Crop Insurance and Food Security: Evidence from Rice Farmers in Eastern India

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Abstract

The paper explores the spread of crop insurance (CI) in India and analyzes the association of factors affecting the demand for crop insurance. Additionally, using large farm-level survey data from Eastern India, the study assesses CI's impact on rice yields of smallholder rice producers. The study tests for robustness of the findings after controlling for other covariates and endogeneity. Results indicate CI has a positive and significant impact on rice yields. In particular, the ATET and ATEUT effect of CI on rice yields is about 47%. However, CI's impact on rice yields is heterogeneous among farm sizes of smallholders. Participation in CI increased rice yields of large farms by 49% but increased rice yields of small farms by only 16%.

Keywords: crop insurance, rice yield, farm size, India, food security, treatment effects, heterogeneous treatment effects

JEL codes: O13; Q14; Q18

Introduction

Agriculture is a risky profession, and the outcomes from agriculture are subject to variations in weather and market forces. Variations due to weather have increased over time due to climate change. It is also likely that climate change will have heterogeneous impacts across geographical regions (Lobell et al., 2008; Dell et al., 2008). Countries in South Asia and Southern Africa are likely to suffer more from climate change than those in Europe or North America, and these changes are likely to have an impact on both production and yield of major crops like rice and maize. The risk and uncertainty in production and yield of crops is not likely to impact just the food security of the nation (Wheeler and von Braun, 2013), but is also likely to directly impact income and poverty among rural populations in general and farming households in particular (Barnwal & Kotwani, 2013). The authors note that rural livelihoods face increased vulnerabilities in food security.

Given this background, it is vital to understand the instability in production of crops, yield, adaptation strategies used, and the effectiveness of the adaptation strategies on food security. In a

recent study, Ray et al. (2015) find that India was among the countries with the highest coefficient of variation for maize and rice yields. Ray et al. (2012) estimate that maize yields have stagnated in 31% of India's maize-growing areas. Similarly, yields have stagnated in 36% of India's rice-growing areas, 70% of its wheat-growing areas, and more than 1 million hectares of its soybean-growing area (Ray et al., 2012). This combination of slowing/stagnant growth and instability in yields could significantly affect the vulnerability and viability of small and marginal farmers in India. India is a vast country of 29 states with varied climatic and soil typology. The instability in food grain production is heterogeneous across the states. For instance, states like Maharashtra, Bihar, Tamil Nadu, Orissa, Madhya Pradesh, Rajasthan, and Gujarat indicate highly unstable food grain production. Though instability in production had declined in some states of India, the variations in farmers' crop incomes are high and indicate an urgent need to work on measures to stabilize crop yields, prices, and revenues for farmers (Chand and Raju, 2008).

In such a context where variability in climate, modern technology, and smallholders' adaptation measures are interacting with increased variability in crop incomes, formal insurance markets could play an important role in fostering agricultural development, increasing productivity, and increasing food security in India (Hazell and Hess, 2010). The Government of India (GoI) under the 2016 *Pradhan Mantri Fasal Bima Yojana* (PMFBY) has recognized the need for crop insurance (CI) in achieving food security. Although CI has existed in India for some time, the spread of CI has gained momentum in recent years due to increasingly frequent extreme climate events, growing agrarian distress, and market reforms. Despite this background, there has been very little literature on the evaluation of insurance products in India (e.g., Tobacman et al., 2017). In their study, Tobacman et al., (2017) evaluated the feasibility of rainfall insurance in three

districts of Gujarat. To best of our knowledge, the literature fails to address the issue of CI and food security of smallholders in India.

Herein lay the objectives of this paper. This study investigates the relationship between CI and food security of smallholder households in India. First, the study explores CI's impact on rice yield of smallholder producers in Eastern India.[1] Second, the study identifies whether the impact is different for insured and uninsured farmers by calculating the average treatment effect on the treated (ATET) and the average treatment effect on the untreated (ATEUT). Finally, the study identifies the heterogeneous impacts of CI on rice yields by farm size (small, marginal, medium, and large). To address the above objectives, the study uses large-scale survey data collected from smallholder rice farmers in six Indian states. These states were selected because they are in similar agro-ecological zones, have the same soil typology of Eastern India and more prone to risk than other regions of India.

This study contributes to the literature in several ways. First, the study addresses CI's impact on food security (rice yield). CI is attractive to policymakers who are seeking ways to address risk and uncertainty in agriculture and overcome their effects on food security. Second, due to budgetary pressures and government's reduced role in the agricultural sector, policymakers are seeking ways to privatize risk management strategies in India, and our analysis is very pertinent in this context. Finally, the analysis is conducted with the unique large representative sample comprising farms of different economic sizes and located in different states of Eastern India.

The rest of this paper is organized into six sections. The next section provides information on survey data. Third section provides a brief historical background of crop insurance in India. The forth section provides measures of food security. The fifth section provides the conceptual and

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[1] Includes states like Bihar, West Bengal, Odisha, Eastern Uttar Pradesh, Jharkhand, and Chhattisgarh.

econometric framework used in the study. Sixth section provides the results, and the final section provides some concluding comments and policy implications.

Survey Data

This study uses data from a primary survey conducted in six states: Bihar, Chhattisgarh, Eastern UP[2], Jharkhand, Odisha, and West Bengal in the eastern region of India, a region considered the hub of poverty and undernourishment in India. The region accounts for more than 50 percent of India's poor and food-insecure population. The region is predominantly agrarian, and farms are mostly small and marginal with limited resources. Smallholders in this region face several challenges, including recurrent floods and droughts, cyclones, and numerous pests and diseases. Farmers also face severe constraints such as rising input prices, declining farm profits, and increasing strains on natural resources. Rice is the eastern region's major crop, accounting for about 60 percent of the gross cropped area. Among the states mentioned above, thirteen predominantly rice-growing districts were selected from each state (*Figure 1*). In each district, we randomly sampled three blocks. We then randomly sampled two villages from each block. A house listing was conducted in each village to obtain a large sample of farm households, from which we randomly selected 20 households to survey. Thus, we collected data from 78 districts spread over 468 villages. The final sample after data cleaning consisted of 8,440 farm households. The sample households consisted of 60 percent marginal farmers, 29 percent small farmers, 7 percent medium farmers and 4 percent large farmers. The survey queried farmers on a variety of operator and household characteristics, variety adoption, source of information, credit and insurance.

Table 1 presents the definition and summary statistics of the variables used in this study. Table 1 shows significant differences between insured and uninsured rice farmers in Eastern India.

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[2] We considered eastern UP only as other parts of the state do not come under eastern region.

For instance, the rice yield for all farmers averages 2.66 tons/acre, but the yield among insured farmers is almost double (3.76 tons/acre) the yield of uninsured farmers (1.83 tons/acre), a difference that is statistically significant at the 1% confidence level.

Table 1 also shows significant statistical differences across various demographic, agricultural, and socio-economic characteristics of insured and uninsured rice farmers in Eastern India. In the sample, 25.2% of all household heads (HH) are illiterate, and 23.9% had less than 5 years of schooling (primary education). More than one-third (36.4%) of HHs had 6 to 10 years of schooling (secondary education), and 14.5% had more than 10 years of schooling (tertiary education). There was a slightly larger proportion of illiterate farmers and a slightly smaller proportion of farmers with primary education among the uninsured rice farmers, compared to the insured rice farmers.

Caste[3], a unique Indian social institution, plays an important role in Indians' economic life, schooling, income, food, and access to inputs and service. Table 1 reveals that almost half (47.1%) of all farmers belonged to the other backward caste (OBC), 20.8% to the general caste, 13.1% to scheduled castes (SCs), and 18.7% to scheduled tribes (STs). The SCs and STs are historically dominant lower castes and lag other caste categories in many socio-economic indicators. In particular, the SCs and STs have had less access to land and assets than OBCs and the general caste. Table 1 shows that among insured farmers, 12.1% belong to the general caste, 50.1% to the OBC, 27% to STs and the remaining 10% to SCs. These percentages could vary across states due to different caste compositions in the states. For instance, Chhattisgarh and Jharkhand states have a larger proportion of farmers belonging to STs, and therefore STs form a larger proportion of

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[3] The Caste system is comprised of four hierarchical categories, the Brahmins, Kshatriyas, Vaishyas, and Shudras. These castes are classified as Scheduled Castes (SCs), the socially and economically marginalized, indigenous ethnic groups that are classified as Scheduled Tribes (STs), and, more recently, another group of castes, which are referred to as Other Backward Castes (OBCs).

insured farmers. The household size of all smallholder rice producers averaged 6.84, with the number of family members lower for insured farmers than for uninsured farmers. The difference was statistically significant at the 1% level. Of all farmers, 73.8% indicated farming is their primary occupation; however, only 70% of insured farmers and 76.7% of uninsured farmers indicated farming is their main occupation. Finally, insured farmers had slightly more farming experience (25.2 years) than uninsured farmers (24.2 years).

In terms of agricultural characteristics, land size for all farmers averaged 2.89 acres (table 1), with land size significantly higher (3.28 acres) for insured farmers than for uninsured farmers (2.59 acres). In terms of irrigation facilities, 54.9% of farmers in the sample had no access to any source of irrigation; 34.2% had access to groundwater irrigation, including pumps and tube well; and 10.9% had access to surface water irrigation, including canals, rivers, and ponds (table 1). Table 1 shows that a larger proportion of insured farmers had no source of irrigation, compared to uninsured farmers, and a larger share of uninsured farmers had access to groundwater irrigation, compared to insured farmers. Findings here might indicate that farmers perceive CI as a substitute for access to irrigation facilities. Thus, rice farmers with access to groundwater irrigation may not perceive the need for CI. In terms of land typologies based on land elevation[4], we find that about 61.6% of all rice farmers have plots that are classified as medium land, 28.7% have plots classified as lowland, and 10.9% have plots classified as upland. Rice is typically cultivated in medium land,

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[4] Technically, the classification of low land, medium land, and up land occurs based on the elevation of the land above sea level. Land elevations of less than 200 meters above sea level are considered low land, those above 400 meters are considered upland, and between 200 meters to 400 meters are considered medium land (https://www.bbc.com/bitesize/guides/zsg639q/revision/3). But our variable is considered based on the responses by farmers on where their plots of land are present. Farmers would have referred to land at higher elevation than typical plots in the village as upland, land at lower elevations would have been classified as lowland, and the average elevation would have been categorized as medium land.

and a study in Eastern India and Bangladesh (Hossasin et al., 2012) found a similar distribution of rice cultivation across medium, low and upland.

Table 1 also reveals significant differences in other socio-economic characteristics of insured and uninsured rice farmers in Eastern India. A higher proportion of insured farmers had soil health cards (15.2%) than did uninsured farmers (4.4%). A higher proportion of insured farmers had debt (27.4%) and Kisan credit cards (50.7%) than did uninsured farmers (13.3% and 21.2%, respectively). This finding is not surprising as access to CI is closely linked to access to credit, and CI is mainly sold through banks and private enterprises. Table 1 shows that insured farmers have more assets than uninsured farmers, and that the proportion of progressive farmers[5] is higher among insured farmers than uninsured farmers. Table 1 shows that insured rice farmers cultivate more crops (1.56) than do uninsured farmers (1.22). We also find that insured farmers have diversified into livestock production, having more cattle, goats, and sheep than uninsured farmers have. The above findings indicate that besides purchasing insurance, risk-averse rice farmers are engaging in additional self-insurance (Ehrlich and Becker, 1972) by cultivating more crops and diversifying income through additional farming enterprises such as livestock.

Finally, table 1 shows characteristics that seem to influence access to CI. However, some unobserved characteristics could be correlated to both access to CI and rice yields. It is in this background that we choose an instrumental variable estimation technique of the treatment effect. We consider two IVs in this regard. The survey queried rice farmers whether they considered drought a significant constraint to farming. We find that 79.5% of insured rice farmers considered drought a constraint, but only 48.5% of the uninsured farmers did (table 1). This finding could have a significant influence on the decision to buy CI. We also find that 10.3% of insured rice

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[5] Progressive farmers comprised 10% of the sample and are defined as those who typically initiated the adoption of newer inputs and provided advice related to use of inputs like fertilizers and pesticides.

farmers belonged to a farmers' club or a group, but only 3.3% of uninsured rice farmers did. Again, membership in a farmers' club or group could indicate access to CI. Therefore, two variables, drought as a constraint and membership in a farmers' club or group, could serve as IVs in this study.

Crop Insurance in India

The provision of the first government-subsidized CI product in India dates to 1972. Since then, various insurance schemes have followed; for a detailed account of the evolution of CI schemes in India, see Raju and Chand (2007 and 2008). For a long time, the publicly funded insurance company, Agricultural Insurance Corporation of India (AIC, India) was the sole provider of CI in India. Despite all the efforts, farmers' CI coverage in India has historically been low (see Dandekar, 1976, 1985; Mishra 1995; Sinha 2004; Clarke et al., 2012 and Mukherjee and Pal, 2017 for details)[6]. The Indian government now offers insurance products that combine the features of weather-based index (WBI) and area-based yield (ABY) crop insurance (Clarke et al., 2012). The *Modified National Agricultural Insurance Scheme* (MNAIS) and the *Pradhan Mantri Fasal Bima Yojana* (PMFBY), launched in 2010 and 2016 respectively, combine the features of WBI and ABY insurance programs.

Several unique features of the PMFBY have gained popularity among food-crop and oilseed farmers. These features include: (1) The sum insured is determined by the district-level technical committee (DLTC), which takes into account the cost of cultivation on the basis of land quality, irrigation expenses, and costs of fertilizer, seeds, and labor; (2) the premium rates is fixed at 2% of the sum insured or the actuarial rate, whichever is less, for Kharif season and at 1.5% for Rabi season; (3) the estimation of crop yield is based on crop-cutting experiments at the village

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[6] Various insurance products in India and challenges related to the spread of crop insurance in the country.

level for four major crops and eight other crops; (4) a bigger role for private insurance companies; (5) a requirement that payments be processed within 30 days of a loss; (6) the timely release of premium subsidy to private companies; (7) the use of modern technology;[7] (8) publicity and awareness, such as significant outreach to farmers through smartphones, electronic and print media, and documentaries. As a result, under the newly launched PMFBY program, the insured area increased slightly from about 54 million hectares (ha) in 2015-16 to about 57 million ha in 2016-17 (Gulati, Terway and Hussain, 2018).

However, during the same period, the number of insured farmers increased 21.3% (from about 47 million to 57 million). The agricultural census of India 2015-16 puts the number of operational holdings at 146 million[8] and operating area at 157 million hectares. This would mean an insurance coverage of roughly 39% based on operational holdings and 36% based on operating area. Seasonally, the PMFBY program provided coverage for about 39 million farmers in the 2016 Kharif cropping season, up from about 25 million farmers during the same cropping season in 2015. The report by Gulati, Terway and Hussain (2018) points out that India's CI program has taken significant, structurally sound steps forward. By launching these programs, the GoI has shown the willingness to provide CI to more farmers and to increase participation by private insurance companies. In the last two seasons (*Kharif* 2016; *Rabi* 2016-17), approximately 24 million hectares have been insured under the PMFBY[9] program, and the gross cropped area during the period was about 200 million hectares[10].

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[7] Use of mobile based technology with GPS stamping to assess crop loss.
[8] http://agcensus.nic.in/document/agcen1516/T1_ac_2015_16.pdf
[9] http://www.aicofindia.com/AICEng/Pages/BusinessProfilePMFBY.aspx
[10] http://agricoop.nic.in/sites/default/files/Annual_rpt_201617_E.pdf. The report has data related to gross cropped area in 2015-16. Given that the deviations in total cropped area are less over the last few years, we could expect that the gross cropped area in 2016-17 is also likely to be similar to 2015-16, which was 200.9 million hectares.

Figures 2 and 3 show the distribution of farmers and insurance coverage across farmland categories in the sample. Figure 2 reveals that a large proportion of farmers, about 85%, are marginal or small farmers, with land holdings of 5 acres or less. A small share, 0.5% of agricultural households, operate large farms of greater than 25 acres. The distribution of farms in the sample reflects a similar distribution of farms in India. When it comes to CI coverage level, figure 3 shows that 43% of all smallholder farms in the sample were covered. The sample estimates show a higher CI coverage than 36% or 39% suggested by 2015-16 agricultural census. Coverage also varies by farm size. CI coverage for marginal and small farmers was 39% and 46%, respectively; semi-medium and medium farmers had much higher coverage of 52% and 62%, respectively; and large farmers (42 farmers) had a coverage level of 40%. Figure 4 presents the distribution by state of CI coverage in the sample rice farmers in Eastern India. The figure reveals that CI coverage is highly heterogeneous. For instance, rice farmers in two states, Chhattisgarh and Jharkhand, had relatively higher CI coverage—88% in Chhattisgarh and 72% in Jharkhand— but farmers in Odisha, a major rice-producing state, had relatively less CI coverage (53%), and significantly fewer rice farmers in Bihar (20%), Eastern UP (11%), and West Bengal (8%) had CI coverage.

Food security

It is widely accepted that a lack of adequate food, whether chronic or transitory, is a principal indicator of food insecurity and poverty. Food insecurity is a major public policy concern in many developing countries, and agricultural development is crucial in addressing this problem. The definition of food security focuses on four distinct but interrelated elements, all of which are essential to achieving food security. These elements are: (1) food availability; (2) food access; (3) food utilization; and (4) food stability (Tweeten, 1997). Discussions in the 1970s emphasized the

supply side of food security, pointing to shortfalls in food availability related to shortages in food supply and high food prices (Sen, 1981).

Food insecurity could be measured at the macro level (e.g., nation, state, district) or at the micro level (e.g., household). Food insecurity and poverty are significant problems for rural households, the majority of which are farming households in developing countries. In the early 2000s, Bickel et al. (2000) developed a guide on how to measure household food security. The guide could not identify a single independent indicator that sufficiently captures the full range of food security/insecurity measures. Several indicators therefore are needed to accurately reflect a household's food security status. According to Bickel et al. (2000), household surveys can be used to provide information on indicators of food security. For example, a household running out of food without money to obtain more food, a respondent's perceptions that food eaten was inadequate in quality or quantity, and a household adjusting the number of meals per day could be used as indicators of food insecurity. Finally, Diao and Pratt (2007) noted the importance of both agricultural and non-agricultural efforts in solving problems of food security,[11] hunger and poverty in developing economies.

One of the most common methods used to assess food access is the Food and Agricultural Organization (FAO) of the United Nations (UN) method, which focuses on estimations of habitual dietary energy supply per capita at the country level. The use of food balance sheets allows for identification of the supply of commodities, utilization, and the supply available for consumption. Advantages of this method include data availability (secondary data) for most of the countries, updated yearly in collaboration with the World Bank. Consumption data and a wide variety of

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[11] Defined as the amount of food physically available to a household (micro level) or in the area of concern (macro level) through all forms of domestic production, commercial imports, reserves and food aid.

indicators for the four pillars of food security, which allow for comparisons at the regional, national, and global level, are also available. At the household level, household expenditure surveys are the third most commonly used method to collect information on food security. Outcomes include caloric intake per capita per household and dietary variety scores, with emphasis on expenditures on food and necessities, quantity of food produced and purchased, as well as food received as gifts or payments. Researchers report advantages of this method in terms of addressing the accessibility dimension of food security and dietary quality data (Smith and Subandoro, 2007), evaluation of household insecurity, and evaluation of food and nutrition programs (Rose and Charlton, 2002). The survey does not address food consumption directly, which can leave room for error in the measurement of food security. From a logistic approach, it is also hard to control whether the food consumed comes from gifts, own production, or purchase. Other measures of food access include the anthropometry index, food consumption score, food variety score, household dietary diversity score, and household food insecurity access scale.

Crop yield is a measure of food availability—an indicator of food security (Fischer, Byerlee, and Edmeades, 2014). In this study, we consider rice yield as the main indicator of food security. Rice is a staple food for more than 4.4 billion Asians. Asia produces and consumes more than 90% of the total rice production. India is the world's second-largest producer and consumer of rice. Rice is the most important individual source of dietary energy in Asia, providing 31% of dietary calories and 22% of total protein intake. Rice's share of food expenditures ranges from 4% to 31% across Asian countries. The poor spend more income on rice than the rich do. A 25% increase in rice prices translates into a 7–10% drop in the real income of the poor (IRRI, 2008). Thus, in India, rice farming plays a vital role in rural income, employment, livelihood, food security, and national stability.

To achieve food security in India, we need to understand yield improvement, and yield-based analysis would be meaningful to understanding food security under an assumption of managed risk. Recall that CI, by offering the chance to shift production risk, enables rice producers to engage in risky business and expand their farming operation by relaxing input and financial constraints (Ahsan et al. 1982). To understand CI's impact on rice yield, we use an ex-post evaluation approach through counterfactual evidence-based statistical analysis. We consider adoption of CI as a treatment provided to farmers and use IVs to deal with the issue of treatment endogeneity. We also test for robustness of our results by comparing the treatment effects using a Heckman two-step selection model.

Conceptual and Empirical Framework

In the context of CI and farm production, conceptual studies such as Ramaswami (1993), Chambers and Quiggin (2002), and Carter et al. (2016) provide a framework for CI's impacts on the reallocation of farm resources. Ramaswami (1993) examines the effect of crop insurance on supply response in a model with single- and multiple-input production functions under an expected utility framework. The effect of insurance is decomposed into risk reduction and moral hazard. Ramaswami (1993) suggests that the direction of the effect of insurance on supply response is ambiguous. Chambers and Quiggin (2002) use the Arrow-Debreu state-contingent approach and investigate the linkage between a crop producer's insurance choice and production decisions when area-yield insurance is available. They provide a sufficient condition for the provision of area-yield insurance to induce a change toward riskier production patterns. Ahsan et al. (1982) showed that with single input and single uncertain output, CI promotes agricultural output. Other studies in the literature show that CI changes the planting structure (Wu 1999; Young et al. 2001). In the early 2000s, Hau (2006) examined the impact of output decision of a risk-averse producer facing

profit risk (price and output uncertainty) in the presence of CI or hedging. Consistent with Ahsan et al. (1982), Hau's analysis reveals that under certain conditions CI can increase agricultural output. We use Hau's (2006) economic model and the following econometric tool to estimate our empirical model.

We consider CI as a binary treatment that a farmer adopts or does not adopt. We consider I to be the binary treatment that takes a value of 1 for insured smallholder rice producer, 0 for otherwise. Let y_1 and y_0 denote potential rice yields for smallholder households with and without CI. The average treatment effect (ATE) of CI on rice yield can be specified as:

$$ATE = E(y_1 - y_0) \tag{1}$$

The estimation of the above is not straightforward with observational data as we observe the rice yield of the household only in the insured or uninsured state, and hence identifying the ATE Ordinary Least Squares (OLS) may not be prudent. As we estimate the ATE, we also are interested in estimating two other parameters: the ATE of CI on yield among insured smallholder rice producers, and the ATE of CI on yield among uninsured smallholder rice producers. The two quantities estimated are the average treatment effect on the treated (ATET) and average treatment effect on the non-treated (ATENT) given by:

$$ATET = E(y_1 - y_0|I = 1) \tag{2}$$

$$ATENT = E(y_1 - y_0|I = 0) \tag{3}$$

To estimate the parameters, we start with the following assumption related to the rice yield among farmers:

$$y_0 = \mu_0 + x\beta_0 + e_0, E(e_0) = 0, E(e_0|x) = 0, \mu_0 = parameter \tag{4}$$

$$y_1 = \mu_1 + x\beta_1 + e_1, E(e_1) = 0, E(e_1|x) = 0, \mu_1 = parameter \tag{5}$$

$$y = y_0 + I(y_1 - y_0) \tag{6}$$

where x is the vector of covariates that affects smallholders' rice yield. These factors include demographics, household attributes, farm characteristics (farm size and plot characteristics), and various other socio-economic characteristics (assets and livestock holdings) of the rice farmers. Substituting (4) and (5) into (6), we obtain:

$$y = \mu_0 + (\mu_1 - \mu_0) * I + x\beta_0 + (x\beta_1 - x\beta_0) * I + e_0 + (e_1 - e_0) * I \tag{7}$$

In the above equation, the treatment effect can be estimated by an OLS if the unobserved factors influencing the treatment (those who have CI) are independent of the error terms e_1 or e_0. In such a scenario, an OLS of the following form will be sufficient in estimating the treatment effects:

$$y_i = \mu_0 + \alpha I_i + \beta_0 x_i + I_i(x_i - \mu_x)\beta + \varepsilon_i \tag{8}$$

where α is the ATE of CI on rice yields, and β provides the estimate of heterogenous treatment effects of CI on rice yields. However, in equation (7), if unobserved factors determining the purchase of CI are also correlated with the error terms, CI treatment is considered endogenous to rice yields and thus OLS estimation would lead to biased estimates. A possible solution is to assess the propensity to purchase CI (I_i) by individual. Specifically:

$$I_i = \theta_0 + x\theta_1 + \mu \tag{9}$$

where μ is the error term. Endogeneity arises if the error term μ is correlated with e_0 or e_1. In such a case, an instrumental variable (IV) method will provide consistent estimates of treatment effect. Applying IV estimation requires at least one variable, z, the instrumental variable (IV), which is correlated to the CI purchase decision but directly uncorrelated with rice yields. Once we have identified the IV, the treatment effects can be estimated by various econometric techniques. We estimate the empirical model, three different IV estimation methods, using *ivtreatreg* in STATA (Cerulli, 2014). All three estimation techniques first use an OLS or probit regression to estimate participation in CI or treatment group on the covariates and IV to predict the value of I_i and use

the predicted probabilities to estimate the treatment effect. The first method, Direct Two Stage Least Squares (D-2SLS), does not consider the binary nature of the CI treatment and uses an OLS regression to estimate the predicted probability of CI participation. The second method, Probit-OLS technique, considers the binary nature of the CI treatment in the first stage. The third method, Probit-2SLS, estimates a Probit of model of CI treatment on covariates and the IV variable to obtain the predicted values of being in CI treatment. In the final stage, an OLS regression of rice yields on covariates and fitted values of CI treatment is used to obtain the consistent estimates of ATEs. The estimates obtained from the Probit-2SLS regression are considered more efficient than those obtained from the other two methods. Additionally, the IV estimates are considered more robust to distributional assumptions of error term than those obtained by Heckman's two-step selection method.[12] Finally, we compare the treatment effects based on IV estimation with estimates obtained from Heckman's two-step selection method (Cerulli, 2014).

Results and Discussion

Table 2 indicates that even after accounting for endogeneity, CI has a positive impact on rice yields. In particular, results in table 2 suggest that CI increases rice yields by 47%. Findings indicate that CI promotes agricultural output by helping farmers managing risk. Lenders in India require borrowers to participate in CI programs. Anecdotal evidence in the study area suggests that farmers tend to use newer and improved seeds, technology, or credit, knowing that CI covers crop failure. Further, as pointed out in Ahsan et al. (1982), CI enables farmers to engage in risky activities that they would not undertake otherwise. Access to and availability of CI changes the farmer's attitude and induces him to undertake risk. For instance, Ray (1974) found that rice farmers in Anuradhapur, a risky district of Sri Lanka that relies on rain-fed irrigation, started

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[12] Heckman's method is considered to be more efficient that IV estimates, if the errors are normally distributed.

cultivating rain-fed rice when CI became available.[13] Additionally, Mishra (1994) found that insured smallholder households invest more in agricultural inputs, leading to higher output and income per unit of land[14], leading to higher output and income per unit of land. Another plausible explanation for our finding is that farmers may increase acreage by adopting improved but uncertain technology when they are assured of compensation in case of crop failure (Hazel, 1992; Bhende, 2005). Finally, in conjunction with a minimum support price (MSP), CI may allow rice farmers to service higher levels of debt with no increase in risk. Our results are consistent with findings in the literature that show insurance changes farmers' behavior toward investing more in crops with more risk and higher returns (Cai, 2016; Karlan et al., 2014)). Cai (2016) found that CI program for tobacco producers in China increased tobacco production by 16%. In another study, Cai et al., (2015) found that adoption of sow insurance significantly increased farmers' sow production, an increase not induced by substituting other livestock.

Table 2 reveals other factors affecting rice yields. For instance, educational attainment of the head of household (HH) is significantly and positively correlated with rice yields. Primary, secondary and tertiary education of the HH increases rice yields by 8.3%, 10.8%, and 15.4%, respectively, compared to HHs who are illiterate. A possible explanation is that education enhances technical and allocative efficiency of resources (Khaldi, 1975). According to Huffman (1977), education also increases farmers' managerial capacity. Better-educated farmers also can use efficiently information from private dealers, companies, and extension agents to their advantage in rice farming. Finally, Goodwin and Mishra (2004) found that education increases farming

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[13] In the developed country case, Wu (1999) and Goodwin et al. (2004), suggest a positive effect of crop insurance on crop acreage.
[14] Horowitz and Lichtenberg (1993) found that U.S. farmers with crop insurance applied more nitrogen per acre and spend more on pesticides and treated more acres with herbicides and insecticides. They argue that fertilizer and pesticides may be risk-increasing inputs.

efficiency. Our finding is consistent with other studies in the literature (Paltasingh and Goyari, 2018), which found that education has a significant impact on the adoption of modern varieties and rice yields. The coefficient of SC and ST is negative and statistically significant at the 5% and 1% level of significance, respectively. Findings in table 2 suggest that SC and ST smallholder households obtain 9.8% and 16.5%, respectively, lower rice yields than general category smallholder households. This finding is not surprising because SC and ST households have lower education and lack resources and transportation facilities compared to other households.

The coefficient of farm size is negative and statistically significant at the 1% level of significance. Results suggest that a 1% increase in farm size decreases rice yield by 0.24% (table 2). Our finding is consistent with the inverse relationship between farm size and productivity. Various studies provide evidence of higher yields among farmers with smaller land sizes (Sen, 1962; Khusro, 1964, 1973; Berry and Cline, 1979; Krishna, 1995; Gaurav and Mishra, 2015). Using large nationally representative survey data from the National Sample Survey Organisation (NSSO), Gaurav and Mishra (2015) found a negative and significant relationship between farm size and net returns per unit of land. Results in table 2 show that sources of irrigation have a significant impact on rice yields. For instance, smallholders with groundwater irrigation facility have 30% higher rice yields than smallholders with no access to irrigation (other than rain-fed). Similarly, smallholders with access to surface water irrigation facilities have 60% higher rice yields than smallholders with no access to irrigation.

Results in table 2 show that compared to smallholders with lowland farms, farmers with medium lands have higher rice yields. Our finding is consistent with Behura et al. (2012), who found that smallholders cultivating in medium lowland and medium lands in Odisha, India, had higher rice yields than smallholders in lowland and upland. Soil type and soil color also are

associated with rice yield.[15] In our results, we find that the yield in black soil is highest, as per expectations, but we find clay soil has lower productivity than sandy loam soils. The variance can be due to the farmers' perceptions and not necessarily to any outcomes of soil tests. Households with soil health cards seem to have lower rice yields than households without soil health cards, possibly because having a soil health card may be associated with poor soil conditions. Smallholders may have wanted to know the reasons for low rice yields, and the first thing they were told was to get their soil tested.

Smallholders also use crop diversification—horizontal agricultural diversification strategy, a risk management strategy─ as a self-insurance mechanism (Ehrlich and Becker, 1972). Results in table 2 indicate that an increased number of crops cultivated decreases rice yields among rice farmers in Eastern India. Enterprise diversification represents a potential means of overcoming some of the negative side effects of monoculture rice farming systems (Taylor, 1994). On the other hand, diversification into animal production (dairy) increases the sources of income and the total income earned by smallholder rice farmers in Eastern India. As a result, rice farmers can allocate more land to crop production (table 2). The number of cattle in the household also is positively associated with crop yield. Table 2 reveals that debt (credit) and assets have a positive and significant impact on rice yields. Recall that credit increases management efficiency, technology adoption, and resource allocation, and it relaxes smallholders' credit constraints. Results in table 2 show a positive and significant impact of debt on rice yields. A possible explanation is that with additional credit (debt) smallholders can relax credit constraints and use the additional credit to

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[15] The relation between soil color, texture, and other characteristics on crop yields have been explored in detail in the Indian context (Arakeri et al., 1959). Typically, black soil has higher moisture retention and medium erosivity compared to brown soil. Yellow and red soil have low moisture retention and medium erosivity (Desbiez et al. 2004). In general, the darker the soil, the higher the productivity. Soil with more clay is expected to provide better yield than sandy soil (Dou et al., 2016).

procure new technology (seeds, fertilizer) and increase usage of fertilizer and irrigation water. Our results are consistent with the findings of Carter (1989).

Parameter estimates on progressive farmers are positive and significant at the 5% level of significance (table 2). Estimates show that progressive farmers, defined as those who initiate early adoption of new technology and receive advice on the use of fertilizer and pesticides, have 10% higher rice yields than other farmers. Our findings are consistent with Feder, Just and Zilberman (1985); Owens, Haddinott, and Kinsey (2003); Jamison and Lau (1982); Jamison and Moock (1984); and Evenson, Pray and Rosegrant (1998). Table 3 presents the heterogeneous treatment effects of CI on rice yields by farm size. Estimates in table 3 indicate that CI has the largest effect on large farms, increasing their rice yields by 49%, but the effect drops significantly (by 30%) for medium-size rice farms in Eastern India. Interestingly, CI's effect on rice yields of marginal farms was higher (16% i.e., 49%-33%) than for small farms (13% i.e., 49%-36%). Thus, we conclude that CI has heterogeneous impact on rice yields—higher for larger farms than small farms. The study also tested if the average treatment effects on treated (ATET) and average treatment effects on untreated (ATEUT) are different. To our surprise, we find that ATET and ATEUT are not different and the yield gains from participation in CI are about 46% for both insured and uninsured smallholder rice farmers in India.

Table 4 provides the results to check the robustness of our estimates and the methods used to estimate the empirical model. Table 4 shows that regardless of the method used, CI has a positive and significant effect on rice yields of smallholder rice farmers in Eastern India. However, the magnitude of CI's impact on rice yield varies with the method used to estimate the empirical model. For instance, the Direct-2SLS estimation technique shows a higher impact, and this could be due to ignoring the binary nature of CI treatment. In contrast, the study finds that the OLS

technique produces a very small impact of CI on rice yields. However, the estimation technique that accounts for endogeneity provides an unbiased and significant impact of CI on rice yields. Findings from this study show CI has a positive and significant impact on rice yields and that the impact varies with farm size.

Finally, there are some limitations to our study. The study has identified CI's impact on rice yield, but data limitations mean that the channels through which this yield improvement is happening have not been explored. For instance, we do not know if the increase in yield is due to increased use of seeds or chemical inputs.

Conclusions and Policy Implications

Since the early 1970s, policymakers in India have tried to protect smallholders by implementing various CI schemes. However, until recently, most of the efforts to make CI a food security vehicle have not been very successful. With a growing population, decreasing farmland sizes, increased budgetary pressure and impetus for productivity growth and food security issues, policymakers are designing market-oriented policies and inviting the private sector to take greater initiatives. One such effort includes designing and selling crop insurance to smallholders. This paper analyzes the impact of crop insurance (CI) on the food security of rice farmers in Eastern India. We used large-scale farm-level data from smallholder rice producers in eight states of Eastern India. Using IV estimation technique, this study found that CI has a positively significant impact on rice yields of smallholders in Eastern India. The study also found that CI's impact on rice yields is similar for insured (ATE) and uninsured (ATENT) smallholders. Finally, the study found that large farms derive more benefits from CI than small, marginal, and medium-sized farms. The results are robust for variety of estimation strategies.

Clearly, CI is an important risk management tool for smallholders in India and can contribute to food security. The findings have various policy implications. The fact that CI has a positive impact on rice yields means there is not strong evidence of moral hazard. In the absence of moral hazard, providing a larger subsidy to CI schemes might be a good idea. Since the treated and untreated group have similar effects, bringing more smallholders under CI schemes is likely to have a positive impact on rice yields. Additionally, CI schemes sold by private insurance companies could help policymakers design polices that are efficient and productive for smallholders. The entry of many players will ultimately create competition in the market, and the cost of providing CI may go down in the long run. Since a large proportion of farmers are small, marginal, and medium size, key barriers to wider access and availability still need to be addressed. Efforts to sensitize these farmers to the advantages of CI will go a long way to enhancing CI coverage.

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Figure 1: Surveyed states and districts of Eastern India
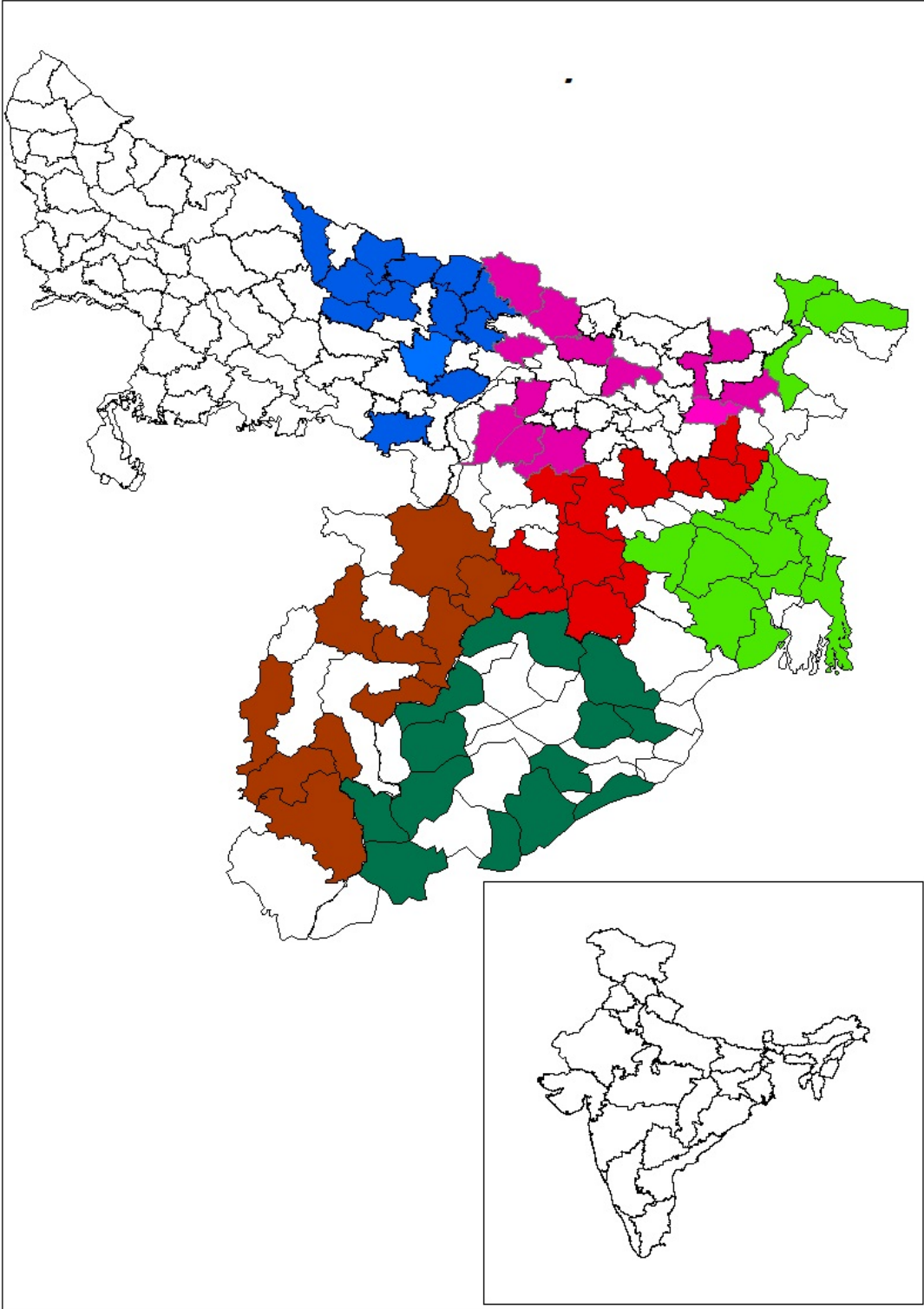
Figure 2: Farm size distribution, India

Medium(10-25 acre), 3.2%
Large(> 25 acre), 0.5%
Semi Medium (5-10 acre), 11.1%
Small (2.5-5 acre), 25.5%
Marginal (<2.5 acre), 59.8%
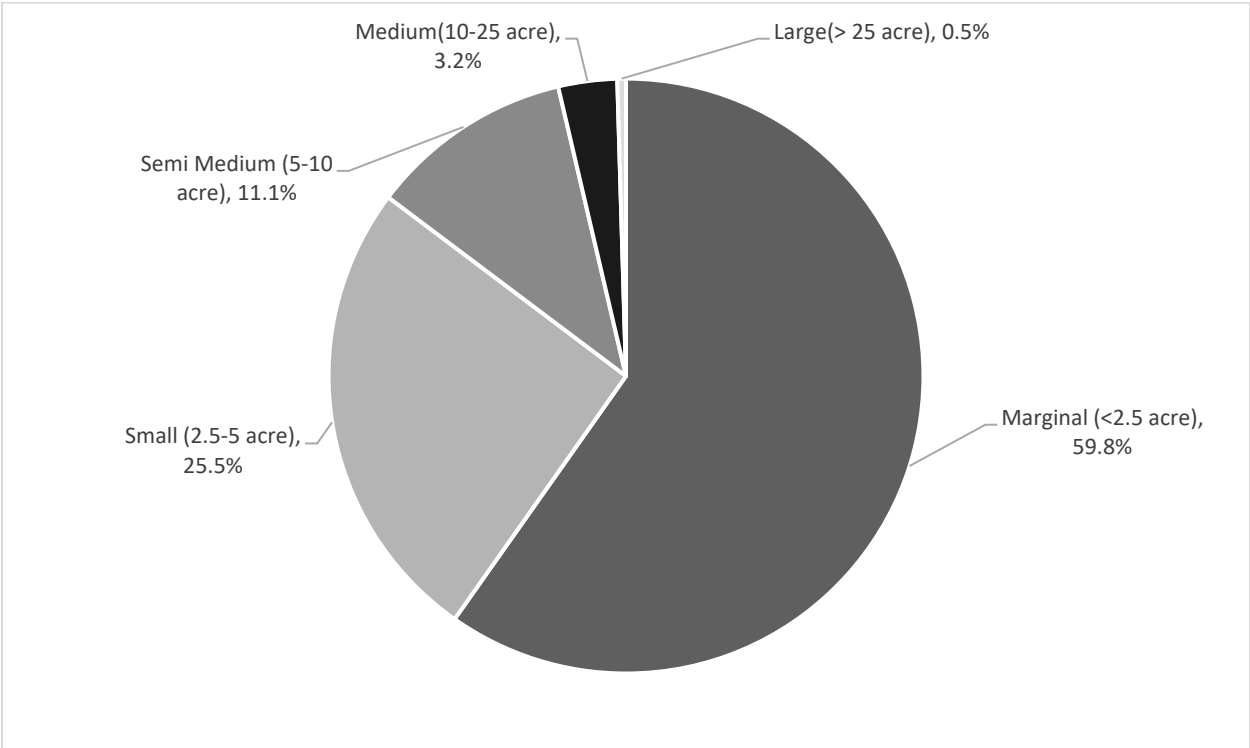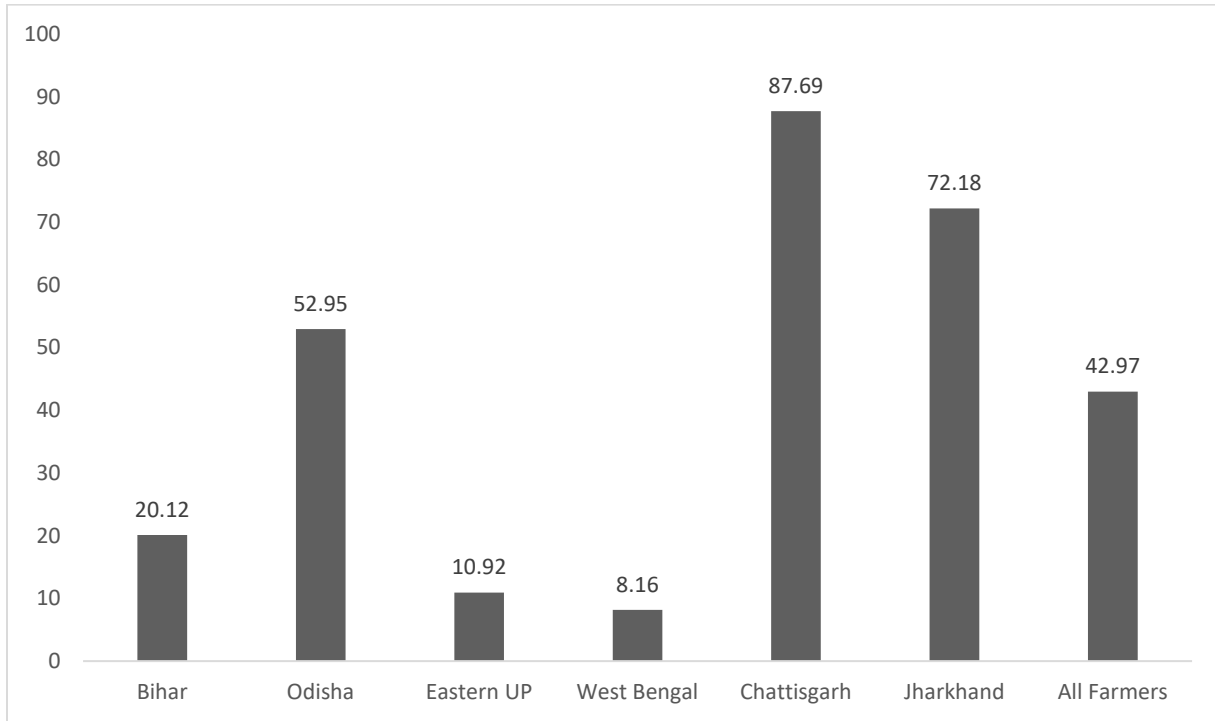
Source: Authors' Own Calculations

Figure 3: Crop Insurance across, by farm size
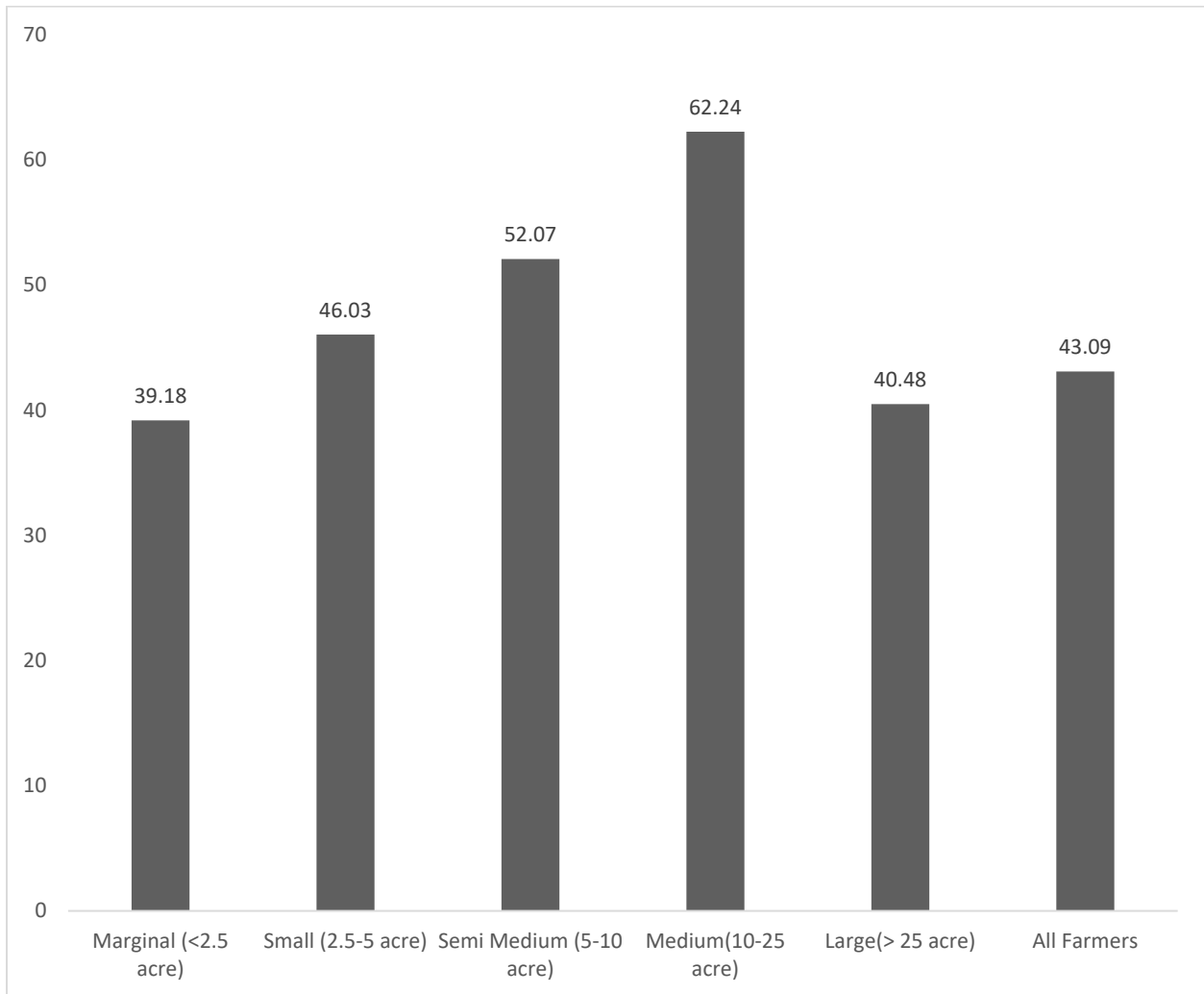
Source: Authors' Own Calculations

Figure 4: Insurance coverage across farmers, by states, Eastern India, 2016

Source: Authors' Own Calculations

Table 1. Variable description and summary Statistics, Eastern India, 2016

Variable	All Farmers	Un-insured	Insured	Difference
	(1)	(2)	(3)	(4)=(3)-(2)
Rice yield (tons/acre)	2.66	1.83	3.76	1.93***
Education, household head (HH)				
Illiterate	25.2%	24.1%	26.6%	2.4%***
Primary (<5 years)	23.9%	24.5%	23.0%	-1.5%***
Secondary (5-10 years)	36.4%	36.4%	36.4%	0.00%
Tertiary (>12 years)	14.5%	14.9%	14.0%	-0.90%
Caste				
Scheduled caste[1] (SC)	13.1%	15.2%	10.4%	-4.8%***
Scheduled tribe[1] (ST)	18.7%	12.3%	27.2%	14.9%***
Other backward class[2] (OBC)	47.1%	44.8%	50.1%	-5.3%***
General caste	20.8%	27.30%	12.10%	15.2%***
Household Size	6.84	7.01	6.60	-0.40***
Farming, HH (=1; 0 otherwise)	73.80%	76.70%	70%	6.7%***
Farming experience, HH (years)	24.6	24.2	25.2	1***
Land Size (acres)	2.89	2.59	3.28	0.69***
Irrigation				
No irrigation	54.9%	46.9%	65.5%	18.6%***
Groundwater (Pump/Tube well)	34.2%	44.2%	20.9%	23.3%***
Surface water (Canal/Well/Pond/River)	10.9%	8.90%	13.50%	4.6%***
Land Type (Typology)				
Lowland	28.7%	29.4%	27.8%	-1.6%***
Medium Land	61.6%	61.1%	62.3%	1.2%
Upland	9.7%	9.5%	9.9%	0.4%
Soil Type				
Sandy soil	22.8%	18.4%	28.8%	10.4%***
Sandy loam soil	38.3%	41.8%	33.4%	8.3%***
Loam soil	19.8%	23.9%	14.3%	9.6%***
Clay soil	19.0%	15.8%	23.3%	7.4%***
Soil Color				
Black	34%	32%	37%	5.4%***
Brown	55%	56%	54%	-2%*
Yellow or Red	10.5%	11.9%	8.6%	-3.4%***
Share of farmers with soil health card	9.0%	4.4%	15.2%	10.9%***
Assets and debt				
Share of farmers with a loan	19.40%	13.30%	27.40%	14.1%***
Share of farmers with a Kisan Credit Card	34.30%	21.20%	50.70%	28.90%
Assets owned by the household[3] (*number*)	5.28	4.97	5.7	0.73***
Number of crops cultivated (*number*)	1.37	1.22	1.56	0.34***
Number of cattle (cows and buffaloes)	2.6	2.17	3.18	1.01***
Number of goats and sheep (*number*)	1.29	0.97	1.74	0.77***

Extension and club participation

Share of progressive farmers[4]	9.8%	7.7%	12.6%	4.8%***
Share who said drought is a constraint	61.8%	48.5%	79.5%	30.9%***
Member of famer group or farmer club[5]	6.30%	3.30%	10.30%	7.02%***

[1] SCs and STs includes, uneducated, poor, and officially regarded as socially disadvantaged people in India.

[2] OBC is a collective term used by the government of India to classify castes that are socially and educationally disadvantaged. It is one of several official classifications of the population of India, along with SCs and STs.

[3] Includes 22 items including agricultural assets like plough sets, bullock carts, duster, chaff cutter, sprayer, diesel pumps, wheel barrows, thresher, power tiller, trolley, and tractors and nonagricultural assets like bicycle, radio, TV, DVD players, mobile phones, two wheelers, four wheelers, refrigerators, coolers, electric fan, and computers.

[4] Defined as those who typically initiated the adoption of newer inputs and also provided advice related to use of inputs like fertilizers, pesticides.

[5] Includes membership in farmers' club, marketing and extension clubs.

Source: IFPRI Survey, Mapping the adoption of improved varieties and management practices-Eastern India.

Table 2. Parameter estimates, probit-2sls IV estimation model, rice yield, Eastern India, 2016. *Dependent variable=log (rice yields)*

Variable	Rice yield
Insured (=1 if farmer has CI; 0 otherwise)	0.469*** (4.09)
Primary (=1 if HH has primary education; 0 otherwise)[1]	0.083** (2.55)
Secondary (=1 if HH has secondary education; 0 otherwise)	0.108*** (3.54)
Tertiary (=1 if HH has tertiary education; 0 otherwise)	0.154*** (3.83)
SC[2] (=1 if household belongs to scheduled caste; 0 otherwise)	-0.098** (2.36)
ST (=1 if household belongs to scheduled tribe; 0 otherwise)	-0.165*** (3.65)
OBC (=1 if household belongs to other backward class; 0 otherwise)	0.048 (1.40)
Household members (number)	0.005 (1.44)
Log (land size)	-0.244*** (18.96)
Groundwater[3] (=1 if farm has ground water irrigation; 0 otherwise)	0.304*** (9.31)
Surface water (=1 if farm has surface water irrigation; 0 otherwise)	0.596*** (15.98)
Farming (=1 if farming main occupation of HH; 0 otherwise)	0.121*** (4.49)
Ln(farming experience, HH)	-0.021 (1.05)
Medium Land[4] (=1 if farm located in the medium land; 0 otherwise)	0.049* (1.72)
Upland (=1 if farm located in the upland land; 0 otherwise)	-0.087** (1.99)
Sandy Loam[5] (=1 if soil type sandy loam; 0 otherwise)	-0.087** (2.51)
Loam (=1 if soil type loam; 0 otherwise)	-0.006 (0.16)
Clay (=1 if soil type clay; 0 otherwise)	-0.063* (1.73)
Brown[6] (=1 if soil color brown; 0 otherwise)	-0.204*** (6.7)
Yellow or Red (=1 if soil color yellow or red; 0 otherwise)	-0.298*** (7.00)
Soil Health Card (=1 if farmer has soil health card; 0 otherwise)	-0.224*** (5.13)

Loan (=1 if farmer has outstanding debt; 0 otherwise)	0.075**
	(2.34)
Kisan credit card (KCC) (=1 if farmer has KCC; 0 otherwise)	-0.017
	(0.45)
Number of assets (number)	0.042***
	(7.50)
Number of crops cultivated (*number*)	-0.057**
	(2.16)
Progressive farmer[7] (=1 if farmer is progressive; 0 otherwise)	0.099**
	(2.47)
Number of cattle (*number*)	0.021***
	(3.94)
Number of goats and sheep (*number*)	-0.088
	(1.55)
Constant	1.731***
	(16.09)
Observations	8,440
R^2	0.107
Adjusted R^2	0.104

Instruments:
Drought is a significant constraint in farming (0.641***);
Farmer a member of farmer club of group (0.183***)

Note: Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$ Standard errors are denoted in parenthesis.
[1] Base group, illiterate.
[2] Base group, general caste.
[3] Base group, no irrigation facilities.
[4] Base group, lowland.
[5] Base group, sandy soil type.
[6] Base group, soil color black.
[7] Defined as those who typically initiated the adoption of newer inputs and also provided advice related to use of inputs like fertilizers, pesticides.

Table 3: Heterogeneous effect of crop insurance on rice yield, Eastern India, 2016

	Treatment Effects
Effect of crop insurance (Base=Large Farmer)	0.489***
	(4.27)
Marginal Farmer (< 2.5 acres)	-0.334**
	(-2.51)
Small Farmer (2.5-5 acres)	-0.353***
	(-2.81)
Medium Farmer (10-25 acres)	-0.305**
	(-2.33)

Table 4: Comparison of estimation methods

Variable	T-test	Probit-2SLS	Probit-OLS	Direct-2SLS	Heckman Two-selection model
Insured	0.11***	0.47***		0.72***	0.43***
Control Function			0.48***		