***	33.80
		(86.08)	(50.99)	(100.04)	
	Male solely	191.17	871.88	-680.71***	-78.07
		(11.55)	(52.88)	(54.13)	
	Heterogeneity	822.67***	-114.18***	936.84***	
		(70.22)	(77.72)	(85.56)	
MRV4 (1996 or later)	Joint	269.15	270.99	-1.84	-0.68
		(17.21)	(13.99)	(22.18)	
	Male solely	72.54	461.83	-389.28***	-84.29
		(9.43)	(30.30)	(31.74)	
	Heterogeneity	196.60***	-190.84***	387.44***	
		23.04	29.76	31.26	
MRV5 (hybrid rice 1995 and later)	Joint	1,246.33	1,149.91	96.42	8.39
		(108.47)	(152.97)	(187.52)	
	Male solely	204.00	1,920.29	-1,716.28***	-89.38

		(5.70)	(75.12)	(75.34)	
	Heterogeneity	1,042.32***	-770.38***	1,812.71***	
		(51.37)	(176.70)	(181.09)	
MRV6 (mixed generation)	Joint	1,043.82	963.51	80.31	8.34
		(43.54)	(30.33)	(53.06)	
	Male solely	262.49	1,312.86	-1,050.37***	-80.01
		(13.64)	(46.53)	(48.49)	
	Heterogeneity	781.33	-349.35	1,130.68	
		(53.22)	(53.19)	(55.13)	

Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: [A] and [B] represents expected yield (kg/ha) observed in the sample.
[C] and [D] represents expected yield (kg/ha) in the counterfactual case.
Conversion: 1 tonne=1000 kg

Appendix

Table A1. Variable definition used in the analysis.

Variables	Definition
Operator	The term operator and husband are interchangeably used in the study
Age (years)	The age of husband (years)
Education level (years)	The years of education of the husband (years)
Difference of years of age and education of the husband and wife	This the difference between the husband and wife age/education.
Household size	Number of adults in the house (16 years and above).
Joint decision-making	The participation of men and women: (1) husband and wife jointly participate in deciding the rice variety; (0) men solely decides the rice variety in the presence of the wife .
Share of productive assets solely owned by women	Share of productive assets which solely owned by women. The productive assets include: animals, farm equipment, small and large durables (e.g. TV, refrigerator, and radio).
Caste	These are designated groups of historically marginalized indigenous people in India. The terms are recognized in the Constitution of India (GoI), and the various groups are designated in one of the categories. Since independence, the scheduled castes and scheduled tribes were given reservation status, guaranteeing political representation.
With off-farm employment	At least one of the household members with off-farm labor like salaried job, business, and works in service industry.
With migrant	At least of one the member is a migrant
Distance (km)	Distance to the nearest market (km)
With credit	Household loans that were availed in the past 24 months for farm and nonfarm purposes.
Share of irrigated area	Share of irrigated rice area to the total rice area.
Proportion of mediumland	This is the proportion of area that a farmer considered to be a mediumland to the total rice area.
Experienced flood/drought 2015 (1 = yes, 0 otherwise)	This indicates if the farmer experienced flood, drought, or both in cropping the year 2015
Seeds use (kg/ha)	Seeds use (kg/ha).
Fertilizer use (kg/ha)	Total chemical fertilizer used in rice production: NPK- nitrogen, phosphorus and

	potassium (15-15-15); DAP - diammonium phosphate (18-44-0); and Urea (46-0-0).
Total plots	Total plots the household is currently cultivating.
Labor	Labor use can be classified as hired labor (person-days/ha); family labor (person-days/ha); and contract labor (person-days/ha). 1 day = 6 hours

Table A2. Parameter estimates-test on the validity of selection estimates.

Variable	Joint decision-making (1/0)	Total yield (kg/ha) with husband solely deciding
With credit	0.309***	0.014
	(0.058)	(0.106)
Difference age (Husband-wife)	0.022***	0.016
	(0.007)	(0.012)
Distance to nearest market (km), log	0.004	-0.032
	(0.012)	(0.022)
Constant	-0.250***	6.631***
	(0.051)	(0.084)
Wald test χ^2/ or F-stat	39.88***	1.590
Number of observations	2,471	1,274

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

Appendix Table A3. Parameter estimates of couples' decision-making strategies and yield (kg/ha) log, endogenous switching regression (ESR) approach

Variables	(1) OLS	(2) ESR	(3)	
			Regime 1 (Joint decision-making =1)	Regime 2 (Joint decision-making =0)
	Total yield (kg/ha), log	Joint decision-making (1/0)	Total yield (kg/ha), log among joint decision-making couple	Total yield (kg/ha), log among male decision-making couple
Joint decision-making (=1 if yes; 0 otherwise)[1]	-0.021			
	(0.075)			
Age of the respondent[2] (years), log	0.110	0.050	0.192	0.005
	(0.147)	(0.140)	(0.210)	(0.182)
Years of education respondent[2] (years), log	0.002	-0.002	0.001	0.003
	(0.005)	(0.004)	(0.007)	(0.006)
Total number household members, log	-0.263	-0.051	-0.133	-0.304***
	(0.092)	(0.089)	(0.142)	(0.115)
Scheduled caste/tribe[3] (=1 if yes; 0 otherwise)	-0.004	0.147	0.077	0.040
	(0.089)	(0.083)	(0.138)	(0.115)
Other backward caste[4] (=1 if yes; 0 otherwise)	-0.003	0.394	0.315	-0.076
	(0.082)	(0.079)	(0.137)	(0.105)
Farm location, Bihar state (=1 if yes; 0 otherwise)	0.576***	0.657***	-0.127***	0.696
	(0.119)	(0.121)	(0.283)	(0.138)
Farm location, Odisha state (=1 if yes; 0 otherwise)	-0.273	2.520***	1.177	-0.668***
	(0.158)	(0.152)	(0.379)	(0.311)
Farm location, West Bengal state (=1 if yes; 0 otherwise)	0.839***	1.651***	2.022***	0.424**
	(0.153)	(0.149)	(0.341)	(0.208)
With off-farm employment[5] (=1 if yes; 0 otherwise)	0.048	0.025	0.075	0.011
	(0.039)	(0.037)	(0.057)	(0.051)

Share of women ownership in productive assets[6]	-0.004***	0.005***	0.003	-0.007***
	(0.001)	(0.001)	(0.002)	(0.002)
With migrants[7] (=1 if yes; 0 otherwise)	0.164**	0.199	0.212**	0.159
	(0.068)	(0.067)	(0.108)	(0.086)
Experienced flood/drought 2015 (=1 if yes; 0 otherwise)	0.021	-0.167**	0.067	-0.108
	(0.070)	(0.066)	(0.106)	(0.091)
Uses machine (1=yes; 0 otherwise)	-0.126	-0.167	-0.269	-0.059
	(0.113)	(0.112)	(0.144)	(0.207)
Uses pesticide (1=yes; 0 otherwise)	0.176**	-0.159**	0.372	-0.086
	(0.069)	(0.067)	(0.109)	(0.090)
Share of irrigated area (%)	-0.0002	0.001	0.002	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Proportion of medium land	-0.234***	0.194	0.072	-0.433***
	(0.068)	(0.065)	(0.103)	(0.091)
Transplanted rice (=1 if yes; 0 otherwise)	-0.453***	0.208	-0.341**	-0.380
	(0.124)	(0.123)	(0.153)	(0.246)
Total number of rice plots	-0.098	-0.017	-0.063	-0.077
	(0.088)	(0.084)	(0.119)	(0.131)
Seeds usage (kg/ha), log	-0.173***	0.017	-0.087	-0.165**
	(0.055)	(0.053)	(0.086)	(0.069)
Total family labor (persons day/ha)[8], log	0.079***	-0.021	0.013	0.079***
	(0.016)	(0.016)	(0.031)	(0.018)
Total hired labor (persons day/ha)[8], log	-0.020***	0.001	-0.029**	-0.009
	(0.007)	(0.007)	(0.012)	(0.009)
Total contract labor (persons day/ha)[8], log	0.008	-0.023***	-0.020	0.020**
	(0.007)	(0.007)	(0.012)	(0.009)
Total fertilizer (kg/ha)[9], log	0.153**	-0.046	0.152	0.096
	(0.066)	(0.064)	(0.107)	(0.079)
MRV1 (before 1977) (=1 if yes; 0 otherwise)	0.333**	0.099	0.497**	0.357**
	(0.132)	(0.126)	(0.219)	(0.158)
MRV2 (1977-85) (=1 if yes; 0 otherwise)	-0.141	-0.143	-0.180	-0.239
	(0.106)	(0.136)	(0.163)	(0.136)
MRV3 (1986-1995) (=1 if yes; 0 otherwise)	0.536***	-0.086	0.467**	0.464***

	(0.135)	(0.150)	(0.214)	(0.166)
MRV4 (1996 or later) (=1 if yes; 0 otherwise)	-0.374***	-0.036	-0.571***	-0.388**
	(0.139)	(0.100)	(0.199)	(0.194)
MRV5 (hybrid rice 1995 and later) (=1 if yes; 0 otherwise)	0.804***	0.024	0.971***	0.566***
	(0.150)	(0.135)	(0.314)	(0.166)
MRV6 (mixed generation) (=1 if yes; 0 otherwise)	0.761	-0.100	0.448**	0.824***
	(0.156)	(0.149)	(0.224)	(0.217)
Constant	6.201***	-1.762***	3.286***	7.544***
	(0.644)	(0.624)	(1.015)	(0.825)
Instruments				
With credit[9] (=1 if yes; 0 otherwise)		0.227***		
		(0.064)		
Difference age (Husband-wife)		-0.019**		
		(0.009)		
Distance to nearest market (km), log		0.026***		
		(0.013)		
σ_i			1.635***	1.365
			(0.060)	(0.027)
ρ_i			0.535***	0.014
			(0.096)	(0.118)

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
[1] Husband and spouse making farming-related decisions jointly.
[2] Respondents are husband.
[3] Includes designated groups of historically disadvantaged indigenous people in India. The terms are recognized in the Constitution of India (GoI), and the various groups are designated in one of the categories. Since independence, the scheduled castes and scheduled tribes were given reservation status, guaranteeing political representation.
[4] Includes castes that are socially and educationally discriminated.
[5] At least one of the household members with off-farm labor like salaried job, business, and works in service industry.
[6] Share productive assets solely owned by women.
[7] At least of one the member is a migrant.
[8] This includes family labor, hired labor, and contract labor. Person-days/ha is same as person-days/ ha in which 6 hours =1 day.
[9] Total chemical fertilizer used in rice production: NPK- nitrogen, phosphorus and potassium (15-15-15); DAP - diammonium phosphate (18-44-0); and Urea (46-0-0) (http:\www.yara.com).