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ABSTRACT

Spouses' Access to Financial Services: Estimating Technological and Managerial Gaps in Production

The study investigates the effect of the spouse's access to financial services (credit or savings) through membership in a self-help group on adopting technology, technical efficiency, and managerial gaps. To estimate the empirical model, we use farm-level data from rice farming households in eastern India, propensity score matching method, and selectivity-corrected stochastic production frontier. Results show that families with access to financial services via a spouse's membership in self-help groups have slightly higher technical efficiency than their counterparts. Both technology and managerial gaps are higher for farms where spouses have access to financial services via SHGs than their counterparts. With access to financial services via spouses, rice farmers used more hired labor, about 1.3 person-days/ha for crop establishment. Thus, women joining self-help groups can increase farm productivity, and extension agents should also focus on spouses and their role in farming decision-making, not just financial management.

JEL Classification: C21, Q12, Q16, Q55, R58

Keywords: self-help group, PSM, selection-correction SPF, production efficiency, hired labor

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INTRODUCTION

Improving farm productivity among smallholder producers has been identified as a critical strategy for increasing income and reducing poverty among developing countries (World Bank, 2008). In India, smallholder families (< than 1 hectare) constitute around 85% of the agricultural producers in the country (GOI, 2017). These smallholder farmers face significant farming hurdles and complex production constraints. These include low technology adoption rates due to poor farming services, lack of access to credit, and low income due to inadequate marketing efficiency (NABARD, 2018). To reduce poverty and increase competitiveness among smallholders, government and donor institutions have emphasized the role of farmers' organizations as an alternative approach for disseminating technology and extension services (Meinzen-Dick, 2014). Farmers' organizations (e.g., cooperatives or self-help groups) also provide smallholders access to financial services (credit and savings services) to improve agricultural productivity and food security (Fletschner and Kenney, 2014).

However, most of the studies that use household as a unit of analysis entirely depend on the husband for decision-making, which may lead to incorrect results since it does not consider gender differences in terms of roles, responsibilities, and rights (Fletschner, 2008). Studies by Ragasa (2014) and Fletschner and Kenney (2014) found that most financial programs are designed for men, who usually own the land, have greater access to credit, and are generally willing to invest in more productive inputs. Women are often discriminated against due to low levels of education and ownership of assets needed for collateral. Thus, leading to gender differences in accessing financial services. For example, Demirguc-Kunt et al. (2018) found that around 83% of Indian men had an account at a formal financial institution compared to their counterparts (77%). Therefore, despite government efforts to promote differential financial policies, there still exists a gender differential in access to financial services. Spouse's inability to source funds from formal lenders (e.g., banks and cooperatives) left them with no choice but to seek funds from informal sources, including self-help groups (Kropp and Suran, 2002).

The Self-Help Groups (SHGs) are typically selected to provide various agricultural inputs, marketing, and educational services. These groups were first implemented under India's Ninth Five-Year Plan (1997-2002). In 2011 SHG program was elevated to a national level and was considered the most extensive poverty alleviation program under the National Rural Livelihood Mission (Census of India, 2011). The primary purpose of SHG is to empower women by assisting with financial and personal problems. Usually, an SHG comprises 10-20 adult women who collectively save money for loans for SHG members (Swain and Wallentin, 2012). Participation in SHGs increases women's self-improvement (e.g., bargaining power and cooperation among women), develops self-confidence, understand their rights as women, and financially independent from informal lenders (Desai and Olosfgard (2019), Patil and Kokate (2017), Swain and Wallestin (2012), Amin et al. (1998), Fernando (1997), Swain and Varghese, (2002), Banerjee and Ghosh (2012), and Mudege et al. (2015)). In addition, several studies found that women's participation in SHG results in an intra-household spillover effect on the husbands. For example, Chowdhury (2009) found that women in Bangladesh with credit from the Grameen Bank, a self-help group, positively affected male-operated micro-enterprises performance but did not affect the performance of women-managed enterprises. Women members of the Grameen Banks handed their loans to their husbands, who started the micro-enterprise, which women only manage. Fletschner (2006) found that households in Paraguay experienced a 25% loss in production efficiency when the husband experienced credit constraints. The efficiency also decreased by an additional 11% if the wife experienced credit constraints.

However, the literature fails to directly link spouses' access to financial services through membership in SHGs and its impact on technology, technical efficiency, and farm performance (output or yield).[1] With the trend in male migration, usually male farmers, from rural to urban areas. Farmers migrate to urban areas for higher and stable off-farm income. As a result, rural areas in India, for example, are witnessing significant changes in gender roles for spouses in farming and financial literacy due to remittance flows (Pingali et al., 2019; ILO, 2019). Thus, empowering women with knowledge of production and financing is essential by providing access to improved agricultural practices and market links. Spouse's membership in SHGs can be used to channel faster technology adoption among farmers. However, existing social norms can hinder a spouse's decision-making and participation in organizational activities. Despite the considerable evidence about the impact of financial institutions on women, there is scarce information about spouses' access to financial services through SHGs and the TE of rice farming in India. One related study by Rahman (2010) examined the relationship between female labor participation and the TE of rice producers. The author found that female labor input significantly increases the TE of rice producers in Bangladesh. In another study, Seymour (2016) developed and used the women empowerment index to explain TE in Bangladesh and found that reducing the gender empowerment gap positively affects the TE of crops. In other words, empowering women in terms of their roles and participation in agriculture increased the TE of crop farms.

Hence, this study aims to assess the impact of a spouse's access to financial services through membership in FSOs on technology adoption, technical efficiency (TE), and productivity. The study aims to determine TE, managerial gaps, and farm performance between farm households with spouses with and without access to financial services via SHGs. The study

[1] Financial Service Organizations (FSO) provide access to financial services for membership.

controls for biases stemming from observables and unobservables, which used an extensive nationally representative household-level survey, the 2016 Rice Monitoring Survey, deployed by the International Rice Research Institute (IRRI).

The study contributes to the literature on two fronts. First, the study focuses on spouses' access to financial services (credit and savings) and their impact on rice production efficiency. Since there is an increase in spouses' access to financial services through SHGs, the study shows whether access to financial resources by spouses can translate into higher production efficiency. Secondly, obtain unbiased estimates on the impact of the spouse's access to financial institutions on rice productivity considering self-selection bias by using Greene's (2010) selection-correction stochastic frontier approach (SFA).

Thus, assessing the impact of spouses' access to financial services on TE and managerial gaps is essential and the first step towards increasing rice smallholders' income and food security. Findings from this study will be helpful in policy legislation a positive message, particularly at a local level, regarding spouse's importance to smallholder farming and competitiveness in India's agricultural sector. In addition, the results can offer a justification for a firm commitment from national institutions such as the Ministry of Finance and Ministry of Rural Development by introducing policy changes that increase spouses' access to financial services (access to loans and savings).

THEORETICAL FRAMEWORK

The theoretical framework conceptualizes the linkage between spouse's access to financial services from SHGs and farm output. Smallholder households maximize the utility from profit (R). Limited or binding credit can lead to productivity and efficiency differentials between families where spouses have access to financial services from SHGs and their counterparts

(Carter, 1989; Mukasa et al., 2017). Smallholder families that receive credit through spouses' membership in SHGs are expected to increase profits that could be achieved through given resources and selling products to the market. The spouses' access to credit enables farming families to buy quality inputs, hire additional labor, and enhance their ability to make sound investment decisions.

Consider a smallholder family with L total land availability and X variable inputs (seeds, fertilizer chemicals, family, and hired labor). Thus, the farm production function is represented as $f(X, L, \Theta)$ where Θ is a vector of production shifters. Let p and w represent the unit market price of output and inputs, respectively. Thus, the profit can be defined as:

$$R = pf(X, L, \Theta) - wX \tag{1}$$

where $f(X, L, \Theta)$ is a concave production function. The family is also assumed to have a certain income I that is allocated for consumption C at the unit price p_c. If $I \geq pC + wX$, then smallholder families can finance the production and consumption expenses without seeking out external financial resources. However, in most smallholder families in India, the farmer's income is insufficient to pay for production and consumption expenses. In this situation, the farmer can only pay for a fraction s, where $0 < s < 1$, of the variable inputs. Hence, $(1 - s)$ portion of variable inputs should be financed through loans from formal and informal sources. In this case, the spouse's membership in SHGs provides credit and savings that fill the financial gap. Spouses in the sample were queried about assets, savings, and borrowing. More than half of the sampled spouses had access to financial services through membership in SHGs. These SHGs provide loans (K) to spouses who are members of the SHGs and charge interest rates r on the loans. Thus, smallholder's problem is to maximize the utility of profit $U(R)$ as follows:

$$Max\ U[R(X)] = U\ [pf(X, L, \Theta) - swX - (1 - s)wX] \tag{2}$$

subject to:

$$(1-s)wX \le K(\Phi,\Theta) + (I - pC - swX) \tag{3}$$

$$0 \le K(\Phi,\Theta) \le \tau L \tag{4}$$

Equation (3) shows that expenditures on variable input, X are limited by smallholder's initial income Y, consumption expenditures pC, and credit limit $K(\Phi,\Theta)$. The maximum amount of credit available to the spouse depends on production attributes Θ (factors affecting rice production such as labor, farm size, farmer's farming experience, and intended use of credit) and family consumption shifters Φ (family size, financial status, and wealth). Equation (4) shows the smallholder family's credit limit and is determined by the value of land owned (L) at unit price τ. This can be interpreted as collateral that farmers or spouses use to seek credit. In other words, the amount of land could be considered the family's creditworthiness. In addition, the two inequalities in Equation (4) represent two constraint scenarios of the farmers: credit-constrained without binding and with binding (Mukasa et al., 2017). The farmer's problem can be solved using a Lagrangean function;

$$L = U[pf(X,L,\Theta) - swX - (1-s)wX] + \lambda[K(\Phi,\Theta) + (I - \mathrm{p}C - swX) - (1-s)wX] + \Gamma[K(\Phi,\Theta) - \tau L] \tag{5}$$

where λ and Γ are shadow prices of the credit constraint and loan limit, respectively. Solving equation 5, one can obtain the following Kuhn-Tucker conditions:

$$U'(.)[pf(.) - sw - (1-s)w] + \lambda[sw - (1-s)w] = 0, \;\; X \ge 0 \tag{6}$$

$$[K(\Phi,\Theta) + (I - pC - swX) - (1-s)wX] = 0, \;\; \lambda \ge 0 \tag{7}$$

$$[K(\Phi,\Theta) - \tau L] = 0, \quad \Gamma \ge 0 \tag{8}$$

If the credit constraint is not binding, then $\lambda = 0$ thus, Equation (6) results in $U'(.)[pf_x(.) - sw - (1-s)w] = 0$. Since $U'(.) \neq 0$ implying that $pf_x(.) = w$. In other words, the marginal value product $pf_x(.)$, at the optimum, should be equal to the marginal cost w of inputs, independent of consumption. On the other hand, if the credit constraint is binding, then $\lambda > 0$ the optimality condition using equation 6 is given as $U'(.)[pf_x(.) - w] - \lambda w] = 0$, thus meaning that $pf_x(.) = w\ [1 + \lambda/U'(.)] > w$ since both λ abd $U'(.)$ are strictly positive. For a credit-constrained smallholder, the marginal value product of variable inputs is higher than the marginal costs by the factor of $[1 + \lambda/U'(.)]$. According to Stiglitz & Weiss (1981), Singh, Squire, & Strauss (1986), and de Janvry, Fafchamps, & Sadoulet (1991) the above results breaks the separability hypothesis between production and consumption decision and changes in smallholder family preferences. Consequently, the shadow price of credit constraint will affect smallholder's farm output. In other words, the higher the shadow price of the credit constraint, the optimal level of inputs used by Indian rice farmers is lower (Ciaian & Swinnen, 2009), which may affect achieving its potential profits. Thus, relaxing credit constraints through loans from SHGs where spouses have access to financial services (credit) may help smallholder rice farmers use better and required inputs to improve rice productivity and profitability. Thus ensuring the viability of small farms.

ESTIMATION STRATEGY

The study's motivation is to assess the impact of spouses' access to financial services and rice production efficiency to estimate rice producers' technology and the managerial gap in eastern India. The study uses a multi-step approach. In part one, the major constraints that affect spouses' access to financial services are evaluated by employing Propensity Score Matching (PSM) to control selection bias for observed characteristics. This study utilizes the corrected sample's stochastic production frontier (SPF) to control the unobserved characteristics in rice production efficiency estimation in the second stage. Lastly, meta-frontiers analysis is used to compare the impact of financial services and technical efficiency (TE) for households where the spouse has access to (without access to) financial services.

The study assumes that the spouse decides (binary choice) to receive financial services by being a member of SHGs. Using the utility maximization framework, the probability of women with access to financial services is determined by comparing the expected benefits of having access (AC_A^*) and the expected benefits of not having an access (AC_{NA}^*). As expected, women will choose to have access to financial services if the expected benefits are greater than the expected benefit of not having access, i.e. $AC^* = AC_A^* \ - \ AC_{NA}^* \ > 0$. The latent variable AC^* is unobservable, which can be influenced by socio-economic and farm characteristics. The decision model can be written as:

$$AC_i^* = \gamma Z_i + \varepsilon_i \qquad F_i = \begin{cases} 1 \ \ if \ F^* > 0 \\ 0 \ \ otherrwise \end{cases} \tag{9}$$

where AC^* is access to financial services indicator=1 if the spouse has access to financial services; 0 otherwise. The Z represents a vector of observable characteristics, i is the ith farmer, γ is a vector of unknown parameters to be estimated, and ε is an error term with mean zero and σ^2. The probability of a spouse participating in SHGs is given as:

$$Pr\ (AC_i = 1)\ = Pr\ (AC_i^* > 0\ )\ = Pr\ \ (\varepsilon_i > -Z_i\gamma)\ = 1 - F - (-Z_i\gamma) \tag{10}$$

where F is the cumulative distribution of ε_i. Spouses' access to financial services through membership in SHGs depends on women's constraints, usually based on socio-economic and geographical characteristics (Beck and De la Torre, 2007). We use the Stochastic Production Frontier (SPF) function developed by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977). The SPF function acknowledges other factors, such as unpredictable weather, drought, and flood, are often experienced in rice production, preventing potential productivity (Koirala et al., 2016; Mishra et al., 2018). The SPF is defined as:

$$Y_i = f(X, AC) + (\varepsilon_i) \qquad where \ \ \varepsilon_i = v_i - \mu_i \tag{11}$$

where Y_i represents the production function for i farm; X is the vector of inputs and other variables, and AC is the spouse's access to financial services. The error component is composed of two parts: v_i and μ_i. The v_i is a random error associated with factors that are outside the control of the farmer (e.g., measurement error and weather) and assumed to be independent and identically distributed $N(0, \sigma_v^2)$ and independent of the μ_i's. On the other hand, μ_i is a non-negative random variable associated with farm-specific factors contributing to production efficiency. μ_i assumed to be independent and identically distributed with non-negative (one-sided) half-normal distribution $|N\left(0, \sigma_\mu^2\right)|$. The value of μ_i is zero if the farm is technically efficient; one if it is technically inefficient (Kalirajan and Shand, 1999).

In estimating SPF, addressing self-selection among spouses with financial services from SHGs is essential to avoid selection bias due to observable and unobservable factors. We use a multi-stage approach following studies (e.g., Villano et al., 2015). The first stage addresses the selection bias of the observable attributes using the Propensity Score Matching (PSM) technique (Rosenbum and Robin, 1983). This technique matches spouses with and without access to financial services based on their observable characteristics. A propensity score for every farmer in the sample is based on their observed characteristics. A Probit modeling approach is used to estimate Eq. (1). Several studies have examined the SPF and selection bias due to unobservable attributes. For instance, Lai et al. (2009) assume that selectivity bias is related to error term in the sample selection Eq. (11). In contrast, Kumbhakar et al. (2009) argue that in the estimation of SPF, selectivity bias is due to the correlation of error term in Eq. (11) and μ_i. However, the above studies require computationally demanding log-likelihood functions but show no superiority in estimates. Therefore, this study follows the SPF model by Greene (2010). Greene's approach is an extension of Heckman's approach, correcting for sample selection. The method corrects for biases arising from unobservable attributes. Thus, Greene's sample-selection SPF model consists of a mixture of conventional SPF (Aigner, Lovell, and Schmidt, 1977) and Heckman's (1976) sample-selection model. The following equations give the sample selection model with the error structure:

Sample Selection: $AC_i = 1\ [\gamma' Z_i + \omega_i > 0], \quad \omega_i \sim N(0,1)$ (12)

SPF: $Y_i = \beta' X_i + \varepsilon_i, \quad \varepsilon_i \sim N(0, \sigma^2)$ (13)

$where\ (Y_i, x_i)$ are observed when $AC_i = 1$. Error structure: $\varepsilon_i = v_i - \mu_i$

$u_i = |\sigma_u U_i| = \sigma_u |U_i|$, where $U_i \sim N(0,1)$

$v_i = |\sigma_v V_i| = \sigma_v |V_i|$, where $V_i \sim N(0,1)$

$(\omega_i\, v_i) \sim N_2[(0,0), (1, \rho\sigma_v, \sigma_v^2\ )]$

where Y_i is logarithmic rice yield of farmer $i = 1,2,\ \ldots, n$, X_i are the logarithmic input quantities, AC_i is a binary variable that takes a value of 1 if the spouse has access to financial services from SHGs; 0 otherwise. The Z_i represents the covariates of the sample selection model, ε_i is the error term of the stochastic frontier model. v_i is the conventional error term and u_i is the efficiency term, ω_i is the error term of the selection equation, and β and γ are the parameters to be estimated. The efficiency term u_i follows a half-normal distribution with dispersion σ_u while ω_i and v_i follow a bivariate normal distribution with variances 1 and σ_v^2, respectively. In the above model, sample selection arises if the noise in the SPF, v_i , is correlated with unobserved attributes in the sample selection equation, ω_i (Greene, 2010). ρ is the correlation between the error in the sample selection and the outcome equations. If ρ is significant, we have evidence of selectivity bias in unobservables. In cases where ρ is insignificant, the maximand will reduce to that of the maximum simulated likelihood estimator of the basic frontier model. Two separate selection correction SPFs are estimated to derive a TE for farms with and without access to financial services from SHGs through spouses.

Stochastic Meta-Frontier

To directly compare TE between groups (e.g., farm, whether a spouse has access to financial services from SHGs), the study follows O'Donnell and Villano's (2015) approach. Specifically, we estimate the meta-frontier, which envelops the individual group (j). The deterministic meta-frontier production function is expressed as:

$$Y_i^* = f(x_i, \beta^*)\, e^{x_i \beta^*} \tag{14}$$

where $Y_i^*$is the meta-frontier output, and β is the vector of meta-frontier parameters that satisfy the constraints $x_i\beta^* \geq x_i\beta_j$. The β_j are parameters for farms with spouses with and without access to financial services group frontiers. Following O'Donnell (2008), the meta-technology ratio (MTR), which is the ratio of the output for frontier production for group j relative to the highest possible meta-frontier output and defined as:

$$MTR = \frac{e^{x_i \beta_j}}{e^{x_i \beta^*}} \tag{15}$$

Finally, the technical efficiency (TE_M) with respect to the meta-frontier can be calculated as:

$$TE_M = TE_j \; x \; MTR_j \tag{16}$$

SURVEY DATA

The study uses the 2016 Rice Monitoring Survey conducted by IRRI. A rice-producing household is defined as a household that produced rice during the past 12 months. The survey targeted eastern India's rural population by randomly selecting rural areas based on India's 2011 Census. Four states in India's eastern part are considered in the study: eastern Uttar Pradesh, Odisha, Bihar, and West Bengal. Table 1 shows the distribution of sample sizes across different states. The study adopted a multi-stage sampling technique in selecting the respondents. In the first stage, the number of districts was randomly selected in each state using the Census of 2011.[2] On the other hand, the second stage involves selecting the number of villages based on the proportion of each state's total rice area, keeping the total number of villages at 720. Household samples are randomly selected among the selected villages using the household census village data.

A total of 101 districts and 1,697 rice-producing households are included in the survey (Table 1). A structured questionnaire was used to interview the primary male and female household decision-makers. Households with married couples and at the same time identified to be the male and female decision-makers are included in the sample. Choosing the married couple as a major criterion is necessary since it is common for Indian households to have an extended family living in one house. Information regarding rice production and farm-related decision-making was collected from husbands, and information regarding livestock, household assets, and decisions regarding farming, savings, and borrowing were collected from spouses. The survey employed male and female enumerators in the interview process to elicit unbiased responses.

The male enumerator interviewed the operator, while the female enumerator interviewed the spouse. The study focused on the 2015 wet season, the primary rice-growing season in eastern India. A computer-assisted personalized interview (CAPI) program, *Surveybe*, was used to collect the data. Membership in SHG represents spouses' leadership and societal influence following the International Food Research Institute (Malapit, 2015). Membership in SHGs varies from agricultural-related (e.g., cooperative, SHG, agricultural producers, water organization) to non-agricultural-related organizations (e.g., civic and religious groups). The survey queried the spouse regarding their participation in any group in this study. In some cases, the spouse is a

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

non-financial related SHG member, making it hard to access financial resources. Thus, access to financial savings in this study includes the spouse's access to financial services (e.g., savings and loans) through their involvement in SHGs.

The definitions and summary statistics (means) of the variables used in the analysis are presented in Table 2. The results show that 52% of the sample comprises households with spouses with access to financial services. The average spouse's educational attainment is very low. Nearly half of the spouses have reached more than primary education. The average household size across the sample was about four, and almost half of the respondents have at least one member with off-farm work (e.g., business, salaried, or government jobs). When it comes to social classification, most smallholder households in the sample (40%) belong to Other backward castes (OBC) classes, followed by general caste and Scheduled Tribe/Scheduled Castes (SC/ST).[3] Interestingly, 48% of OBC families have spouses with access to financial services, compared to 26% of SC/ST families and 29% of general caste categories. Many households have access to government services, such as below-poverty line (BPL) cardholders—58% of BPL cardholders belong to families where the spouse has no access to financial services from SHGs. [4] In addition, nearly half of the households have young children (age nine and

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[3] Other backward caste includes castes that are marginalized sectors of the Indian society. On the other hand, general caste is a group of people who do not qualify for any of the affirmative action schemes operated by the Government of India (excludes scheduled castes and scheduled tribes, and other backward classes). This group of people does not qualify for any of the affirmative action schemes operated by the Government of India (excludes scheduled castes, scheduled tribes, and other backward classes). Lastly, the scheduled tribe/caste are considered designated groups of historically marginalized indigenous people in India and recognized by the Government of India (GoI). Since independence, the Scheduled Castes and Scheduled Tribes (SC/ST) were given reservation status, guaranteeing political representation.

[4] Below Poverty Line (BPL) is a population that the Indian government identifies to be economically disadvantaged. BPL cards are issued to people are considered to fall under the BPL category and they derive benefits from the government's welfare programs (Ram et al., 2009).

under). Table 2 shows that only a few spouses own a mobile phone in terms of assets, and most households own at least two livestock (e.g., sheep or cattle).

Rice yields in the sample were significantly lower, with an average of 1,917 kg/ha than the national average of 3,700 kg/ha (IRRI, 2019). The average cultivated rice acreage among the sample is 0.41 ha, considered marginal in the Indian context. Nearly half of the sampled farmers have medium land in land topography.[5] In addition, more than half of the households use supplemental irrigation (59%), mainly groundwater irrigation (shallow or deep tube wells), suggesting that farms in eastern India still rely on rainfall as the primary source for irrigation. Recall that Pandey et al. (2007) note that one reason for the low adoption of technology in eastern India is the frequent flooding and droughts, thus hindering productivity. Abiotic stresses, such as floods and drought, are significant problems that affect production in the area. In 2015, around 65% of the smallholder rice producers were affected by floods and drought.

The major inputs used in rice production are seeds, fertilizer (NPK, Urea, and DAP), and labor. [6] The average rice farmer in the sample used about 34.6 kg/ha of rice seed. Similarly, the average rice farmer used 279 kg/ha fertilizer (NPK, Urea, and DAP). Interestingly, most households use machinery, but only a few (13%) own large farm equipment (such as threshers, tractors, and power tillers). Table 1 reveals that smallholder rice producers, on average, use 62 person-days/ha of total labor, and more than 60% of the households employ hired labor. Farmers mix the rice seed variety in the cropping season (Appendix Table 1). For example, around 30% of farmers used mixed rice seed varieties, while 18% only used rice varieties, MRV2 (1977-85).

[5] Medium land is the land that is intermediate between lowland and upland.
[6] NPK fertilizer is composed of nitrogen, phosphorus, and potassium while DAP fertilizer is referred to as diammonium phosphate.

Surprisingly, 11% of the farmers still use local rice seed varieties despite the government's effort to develop and disseminate new ones.

A matching technique generates counterfactual groups to match households with spouses with access to financial services from SHGs. Following Greene (2010), the probit model was estimated using the observable characteristics to produce propensity scores. This study employs the nearest neighbor matching (NNM) algorithm with a maximum of five matches with a caliper of $0.025\sigma_p$.[7] The selection of the matching algorithm is presented in Appendix Table 2 yielded a total of 1,656 matches. Appendix Table 3 shows the comparison of means was used to examine if there are no significant differences between the two groups in the matched sample, thus fulfilling the covariates' balancing condition (Caliendo and Kopeinig, 2008).

Table 3 shows the marginal effects of the estimates from the probit model for the matched and unmatched sample. Results show that households with BPL cards, livestock, and spouses who own mobile phones are more likely to have access to financial services from SHGs. In contrast, families with children under nine years[8] and farm families located in Bihar, Odisha, and West Bengal, compared to eastern UP, are less likely to have access to financial services from SHGs. The models (unmatched and matched) have similarities and differences. Table 3 reveals that the signs of the coefficients are the same in both models. The key differences are that the matched sample shows fewer statistically significant coefficients, and the hypothesis that coefficients are simultaneously zero is rejected only in the unmatched model. The two differences are consistent with reducing the variability of the sample attributes induced by the PSM. Figure 1 shows the density plots of the propensity scores for spouses with and without

[7] $\sigma_p = \sqrt{\sigma_0^2 + \sigma_1^2/2}$, where 0 and 1 are standard deviations of estimated propensity scores of the control and the treatment groups, respectively (see Cochran and Rubin, 1973).
[8] Shah and Panigrahi (2015) argue that number of young children, who require more attention at home, often discourages women from participating in SHGs activities.

access to financial services from SHGs. The common support is also satisfied, with propensity scores ranging from 0.18 to 0.96.

Two functional forms commonly used in the literature were estimated in estimating production frontier efficiency: Cobb-Douglas and the translog function (Villano et al., 2015; Seymour, 2017). To identify the appropriate functional form, a likelihood ratio test reveals the rejection of the Cobb-Douglas function (LR= 17.11, p-value=0.06, Appendix Table 4). Thus, the following translog function was estimated as:

$$lnY_i = \beta_0 + \sum_{j=1}^{4} \beta_j lnX_{ij} + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4} \beta_{jk}\ ln\ \ X_{ij}\ lnX_{ik} + \sum_{l=1}^{18} \gamma_l D_l + v_i - \mu_i \quad (17)$$

where Y_i is the rice yield (kg/ha) of the ith farmer, X_j denotes the vector of input used in the production, including the quantity of seeds (kg/ha), total fertilizer (kg/ha), total labor used in rice production (person-per-day/ha), and total cultivated rice area (ha). There are 18 dummy D_l variables, which include the land topography or the proportion of medium land (D_1), farm location (D_2= Bihar; D_3= Odisha; and D_4= West Bengal); caste (D_5= Scheduled tribe; D_6= Other backward); the occurrence of flood/drought in the 2015 wet season (D_7=1 if there was flood/drought); with supplemental irrigation (D_8=1 if the plot is irrigated; 0 otherwise); uses machines (D_9=1 if farm uses machines; 0 otherwise); large farming equipment ownership (D_{10} =1 if large equipment is owned; 0 otherwise); hired laborer (D_{11}=1 if farm hired labor; 0 otherwise); type of rice varieties used by the smallholder ($D_{12} - D_{17}$); and the spouse's access to financial access services (D_{18} = 1 if the spouse has access to financial services). The parameters β, θ, δ, and ϑ are parameters estimated, and v and μ are elements of the error term ε, is an uncorrelated error term (sample selection model in the first stage) with $N(0, \sigma_\varepsilon)$ distribution.

A pooled SPF for the matched sample was estimated with the spouse's access to financial services (through SHGs) as a dummy variable in rice production. The LR test was used to examine the technology difference between households with access and without access to financial services (Battese and Coelli, 1998). The null hypothesis assumes no difference between the pooled frontier and two separate frontiers. The LR test rejected the null hypothesis (LR= 92.59, p-value=0.00). Thus, we estimated two separate SPF models (conventional and sample selection). The analysis of SPF for conventional and sample-selection models was estimated using NLOGIT 6. The meta-frontier function was computed using linear programming for the optimization problem using MATLAB.

RESULTS AND DISCUSSION

Stochastic production function estimates

Tables 4 and 5 provide the conventional and selectivity-corrected SPF estimates for unmatched and matched samples. Table 4 and 5 present the partial production elasticities of all models with different magnitudes and significance. [9] However, the results in Table 4 show that the self-selection, denoted by ρ is insignificant, which may lead to the wrong impression of the unbiased estimates. Thus, there is a need to address the self-selection using the two-stage approach. Table 5 shows self-selection in the matched sample households with spouses with access (-0.657, p-value=0.042) and without access to financial services (-0.838, *p*-value=0.001) from SHGs. The selectivity-correction term is significant, suggesting that unobserved factors influence the spouses' decision to engage in financial assistance provided by SHGs. Our finding is consistent with other studies that found evidence of selection bias related to program participation (Villano et al., 2015; Mishra et al., 2018).

Regarding major inputs, the results from the selectivity-corrected SPF of the matched sample (Table 5, last two columns) show that the quantity of rice seeds used in rice production

[9] The variables of the translog models used in Table 4 and 5 are normalized by their geometric means to be interpreted as partial elasticities (Coelli et al., 2003).

significantly reduces rice productivity, particularly in households with access to financial services. In other words, a 10% increase in seed usage decreases rice output by 9%. Most farmers in eastern India's flood-prone areas use the puddled transplanting method to grow rice. As a result, use more than the recommended amount of seed (seeding rate up to 60% higher than normal) to compensate for the potential crop losses during the nursery growing period (germination rate and bird and animals eating way young seedlings). A negative relationship between seeds and output may result from farmers' over-utilizing seeds (Majumder et al., 2016). This finding is consistent with Mishra et al. (2015), who found a negative and significant relationship between the quantity of seeds and rice output in Bangladesh. However, the above finding contrasts with Mishra et al. (2018) and Mariano et al. (2011), who found a positive and significant relationship between the quantity of seeds and rice output.

Results suggest geographical heterogeneity in terms of rice productivity. Farm location has the highest contribution to rice productivity. Compared to farms located in eastern Uttar Pradesh, results indicate a significant potential for increasing productivity in Bihar, West Bengal, and Odisha, particularly in households where the spouse can access financial services. The occurrence of drought and/or flood significantly reduces rice output for both groups in the sample-selection group of the matched sample. In particular, the event of stress conditions (drought/floods) decreases rice output by 16% and 19% for farm families with spouses with and without access to financial services from FSOs, respectively. This finding is consistent with Mishra et al.'s (2015), who found that abiotic stresses (drought and flood) reduced rice production among rice farmers in Bangladesh.

While the labor input is insignificant for both groups (Table 5, last two columns), hiring laborers decreases rice output. For example, hired labor decreases rice output by about 17%

among households where spouses have access to financial services. On the other hand, hired labor reduces rice output by about 8% among families where the spouse has no access to financial services. Interestingly, Table 5 shows that farm mechanization increases rice output by about 16% among households where the spouse has access to financial services. Similarly, farm machinery increases rice output, but a smaller increase by 10%, for farms where the spouse has no access to financial services. Our finding is consistent with Mariano et al. (2011), who found that machinery (e.g., harvester and thresher), a labor-saving technology, increases rice output among Filipino rice farmers.

Lastly, Table 5 shows that farmers using MRV2 (1977-75) and MVR4 (1996 or later) rice varieties have significantly higher rice output than farmers using local rice varieties. However, the magnitude of the increase in rice output is higher for farm households where the spouse has access to financial services access (21% for MRV2 and 23% for MRV4) than households where the spouse has no access to financial services (13% for MRV2 and 21% for MRV4). Familiarity and compatibility of a rice variety to the production conditions and agro-climatic environment may explain both groups' positive relationship. For example, rice varieties MRV4 were developed for adverse agro-climatic environments, wherein *Swarna-Sub1* (flood-tolerant variety) is a popular variety. For instance, Dar et al. (2012) show that farmers using *Swarna-Sub1* have a 66% yield advantage compared to other rice varieties. Indeed, our findings underscore the importance of access to financial resources in rice production. An explanation could be that spouses' membership in SHGs relaxed households' liquidity constraints and helped farmers purchase more quality inputs, such as rice varieties compatible with the growing climate and environmental conditions. In addition, the technical inefficiency variable λ (LR=176.51, *p*-value=0.00) is significant in Table 5, thus rejecting the null hypothesis ($\lambda = 0$) at the 1% level of significance. This finding suggests that technical inefficiency is associated with output loss for farming families with and without access to financial services from SHGs where spouses are members.

Technical efficiency and yield performance

Table 6 shows the descriptive statistics for the MTRs (equation 15) and metafrontier TEs (equation 16) for matched samples. In contrast, the metafrontier analysis results with both conventional and sample selection models were reported. The signs and magnitude of the estimates show a difference in the effect of spouses' access to financial services on MTR and TE-metafrontier for unmatched and matched samples. The results for the matched sample (lower part of Table 6) show the magnitude of the estimated TE coefficient after correcting for sample-selection bias. Results reveal that the TE of smallholder farms whose spouses have access to financial services through SHGs is slightly higher (54%) and statistically significant than their counterparts (53%). A plausible explanation could be that access to financial services (loans and savings) via spouses' membership in SHGs may induce farmers to buy more quality inputs like fertilizer, reallocate labor between farm and non-farm, and hire labor to perform farm work. The finding is consistent with Heriqbaldi et al. (2015), who found that government assistance to farmers increases TE. Brázdik (2006) also found that farmers with credit constraints had lower TE.

However, comparing TE between groups is inappropriate since estimates are computed based on each group's frontier. Table 6 reveals that smallholders with access to financial services (via spouses' membership in SHGs) have a positive and statistically significant effect on technology and managerial gaps, as shown in the last two rows of Table 6. Specifically, findings reveal that spouses' access to financial services increases the MTR by about 6.1% and the TE-metafrontier by about 3.6%.[10] In other words, the above results show that technology and managerial gaps are higher for smallholders whose spouses have access to financial services via SHGs than their counterparts.

We look at key variables to assess the factors that may contribute to higher MTR and TE-metafrontier. The results in Table 7 show statistically significant differences between input usage by smallholders with access to financial services and their counterparts. On average, smallholders with access to financial services applied more fertilizer, about 38kg/ha, than their counterparts. Of the three major fertilizers (NPK, DAP, and Urea), smallholders with access to financial services used more DAP, about 20kg/ha, than their counterparts. Table 7 shows that most of the reduction in labor came from a reduction in the labor used in crop management (labor used in applying fertilizer, pesticide irrigation, and weeding). Indeed, we find that smallholders with access to financial services used less labor, about 2 person-days/ha, than their counterparts. Among the types of labor, results in Table 7 reveal that smallholders without access to financial services used more family labor than households without access to financial services. Note that the high family labor requirement among households without access to financial services is during harvesting and post-harvest season, requiring at least two persons day/ha. Results show that the two groups have different farm management styles regarding hired labor requirements. The finding is consistent with the theory that family labor may be well suited for non-farm work or non-farm family businesses.

Labor costs are the largest rice production costs (Janiah and Hossain, 2013). However, when comparing labor needs, farmers should be cognizant of the quality of labor, labor productivity, and opportunity costs of family labor. Indeed, Table 7 shows that smallholder rice

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[10] The MTR was computed using O'Donnell's (2008) approach. The estimated parameters from TL selectivity-corrected SPF specified in Eq (16) were fitted using linear programming in MATLAB.

farmers with access to financial services, via spouses used more hired labor, about 1.3 person-days/ha for crop establishment (activities include land preparation, nursery and planting, and transplanting/planting). A plausible explanation is that households with access to financial services reallocate family labor to higher-paying off-farm jobs and, in return, hire contract labor to perform farming tasks. Contract labor tends to be more efficient and cost-effective relative to hiring daily wage workers.

Further, reliance on hired and contract labor indicates that eastern India's labor market is developed. Results in Table 7 show that smallholders with access to financial services have higher, about 0.40 person day/ha, contract labor for harvesting/post-harvest activities (includes harvesting, bundling, threshing, drying, and transporting) than households without access to financial services. The above findings indicate that smallholders with access to financial services are smart businessmen who better understand the time value of money. They tend to allocate family labor to higher-paying off-farm jobs while hiring labor, including contract labor, for crop establishment and harvesting post-harvest activities.

CONCLUSION AND IMPLICATIONS

The role of spouses in smallholder agriculture is changing rapidly. Gender-differentiated government policies, market-oriented agriculture, migration, and a robust off-farm economy mainly drive the change. Access to credit from SHGs has been an important source of liquidity in India. Government policies on gender equity have opened doors for access to financial services (loans and savings) through SHGs by spouses, a recent trend that is becoming important in farming. Thus, this study aimed to analyze the spouse's access to financial services from SHGs on smallholders' managerial and technology gaps in eastern India. We used unique farm-level data from rice producers in four eastern states of India—eastern UP, Bihar, Odisha and

West Bengal. The states are the top producers and consumers of rice in India. The study used an innovative framework that combined sample-selection corrected stochastic production frontier (SPF) and PSM method to measure technical efficiency and separate the technology and managerial gaps for farms specializing in rice production.

The results revealed that the presence of young children, poverty status, ownership of mobile, and the number of livestock influenced spouses' access to financial services via SHGs. Thus, from a policy perspective, SHGs could design programs that encourage the participation of young spouses with young children in their organization. Regarding output, seed usage negatively affected rice output for the farm where spouses had access to financial services. Thus, farmers can reduce the amount of seeds used in rice production while maintaining yield and decreasing costs. Among farm households without access to financial services, fertilizer usage, and acreage were significant drivers of rice output.

Results revealed technical efficiency (TE) was higher for farmers whose spouses had access to financial services than for the control group. The study identified the presence of selectivity bias and found significant differences in technological and managerial gaps between smallholders whose spouses had access to financial services and their counterparts. Specifically, the gaps between rice producers whose spouses have access to financial services through SHGs and their counterparts seemed more noticeable after selection bias. The difference between spouses with and without access to financial services becomes prominent when analyzing the impact on meta-frontier yield. The study underscores the finding that farmers with access to financial services tend to allocate family labor to higher-paying off-farm jobs and hire workers, including contract labor, for crop establishment and harvesting post-harvest activities.

The findings from this study have several important implications. First, the study shows the importance of the gender roles of spouses in access to financial services and its impact on rice production in a large economy like India. Thus, policymakers could design policies encouraging spouses' participation in financial and farm organizations. Thus resulting in greater understanding of finances, credit savings, and decision-making. Second, machinery is an essential contributor to rice productivity and technical efficiency. Rapid growth in the rural non-farm sector in Asia has led to labor shortages in farm activities. Thus, crop production is increasingly relying on labor-saving technologies like farm machinery. Investments in the public and private sectors could lead to greater adoption of machinery and increased rice production. Lastly, the estimated technical efficiencies among rice farmers are relatively lower than other estimates. To this end, evidence suggests that despite extensive seed development and dissemination programs to increase rice yield, it is not enough to rely on the rice varieties' capabilities alone.

Since mobile phone ownership affects a spouse's access to financial sources, one can explore mobile phones as an information communication technology (ICT) tool in adopting and promoting rice technology. India's Rice Knowledge Management Portal (RKMP) provides information (e.g., variety selection, pest/disease management, site-specific questions) to significant stakeholders (such as farmers, extension workers, and policymakers) in rice farming (Kumar et al., 2018). However, providing them with mobile phones is insufficient to ensure that spouses access this information. Women should also be prepared for the use of ICTs. Recall that most of the women in the sample have low educational attainment. Information content regarding financial services and rice production should be site-specific and compatible with the spouse's availability in decision-making. Additionally, women/spouses need proper information gathering and ICT tools training. The government and private sectors should strengthen partnerships in providing affordable infrastructure (e.g., internet connection) to guarantee continuous technology use among women/spouses.

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Figure 1: Density of the propensity score for household where spouses with access and without access to financial services.

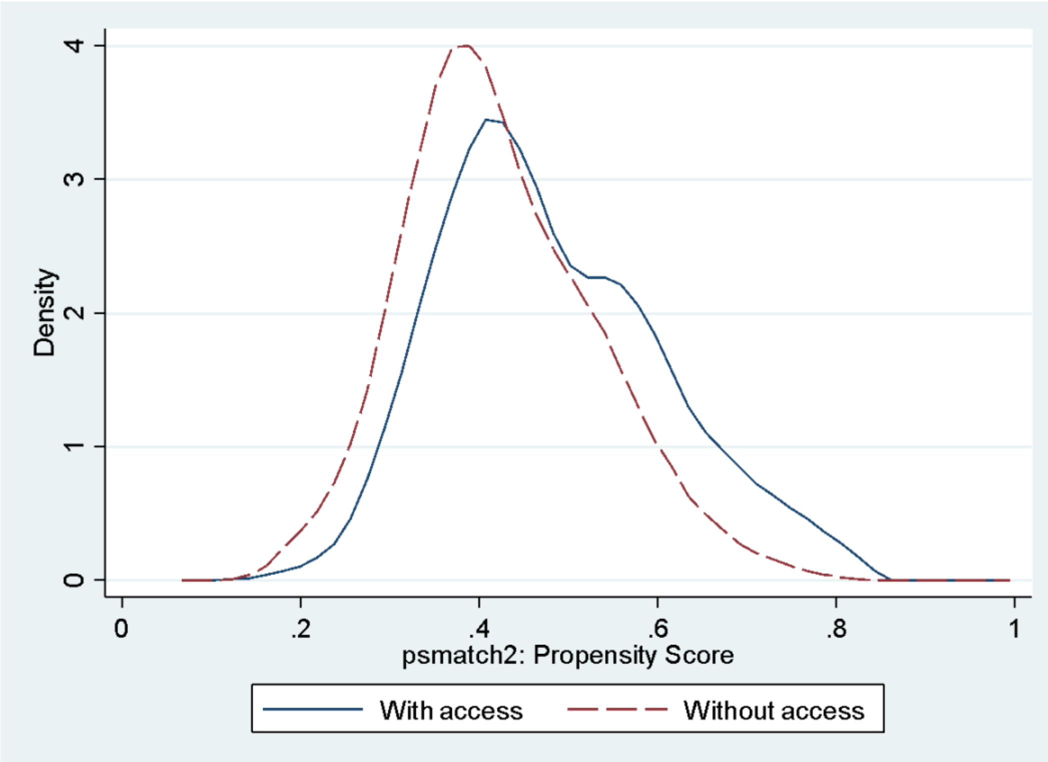

Table 1: Sample districts and smallholder households, eastern India, 2016

State	Number of districts	Number of households
Eastern Uttar Pradesh	37	472
Odisha	30	548
Bihar	16	299
West Bengal	18	378
Total	*101*	*1,697*

Source: 2016 Rice Monitoring Survey conducted by IRRI.

Table 2: Definition of variables and descriptive statistics (mean), eastern India 2016.

Variable	Description	With Access (n=884)	Without access (n=813)	Pooled (n=1,697)
Spouse_Age	Age of spouse (years)	42.00	42.19	42.09
Spouse_P	Spouse education, primary or below (=1 if yes; 0 otherwise)	0.19	0.20	0.19
Spouse_M	Spouse education, above primary (=1 if yes; 0 otherwise)	0.27	0.26	0.27
Spouse_I	Spouse uneducated	0.54	0.55	0.54
H_Size	Total adult members (Age>15 or older)	3.81	3.51	3.67
Children	Children in household 9 or under (1=yes; 0=otherwise)	0.47	0.48	0.48
BPL	Household with Below Poverty card (1=yes; 0=otherwise)	0.55	0.58	0.56
Livestock	Total livestock owned (e.g., buffalo, dairy cattle, goats, sheep, chicken, ducks, and pigs)	1.48	1.50	1.49
Off-farm Inc	Farmer or spouse off-farm employment (1=yes; 0=otherwise)	0.44	0.54	0.48
G_irrigation	Household uses groundwater irrigation (1=yes; 0=otherwise)	0.17	0.16	0.16
Mobile phone	Spouse own personal mobile phone (1=yes; 0=otherwise)	0.31	0.16	0.24
SC/ST	=1 if operator is Scheduled caste or Scheduled tribe; 0 otherwise.	0.26	0.32	0.29
OBC	=1 if operator is classified as socially disadvantaged and backward; 0 otherwise.	0.45	0.35	0.40
General caste	=1 if operator belong to general caste (1=yes; 0=otherwise)	0.29	0.32	0.30
Farm Bihar	=1 if farm located in Bihar (1=yes; 0=otherwise)	0.28	0.27	0.28
Farm Odisha	=1 if farm located in Odisha (1=yes; 0=otherwise)	0.24	0.41	0.32
Farm WB	=1 if farm located in West Bengal (1=yes; 0=otherwise)	0.18	0.27	0.22
Farm UP	=1 if farm located in eastern Uttar Pradesh (Base)	0.29	0.05	0.18
SPF				
Yield	Rice yield (kg/ha)	1,784.34	2,060.85	1,916.81
Seed	Total seed (kg/ha)	33.53	35.70	34.57
Fertilizer	Total fertilizer, NPK (Nitrogen, Phosphorus and Potassium), Urea, and DAP (diammonium phosphate)	297.33	259.65	279.28
Labor	Total labor used (persons day/ha)	61.50	63.24	62.33
Rice_Area	Total area (ha)	0.41	0.41	0.41
FD_2015	=1 if farm faced flood and drought occurrence in 2015; 0 otherwise	0.65	0.64	0.65
S_IRRI	=1 if farmer uses supplemental irrigation; 0 otherwise	0.69	0.49	0.59
M_Land	Share of farmers with medium land (lowland and upland)	0.56	0.42	0.49

Machine	=1 if farm uses machine in rice production; 0 otherwise	0.89	0.82	0.86
F_Equip	=1 if household owns large agri. equipment (land leveler, tiller, thresher); 0 otherwise	0.14	0.12	0.13
Hired labor	=1 if household hired labor; 0 otherwise	0.60	0.66	0.63
Local Variety	=1 if rice variety without government released information; 0 otherwise	0.13	0.12	0.13
MV1	=1 if rice variety released before 1977; 0 otherwise	0.12	0.10	0.11
MV2	=1 if rice variety released 1977-85; 0 otherwise	0.17	0.20	0.18
MV3	=1 if rice variety released 1986-199); 0 otherwise	0.12	0.10	0.11
MV4	=1 if rice variety released 1996 or later; 0 otherwise	0.07	0.07	0.07
MV5	=1 if hybrid rice variety released 1995 and later; 0 otherwise	0.12	0.09	0.10
MV6	=1 if mixed modern rice variety except hybrid; 0 otherwise	0.27	0.32	0.30

Source: 2016 Rice Monitoring Survey conducted by IRRI.

Table 3: Marginal Effects from Probit Estimates of the Unmatched and Matched Groups, eastern India 2016.

Dependent: Access to financial services	Unmatched		Matched	
	Marginal effects	SE	Marginal effects	SE
Spouse_Age	-0.002*	(0.001)	-0.002	(0.001)
Spouse_P[1]	0.051	(0.035)	0.047	(0.036)
Spouse_M[2]	0.058*	(0.034)	0.055	(0.034)
Household size[3]	0.016*	(0.009)	0.014	(0.010)
Children	-0.066**	(0.027)	-0.055**	(0.027)
Below Poverty card	0.054**	(0.027)	0.052*	(0.027)
Livestock[4]	0.023**	(0.010)	0.021**	(0.010)
Off-farm income[5]	-0.028	(0.045)	-0.016	(0.046)
Ground irrigation [6]	-0.017	(0.036)	-0.018	(0.037)
Mobile phone	0.138***	(0.031)	0.132***	(0.031)
SC/ST[7]	0.057	(0.036)	0.052	(0.036)
OBC[8]	0.036	(0.034)	0.031	(0.034)
Farm Bihar	-0.347***	(0.057)	-0.352***	(0.057)
Farm Odisha	-0.491***	(0.043)	-0.484***	(0.044)
Farm West Bengal	-0.473**	(0.037)	-0.464***	(0.039)
Log-Likelihood	-1,049.50		-1,032.25	
Total observations	1,697		1,656	

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

Notes: [1] Spouse completed class 5/primary or class below. [2] Spouse completed class 5/primary or degree above. [3] Adult (>15 years old) members of the household. [4] Livestock includes the following: buffalo, dairy cattle, goats, sheep, chicken, ducks, and pigs. [5] At least one of the couples has off-farm employment (such as service, business, or government). [6] Household uses groundwater irrigation sources such as shallow and deep-water tube well.

[7] 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. [8]Includes castes that are socially and educationally marginalized.

Table 4: Estimates of the Conventional and Sample Selection SPF: Unmatched sample.

		Pooled	Conventional		Sample Selection	
			With access	Without access	With access	Without access
Constant	β_0	7.688***	7.672***	7.814***	7.736***	7.767***
		(0.078)	(0.115)	(0.111)	(0.133)	(0.212)
Seed	β_1	-0.059**	-0.096***	0.020	-0.095**	-0.004
		(0.023)	(0.032)	(0.032)	(0.034)	(0.040)
Fertilizer	β_2	0.125***	0.094	0.142***	0.073	0.136**
		(0.040)	(0.062)	(0.049)	(0.067)	(0.056)
Labor	β_3	0.051*	0.080**	0.005	0.077*	0.006
		(0.027)	(0.037)	(0.033)	(0.042)	(0.042)
Area	β_4	0.121**	0.098	0.154**	0.073	0.118*
		(0.047)	(0.070)	(0.059)	(0.075)	(0.069)
$Seed^2$	β_{11}	0.129**	0.166**	0.041	0.166*	0.027
		(0.056)	(0.075)	(0.076)	(0.086)	(0.097)
$Fertilizer^2$	β_{22}	0.044	-0.078	0.312**	-0.089	0.371*
		(0.126)	(0.205)	(0.159)	(0.237)	(0.199)
$Labor^2$	β_{33}	0.074	0.006	0.199**	-0.004	0.182**
		(0.066)	(0.093)	(0.080)	(0.131)	(0.091)
$Area^2$	β_{44}	0.017	0.019	0.020	-0.015	-0.046
		(0.100)	(0.138)	(0.147)	(0.153)	(0.189)
Seed*Fertilizer	β_{12}	0.039	0.039	0.079	0.045	0.101
		(0.054)	(0.079)	(0.069)	(0.094)	(0.078)
Seed*Labor	β_{13}	0.004	0.035	-0.042	0.038	-0.028
		(0.041)	(0.056)	(0.054)	(0.075)	(0.068)
Seed*Area	β_{14}	0.089	0.144*	0.025	0.150	0.020
		(0.058)	(0.084)	(0.074)	(0.093)	(0.097)
Fertilizer*Labor	β_{23}	-0.073	-0.007	-0.170*	-0.027	-0.221*
		(0.061)	(0.087)	(0.094)	(0.107)	(0.116)
Fertilizer*Area	β_{24}	-0.018	-0.089	0.137	-0.113	0.148
		(0.095)	(0.148)	(0.118)	(0.179)	(0.158)
Labor*Area	β_{34}	-0.015	0.030	-0.071	0.015	-0.104
		(0.068)	(0.096)	(0.108)	(0.121)	(0.129)
Medium land	Med	-0.064**	-0.104**	0.010	-0.100	0.019
		(0.025)	(0.038)	(0.031)	(0.039)	(0.035)
Bihar	D_1	0.406***	0.356***	0.296***	0.406***	0.353**
		(0.044)	(0.052)	(0.084)	(0.084)	(0.126)
Odisha	D_2	0.318***	0.402***	0.092	0.485***	0.104
		(0.049)	(0.067)	(0.082)	(0.112)	(0.155)
West Bengal	D_3	0.658***	0.702***	0.478***	0.745***	0.511***
		(0.051)	(0.071)	(0.085)	(0.109)	(0.148)
Caste: ST	D_4	-0.103***	-0.084*	-0.095**	-0.087	-0.090
		(0.032)	(0.048)	(0.036)	(0.055)	(0.048)
Caste: OBC	D_5	-0.031	-0.104**	0.045	-0.097*	0.045

		(0.030)	(0.044)	(0.039)	(0.050)	(0.051)
Stress	D_6	-0.179***	-0.151***	-0.164***	-0.154***	-0.188***
		(0.027)	(0.041)	(0.034)	(0.045)	(0.042)
Irrigation	D_7	0.050	0.093*	-0.003	0.086*	0.012
		(0.032)	(0.049)	(0.036)	(0.048)	(0.049)
Machine	D_8	0.134***	0.158**	0.130***	0.178**	0.147***
		(0.038)	(0.068)	(0.040)	(0.069)	(0.045)
Equipment	D_9	-0.140***	-0.166***	-0.065	-0.170***	-0.074
		(0.035)	(0.051)	(0.041)	(0.054)	(0.046)
Hired labor	D_{10}	-0.102***	-0.176***	-0.069*	-0.175***	-0.080*
		(0.028)	(0.040)	(0.039)	(0.042)	(0.047)
MV1	D_{11}	-0.005	-0.111	0.059	-0.125*	0.072
		(0.046)	(0.068)	(0.055)	(0.066)	(0.063)
MV2	D_{12}	0.248***	0.259***	0.162***	0.228***	0.177***
		(0.042)	(0.061)	(0.046)	(0.058)	(0.056)
MV3	D_{13}	0.073	-0.011	0.124*	-0.043	0.144*
		(0.049)	(0.069)	(0.065)	(0.065)	(0.075)
MV4	D_{14}	0.253***	0.276***	0.176***	0.258***	0.203***
		(0.053)	(0.077)	(0.062)	(0.076)	(0.066)
MV5	D_{15}	0.059	0.048	0.022	0.009	0.044
		(0.051)	(0.071)	(0.066)	(0.076)	(0.096)
MV6	D_{16}	0.192***	0.146**	0.194***	0.107**	0.233***
		(0.041)	(0.058)	(0.047)	(0.054)	(0.053)
Financial access	FA	-0.042*				
		(0.024)				
Lambda (λ)		4.533***	3.869***	8.712***		
		(0.362)	(0.388)	(1.370)		
Variance (σ^2)		0.926***	0.909***	0.939***		
		(0.000)	(0.001)	(0.001)		
Sigma -u (σ_u)					0.917***	0.904***
					(0.030)	(0.021)
Sigma – v (σ_v)					0.213***	0.145***
					(0.036)	(0.025)
Rho (ρ)					-0.431	-0.185
					(0.486)	(0.827)
Log likelihood function		-1,362.85	-714.74	-604.99	-1,235.00	-1,136.51

*p<0.10, **p<0.05, ***p<0.001. Standard errors are inside the parenthesis.

Table 5: Estimates of the Conventional and Sample Selection SPF: Matched sample.

		Pooled	Conventional		Sample Selection	
			With access	Without access	With access	Without access
Constant	β_0	7.688***	7.672***	7.837***	7.781***	7.766***
		(0.079)	(0.115)	(0.103)	(0.134)	(0.078)
Seed	β_1	-0.067***	-0.096***	0.004	-0.090**	-0.006
		(0.023)	(0.032)	(0.030)	(0.033)	(0.022)
Fertilizer	β_2	0.126***	0.092	0.138**	0.093	0.097***
		(0.041)	(0.062)	(0.049)	(0.070)	(0.034)
Labor	β_3	0.048*	0.081**	-0.010	0.064	-0.010
		(0.027)	(0.037)	(0.032)	(0.042)	(0.026)
Area	β_4	0.114**	0.097	0.120**	0.081	0.068*
		(0.048)	(0.070)	(0.057)	(0.076)	(0.039)
Seed^2	β_{11}	0.120**	0.166**	-0.002	0.110	-0.035
		(0.056)	(0.075)	(0.072)	(0.070)	(0.055)
Fertilizer^2	β_{22}	0.067	-0.087	0.379**	-0.082	0.384***
		(0.128)	(0.206)	(0.161)	(0.248)	(0.118)
Labor^2	β_{33}	0.076	0.005	0.187**	-0.015	0.156**
		(0.067)	(0.094)	(0.078)	(0.131)	(0.058)
Area^2	β_{44}	0.044	0.018	0.093	-0.061	-0.039
		(0.103)	(0.139)	(0.145)	(0.154)	(0.124)
Seed*Fertilizer	β_{12}	0.056	0.040	0.118*	0.035	0.125**
		(0.055)	(0.080)	(0.064)	(0.094)	(0.051)
Seed*Labor	β_{13}	0.001	0.035	-0.061	0.015	-0.056
		(0.041)	(0.056)	(0.050)	(0.070)	(0.045)
Seed*Area	β_{14}	0.096	0.145*	0.019	0.107	0.016
		(0.059)	(0.085)	(0.072)	(0.087)	(0.064)
Fertilizer*Labor	β_{23}	-0.061	-0.007	-0.121	-0.060	-0.200***
		(0.062)	(0.087)	(0.096)	(0.110)	(0.068)
Fertilizer*Area	β_{24}	0.008	-0.094	0.219*	-0.134	0.163*
		(0.097)	(0.148)	(0.117)	(0.185)	(0.093)
Labor*Area	β_{34}	-0.001	0.030	-0.029	-0.028	-0.115
		(0.069)	(0.097)	(0.108)	(0.123)	(0.074)
Medium land	Med	-0.063**	-0.103**	0.025	-0.103**	0.039*
		(0.026)	(0.026)	(0.026)	(0.041)	(0.022)
Bihar	D_1	0.410***	0.356***	0.300***	0.437***	0.411***
		(0.044)	(0.052)	(0.077)	(0.084)	(0.052)
Odisha	D_2	0.320***	0.404***	0.095	0.534***	0.237***
		(0.050)	(0.067)	(0.077)	(0.109)	(0.048)
West Bengal	D_3	0.663***	0.703***	0.464***	0.815***	0.592***
		(0.053)	(0.071)	(0.079)	(0.111)	(0.048)
Caste: ST	D_4	-0.112***	-0.083*	-0.117***	-0.104*	-0.163***
		(0.032)	(0.048)	(0.035)	(0.056)	(0.027)
Caste: OBC	D_5	-0.034	-0.102**	0.035	-0.104**	-0.014

		(0.031)	(0.044)	(0.039)	(0.052)	(0.031)
Stress	D_6	-0.183***	-0.150***	-0.170***	-0.157***	-0.192***
		(0.028)	(0.041)	(0.034)	(0.046)	(0.023)
Irrigation	D_7	0.051	0.094*	0.001	0.083*	-0.028
		(0.032)	(0.049)	(0.036)	(0.049)	(0.031)
Machine	D_8	0.122***	0.159**	0.106**	0.157**	0.097***
		(0.039)	(0.068)	(0.039)	(0.075)	(0.029)
Equipment	D_9	-0.141***	-0.167***	-0.052	-0.179***	-0.044
		(0.036)	(0.051)	(0.039)	(0.057)	(0.031)
Hired labor	D_{10}	-0.102***	-0.175***	-0.081**	-0.168***	-0.084***
		(0.029)	(0.040)	(0.037)	(0.043)	(0.024)
MV1	D_{11}	0.0003	-0.112	0.097*	-0.118*	0.136***
		(0.047)	(0.068)	(0.055)	(0.068)	(0.035)
MV2	D_{12}	0.255***	0.258***	0.163***	0.208***	0.129***
		(0.043)	(0.061)	(0.044)	(0.059)	(0.029)
MV3	D_{13}	0.093**	-0.007	0.168***	-0.045	0.251***
		(0.050)	(0.069)	(0.061)	(0.067)	(0.051)
MV4	D_{14}	0.260***	0.276***	0.202**	0.231***	0.214***
		(0.054)	(0.077)	(0.060)	(0.072)	(0.039)
MV5	D_{15}	0.068	0.046	0.026	0.016	0.049
		(0.051)	(0.071)	(0.062)	(0.078)	(0.055)
MV6	D_{16}	0.209***	0.144**	0.238***	0.107*	0.244***
		(0.042)	(0.058)	(0.045)	(0.055)	(0.033)
Financial access	FA	-0.038				
		(0.024)				
Lambda (λ)		4.510***	3.915***	10.576***		
		(0.369)	(0.398)	(1.960)		
Variance (σ^2)		0.929***	0.912***	0.951***		
		(0.000)	(0.001)	(0.001)		
Sigma -u (σ_u)					0.919***	0.937***
					(0.033)	(0.012)
Sigma – v (σ_v)					0.241***	0.074***
					(0.049)	(0.018)
Rho (ρ)					-0.657**	0.838***
					(0.323)	(0.244)
Log likelihood function		-1,336.75	-714.74	-577.63	-1,224.64	-1,094.81

*p<0.10, **p<0.05, ***p<0.001. Standard errors are inside the parenthesis.

Table 6: Estimates of spouses' access to financial services on technical efficiency, technology, and managerial gap, rice production in eastern India, 2016.

	With access (1)		Without access (2)		Difference (3)
	Mean	SE	Mean	SE	Mean
Unmatched sample					
Conventional SPF					
Pool TE[a]	0.557	0.006	0.573	0.007	0.017*
TE[b]	0.561	0.007	0.648	0.005	0.087***
Sample Selection SPF					
TE	0.552	0.007	0.545	0.009	0.006
Metatechnology ratio (MTR)	0.618	0.006	0.569	0.006	0.049***
TE-Metafrontier[c]	0.338	0.005	0.305	0.006	0.033***
Matched sample					
Conventional SPF					
Pool TE[a]	0.556	0.007	0.571	0.007	0.015
TE[b]	0.561	0.007	0.671	0.004	0.110***
Sample Selection SPF					
TE	0.542	0.007	0.533	0.009	0.009
Metatechnology ratio (MTR)	0.608	0.006	0.547	0.007	0.061***
TE-Metafrontier[c]	0.328	0.006	0.291	0.006	0.036***

*p<0.10, **p<0.05,***p<0.001.

[a] TE estimates using conventional SPF and pooled data set.

[b] TE estimates relative to the individual's group frontier using conventional SPF.

[c] TE estimates relative to the metafrontier.

Table 7: Effects of Spouses' Access to Credit on Key Input Variables, Rice Production in Eastern India.

	With Access (1)		Without Access (2)		Diff (3)
	Mean	SE	Mean	SE	
Seed (kg/ha)	33.63	0.88	35.60	1.08	-1.97
Total fertilizer (kg/ha)	298.01	6.56	259.56	5.71	38.44***
NPK	97.02	2.70	87.73	2.35	9.29**
DAP	100.77	2.67	80.40	2.28	20.37***
Urea	100.22	2.48	91.44	2.41	8.79***
Total labor (persons-day/ha)	61.57	1.49	63.30	1.62	-1.73
Crop establishment[1]	29.75	0.75	28.32	0.78	1.43
Crop management[2]	13.52	0.51	15.50	0.62	-1.98**
Harvesting/post-harvest[3]	18.29	0.66	19.47	0.61	-1.18
Family labor (persons-day/ha)					
Crop establishment[1]	10.44	0.46	11.45	0.54	-1.02
Crop management[2]	8.06	0.33	9.20	0.41	-1.14**
Harvesting/post-harvest[3]	11.99	0.57	13.58	0.57	-1.59**
Hired labor (persons-day/ha)					
Crop establishment[1]	8.05	0.44	6.78	0.40	1.27**
Crop management[2]	2.09	0.18	3.17	0.23	-1.08***
Harvesting/post- harvest[3]	5.44	0.35	5.43	0.33	0.01
Contract labor (persons-day/ha)					
Crop establishment[1]	11.26	0.63	10.09	0.65	1.17
Crop management[2]	3.37	0.34	3.13	0.34	0.24
Harvesting/post-harvest[3]	0.86	0.14	0.46	0.11	0.40**
Farmers with loans	0.31	(0.02)	0.14	(0.46)	0.17***
Total loan[4] (Rs)	12,377	2,472	3,576	411	8,801***
Proportion of loan for farming	0.54	0.03	0.67	0.04	-0.13**
Proportion of loan for non-farming	0.46	0.03	0.33	0.04	0.13**

*** p<0.01, ** p<0.05, * p<0.1.

[1]Crop establishment labor activities include land preparation, nursery and planting, and transplanting/planting.[2] Crop management labor activities include application of fertilizer, pesticide, irrigation, weeding, and irrigation.[3] Harvesting/post-harvesting labor activities include harvesting, bundling, threshing, drying, and transporting.

[4]These include all loans availed for the past 12 months from different sources.

Appendix

Appendix Table 1: Description of Rice Varieties by Year of Released in Eastern India, 2016.

Variety type	Year released	Characteristics	Popular rice varieties in the sample and its released year
MRV1	Before or during 1976)	higher yield than traditional varieties and responsive to fertilizer but susceptible to pest and diseases.	Mahsuri (1972) and Annapura (1976)
MRV2	1977–1985	Resistant to multiple pests and diseases, making the yield more stable.	Swarna (1979)
MRV3	1986–1995	Better grain quality and improved pest resistance	MTU-1010 (1995), Moti (1988), and Pooja (1999)
MRV4	released 1996 later except hybrid rice varieties (HRV)	Varieties for adverse environments	Swarna-Sub1 (2009)
MRV5	released after 1995	superior productivity compared to the previously discussed MRV generations	Arize 6444 (2015), PHB 71 (1997), and GK-5000 (2008)
MRV6	Mixture of rice varieties except for MRV5 and local rice varieties		

Source: Laborte et al. (2015), Launio et al. (2008) and Indian Institute of Rice Research (IIRI).

Appendix Table 2: Standardized Percentage Balance, Pseudo R^2, and Final Sample Size Using Different Matching.

Type of matching	Standardized percentage bias[a]		Pseudo R^{2} [b]		LR-test		Final sample (units dropped)	
	Before matching	After matching	Before matching	After matching	Before matching	After matching	Treatment	Controlled
NN (5)	12.3%	2.2%	0.107	0.098	3.99**	3.59*	879 (5)	777 (36)
Kernel (0.04)	12.3%	2.0%	0.107	0.106	3.99**	4.20**	879 (5)	813 (0)
Radius	12.3%	2.4%	0.107	0.857	3.99**	2.35	879 (5)	702 (111)

*** p<0.01, ** p<0.05, *0.10

[a] Standardized percentage balance – mean of the treated (with access) minus the mean of the control (without access) divided by the average of the square root of the variance of the treated and control samples. Matching is sufficient if standardized bias is below 3% or 5%.

[b] Lower Pseudo R^2 after the matching and there is no systematic difference.

Appendix Table 3: Means Before and After Matching.

	Before matching			After matching			% R bias
	With access	Without access	*t-stats*	With access	Without access	*t-stats*	
Sample selection							
Spouse age (years)	42.00	42.19	-0.35	42.02	42.34	-0.60	-64.10
Spouse education: < primary (=1 if yes; 0 otherwise)[1]	0.19	0.20	-0.29	0.19	0.21	-1.23	-324.00
Spouse education: > primary (=1 if yes; 0 otherwise)[2]	0.27	0.26	0.89	0.28	0.27	0.30	66.50
Household size[3]	3.81	3.51	3.74***	3.81	3.82	-0.15	95.80
With kids under 9 years old (1=yes; 0=otherwise)	0.47	0.48	-0.48	0.47	0.48	-0.47	3.70
Below Poverty card (1=yes; 0=otherwise)	0.55	0.58	-1.26	0.55	0.51	1.61	-25.30
Number of livestock[4]	1.48	1.50	-0.23	1.48	1.50	-0.25	-3.80
Off-farm source of income (=1 if yes; 0 otherwise)[5]	0.44	0.54	-4.27***	0.44	0.44	0.08	98.20
Spouse owns phone (1 if yes; 0 otherwise)	0.31	0.16	7.27***	0.31	0.32	-0.72	89.30
Ground water irrigation (1 if yes; 0 otherwise) [6]	0.17	0.16	0.16	0.17	0.18	-0.66	-323.00
Scheduled caste/tribe (=1 if yes; 0 otherwise)[7]	0.26	0.32	-2.77**	0.27	0.26	0.18	93.70
Other backward caste (=1 if yes; 0 otherwise)[8]	0.45	0.35	4.04***	0.45	0.45	0.07	98.30
Farm located in Bihar (1=yes; 0=otherwise)	0.28	0.27	0.56	0.29	0.29	-0.24	56.80
Farm located in Odisha (1=yes; 0=otherwise)	0.24	0.41	-7.33***	0.24	0.25	-0.04	99.40
Farm located in West Bengal (1=yes; 0=otherwise)	0.18	0.27	-4.33***	0.18	0.18	0.24	95.00
SPF							
Yield (kg/ha)	1,784.3	2,060.8	-5.23	1,787.0	1,867.9	-1.59	70.80
Seed (kg/ha)	33.53	35.70	-1.60	33.63	29.97	2.93***	-68.80
Total fertilizer (kg/ha)	297.33	259.65	4.35	298.01	274.15	2.76**	36.70
Total labor (person-day/ha)	61.50	63.25	-0.80	61.57	60.68	0.44	49.20
Total cultivated rice area (ha)	0.41	0.41	-0.14	0.41	0.41	0.04	73.4
Experienced flood/drought 2015 (=1 if yes; 0 otherwise)	0.65	0.64	0.67	0.65	0.68	-1.21	-75.40
Use supplemental irrigation (1=yes; 0 otherwise)	0.69	0.49	8.47	0.68	0.66	1.02	88.50
Proportion of medium land	0.56	0.42	6.14	0.56	0.48	3.49***	43.80
Use farm machine (1=yes; 0=otherwise	0.89	0.82	3.85	0.89	0.89	-0.02	99.70

Appendix Table 3 (continued)

	Before matching			After matching			
	With access	Without access	*t-stats*	With access	Without access	*t-stats*	% R bias
Owns large farming equipment (=1 if yes; 0 otherwise)[9]	0.14	0.12	1.33	0.14	0.10	3.18***	-124.50
Hired labor (1=yes; 0=otherwise)	0.60	0.66	-2.44	0.60	0.62	-1.09	55.90
MRV1 (before 1977) (=1 if yes; 0 otherwise)	0.12	0.10	1.03	0.12	0.10	1.32	-25.00
MRV2 (1977-85) (=1 if yes; 0 otherwise)	0.17	0.20	-1.38	0.17	0.15	0.97	34.30
MRV3 (1986-1995) (=1 if yes; 0 otherwise)	0.12	0.10	1.63	0.12	0.22	-5.38***	-282.80
MRV4 (1996 or later) (=1 if yes; 0 otherwise)	0.07	0.07	-0.07	0.07	0.05	1.14	-1327.40
MRV5 (hybrid rice 1995 and later =1 if yes; 0 otherwise)	0.12	0.09	1.80	0.12	0.11	0.68	61.70
MRV6 (mixed generation) (=1 if yes; 0 otherwise)	0.27	0.32	-2.13	0.27	0.26	0.65	71.20

[1] Spouse completed class 5/primary or class below.
[2] Spouse completed class 5/primary or degree above.
[3] Adult (>15 years old) members of the household.
[4] Livestock includes the following: buffalo, dairy cattle, goats, sheep, chicken, ducks, and pigs.
[5] At least one of the couples has off-farm employment (such as service, business, or government).
[6] Household uses groundwater irrigation source such as shallow and deep water tubewell.
[7] 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.
[8] Includes castes that are socially and educationally marginalized.
[9] Large agricultural equipment (such as land leveler, tiller, and thresher).
Source: 2016 Rice Monitoring Survey conducted by IRRI.

Appendix Table 4: Hypothesis Tests.

Test	Test statistics	p-value	Outcome
Frontier test (Ho: No inefficiency component)	LR = 176.513	0.000	Frontier not OLS
Test for constant returns to scale (Ho: CRS)	χ^2= 1076.154	0.000	Returns to Scale is not constant
Pooing test (Ho: pooled sample)	χ^2= 92.589	0.000	Sperate two groups
Cobb-Douglas or Translog (Ho: Cobb-Douglas)	LR = 17.11	0.060	Translog function