Caste, Technology and Social Networks

I. Gupta[1]; P.C. Veettil[1]; S. Speelman[2]

1: International Rice Research Institute, Agri-Food Policy Platform, India, 2: Ghent University, Department of Agricultural Economics, Belgium

Corresponding author email: i.gupta@irri.org

Abstract:

This paper analyzes the role of informal social networks in technology diffusion in a caste-based society in which a social hierarchical structure is prevalent. Often, information and technology diffusion are constrained by social and economic boundaries. In a complex and hierarchical social system in which caste plays a very decisive role in everyday life as well as in the political and policy fabric of the regional, state, and national system, proper targeting and dissemination of technology to the marginalized sections of society are very important for their development. Taking diffusion of improved rice varieties as an example, we analyze whether technology diffusion is confined within caste-based social networks or whether technology can break caste boundaries and spread across social networks. We found that informal networks tend to concentrate within caste-based groups and hence observed significantly stronger social network within caste than across caste categories. Strong within caste network discourages hybrids but facilitates stabilized technologies such as improved varieties whereas strong across caste networks discourage adoption of older and traditional varieties. It is important to highlight that existence of stronger within as well as across caste networks for scheduled tribes (ST) facilitated these marginalized communities to adopt improved and hybrid varieties.

Acknowledegment:

JEL Codes: O33, Q12

#739

Caste, Technology and Social Networks

Abstract

This paper analyzes the role of informal social networks in technology diffusion in a caste-based society in which a social hierarchical structure is prevalent. Often, information and technology diffusion are constrained by social and economic boundaries. In a complex and hierarchical social system in which caste plays a very decisive role in everyday life as well as in the political and policy fabric of the regional, state, and national system, proper targeting and dissemination of technology to the marginalized sections of society are very important for their development. Taking diffusion of improved rice varieties as an example, we analyze whether technology diffusion is confined within caste-based social networks or whether technology can break caste boundaries and spread across social networks. We found that informal networks tend to concentrate within caste-based groups and hence observed significantly stronger social network within caste than across caste categories. Minorities had a very strong network within the community, but weak networks across different caste groups. Strong within caste network discourages hybrids but facilitates stabilized technologies such as improved varieties whereas strong across caste networks discourage adoption of older and traditional varieties. It is important to highlight that existence of stronger within as well as across caste networks for scheduled tribes (ST) facilitated these marginalized communities to adopt improved and hybrid varieties.

Keywords: *technology adoption, varietal diffusion, social networks, caste, India*

1. Introduction

Improved agricultural technologies increase agricultural productivity or farm income and help to improve the livelihoods of the poor. However, the challenge lies in the effective targeting and dissemination of these technologies. In this paper, the adoption of improved rice varieties is taken as an example to study technology diffusion. Because seed is one of the most critical inputs in agricultural production; the responses of all other inputs depend on the quality and genetic makeup of the seeds. A sustained increase in agricultural production and productivity requires the continuous development of new seeds suited to various agro-climatic regions and the efficient production and supply of those improved varieties to users so as to achieve higher seed replacement and faster varietal turnover. However, the Indian seed system is inherently very complex and unique, having responsibilities and roles intertwined between different levels of (formal and informal) institutions at national, state, and regional levels involving public, private, and development partners. Different institutions and organizations such as research institutes (variety development and nucleus/breeder seed generation), certification agencies, and national and state seed policies play a vital role in this system. But, these are only the organized or formal channels of seed dissemination. One should note that the unorganized or informal channels are the ones that dominate the system. By unorganized channels, we refer to the informal social networks among farmers through which they exchange farm-saved seeds, technology, and information. Serrat (2010) defines social networks as nodes of individuals, groups and organizations that tie in one or more types of interdependences. These interdependences include shared values, visions and ideas, social contacts, kinship, conflict, financial exchanges, trade, joint membership in organizations and other aspects of human relationships.

However, informal social networks among farmers are one of the dynamics that has been relatively less explored (Maertens and Barrett, 2012). A lack of understanding about how social networks function with regards to technology adoption can at times adversely affect the effective targeting and dissemination of technologies, or in this case seeds of improved rice varieties. This holds true particularly in a developing country such as India where landholdings are small and fragmented. As per the all India report on number and area of operational holdings, based on the Agricultural Census 2010-11 conducted by the Ministry of Agriculture (Government of India, 2014), the small and marginal landholdings taken together (below 2 hectare) constituted 85 percent of the total farming community cultivating nearly half of the

total cultivated area. Furthermore, average size of holdings have declined over the years and it has come down to 1.15 hectare in 2010-11 from 2.28 hectare in 1970-71. In addition to this farmers in India are heterogeneous in terms of their socioeconomic status. India has a complex and hierarchical social system in which caste plays a decisive role in everyday life as well as in the policy fabric of the regional, state, and national system. The caste category that an individual belongs to often determine their access to goods and services, information and even their social connections (Desai and Dubey 2011). Caste is one of the factors on the basis of which social connections or networks are formed in India (Munshi, 2014) and so in this paper, we look at an important characteristic of village-level informal social networks: caste. Thus, given the complexity of informal social networks and the role caste plays in various aspects of an individual's life, we hypothesize that 1) informal social networks are concentrated within a caste group and varietal diffusion depends on these caste-based informal networks, and 2) the caste system acts as a barrier to diffusion of new technology due to the presence of stronger within caste networks.

The rest of this paper is organized as follows: Section 2 discusses the existing literature on caste and social networks. Section 3 discusses the study site and the sampling procedure used. Section 4 gives a description of the data collected. Section 5 describes the methodology used to estimate social networks and model varietal adoption. This is followed by Section 6, which summarizes the results, and Section 7, which offers some conclusions.

2. The Literature

a. Social networks

The adoption of improved technologies by farmers is not immediate. To understand the diffusion of any technology, it is important to understand the dynamics involved in the process of technology adoption. Farmers depend on their connections for information regarding the feasibility and profitability of new technologies. New technologies are often introduced to progressive or model farmers in a village with the hope that other farmers will observe their benefits and adopt them. Extension services often rely on this assumption while targeting the dissemination of any technology to the farmers (Magnan et al 2013). Although this approach assumes that all farmers in a village would be influenced by one individual's decisions and follow suit, reality might be different. Adoption decisions are often not dependent on the whole village but rather on famers' reliance on individual networks. This holds particularly true in the

context of rural India, where social structures such as caste play a role in influencing village dynamics (Matuschke and Qaim, 2009).

Glendenning et al (2010) explain that even though India has a variety of extension service approaches at play, farmers often do not have access to any information source. This ultimately has a detrimental effect on their income and poverty levels. The authors conclude that developing an extension system that understands farmer behaviour and communication through social networks is vital. An example of the importance of studying informal social networks is a study on the effect of social networks on mobile money adoption in Uganda by Murendo et al (2015). This study finds that learning within networks helps in the faster diffusion of information about mobile money and also increases its adoption. The authors recommend that programs that promote the use of this technology should do so through social networks and that this would have a multiplier effect on the diffusion of mobile money in Uganda.

In their paper on capturing social networks effects in the diffusion of hybrid rice in Bangladesh, Ward and Pede (2014), find neighbour effects to be a significant determinant of hybrid rice adoption. They show that in comparison to interactions with agricultural extension officers network effects are much stronger and that a network with nearby hybrid rice adopters is more influential than a network of distant adopters. The authors point out that networks based on location, kinship, friendship and religion can help in the dissemination of technologies to farmers. According to Bandiera and Rasul (2006), based on their study on social networks and technology adoption in Mozambique, adoption decision of sunflowers by farmers are correlated with the choices of their family and friends and uncorrelated among individuals of different religions. Case (1992) finds strong neighbourhood effects when it comes to the adoption of a new technology in Indonesia. According to her, neighbours influence farmers' decisions to adopt a technology. The author cautions, that ignoring these interactions between farmers could cause one to overestimate the effect of household characteristics on adoption decisions. In a similar study, Conley and Udry (2010), find that in the case of pineapple cultivation in Ghana, farmers adjust their inputs in accordance to their information neighbours who were successful in earlier periods. The authors thereby highlight the importance of social learning and the network connections through which information flows, in influencing the farmers' cultivations decisions. Based on a panel data set from India, from the Rural Incomes Survey, 1968-69, Foster and Rosenzweig (1995), also find evidence of learning spill overs. They show that farmers with experienced neighbours are significantly more profitable than

those with inexperienced neighbours. Hence, understanding informal social networks is crucial for targeting technologies in a better and more effective manner. Social network analysis can impact policies and programs, including their design, implementation, and results (Serrat 2010), if ways in which to harness its potential can be identified.

b. Caste

The Indian caste system is a system of closed social stratification and occupational transmission through generations wherein a person's status in society is ascribed to the caste he or she is born into (Debnath and Jain, 2015). Freitas (2006) mentions that a caste possesses five characteristics - occupational specialization, purity scale, hierarchy, commensality and acriptiveness. Members of a caste follow a particular occupation which is often ranked on the basis of purity. It is an endogamous and rigid system that ranks people right from their birth. Caste in India is made up of the concepts of *varna* and *jati*. *Varna* refers to the class a person is born into and within each class are occupation-based stratifications called *jati.* Historically, there have been dominant castes that by virtue of their birth have enjoyed certain privileges and positions of power, which have been denied to the marginalized castes (Deshpande, 2010).

The Indian Constitution seeks to safeguard the interests of these marginalized groups who have been discriminated against. Part III, Articles 15, 16, and 17 of the Constitution[*], prohibits discrimination on the grounds of religion, race, caste, sex, or place of birth. For administrative purposes, these marginalized groups have been classified into three categories: the Scheduled Castes (SCs), Scheduled Tribes (STs), and Other Backward Classes (OBCs). SCs are individuals who were treated as untouchables and are the lowest ranked *jatis*. STs refer to marginalised tribal communities and OBCs are individuals who belong to the low to middle ranking castes (Goel and Deshpande, 2016). Conforming to affirmative action policies, the government of India, provides reservation to these groups in state and central educational institutions, legislatures, and government jobs. The fourth category is the General category, which includes those groups that have historically been the privileged and dominant castes. In our study, we have classified the farmers into these four groups. Additionally, a fifth category,

[*] http://lawmin.nic.in/coi/coiason29July08.pdf

called Minority[†], has been used, which consists of all those who belong to a religious minority and not the dominant religious group of *Hindus* in India (Debnath and Jain, 2015).

Indian villages bear testimony to this system of discrimination where caste plays a crucial role in terms of people's access to resources. Customarily, higher castes dominate the agricultural sector in their role as landlords and lower castes perform farming activities as tenants or laborers. Villages in India are often divided into hamlets that are inhabited by people belonging to a particular caste category and exchange of resources and information across these hamlets is often restricted by their caste compositions. Caste or religion-segregated informal gatherings are very frequent in villages, where the people often share information, and hence the chances of networks concentrated within them are high. Social transactions such as marriages (Debnath and Jain, 2015; Bidner and Eswaran, 2015) and economic transactions such as risk pooling and investments (Ligon, 1998; Banerjee and Munshi, 2004) also take place within a caste. Desai and Dubey (2011) in their paper on caste in the 21st century, argue that a social structure based on caste, over years, has translated into unequal access to land, education, business ownership and occupation. The authors also talk about inequality in outcomes as highly qualified individuals belonging to lower castes face economic and social discrimination. Lower castes have unequal access to land, low educational status, lower consumption expenditure, lower access to nutrition and healthcare. As per the Agricultural Census, 2010-11, SCs and STs together constitute only 21 percent of the small and marginal landholdings (below 2 hectares), accounting for 20 percent of area operated under these landholdings. In particular, for SC farmers 92% of their landholdings is under 2 hectares while this figure stands at 78% for the ST farmers. Access to services such as credit are also restricted by caste. Kumar and Venkatachalam (2016), in their paper on caste based differences in farmers' access to loans, find evidence of discrimination against ST farmers right at the stage of loan approval. Due to this they argue that STs and SCs are 16 to 20 percent less likely to apply for loans as compared to the higher castes.

There are few studies on caste-based social networks and their impact on the adoption of agricultural technologies. However, in a different but relevant study on social networks and health insurance in the state of Andhra Pradesh, Debnath and Jain (2015) investigate the role of caste-based networks in driving first-time use of a public welfare program. In that article,

[†] This refers to individuals belonging to religious minorities, such as Muslims and Christians. No other religions were found in the sample.

the authors describe caste as a naturally "occurring social network." They find that a unit increase within the caste at the village level increases first-time use by 20%. Munshi (2014) in his paper on community networks, highlights that caste based labor market networks have been present in India since colonial rule. He describes how caste based networks in India have played a role in providing insurance to its members and smoothening consumption. They further illustrate how loans within caste based networks are one of the major sources of informal credit. Based on data from the 2005 Indian Human Development Survey, Munshi and Rosenzweig (2016) report that more than 20 percent of loans based on caste carry no interest payments or collateral.

In their paper on identifying central individuals in a social network, Banerjee et al (2016), argue that rational individuals can identify individuals who are central in a network by tracking gossip about people. These individuals were not traditional leaders or people with many friends but they were central to the diffusion of information. The authors conducted a randomised field experiment and tracked the diffusion of a piece of information which was given to a small number of "seeds" in each community. They subsequently found that diffusion of information was three times when these seeds were nominated by people as opposed to randomly chosen seeds. Similarly we argue that caste based networks can be used to identify central individuals as opposed to looking at traditional leaders or progressive farmers in a village. Central individuals within a caste would be able to spread information faster because of the closely knit ties that individuals who belong to a same caste have.

3. The Study Site and Sampling

A survey was conducted in 2015 in three major rice-growing states in eastern India: Bihar, Odisha, and West Bengal. Five districts[‡] were chosen in each state based on three criteria: (1) rice intensity of 50% or more, (2) agro-ecological zone[§], and (3) irrigation status. In each

[‡] The following districts were selected:
Bihar: Rohtas and Gaya (AE 9); Madhubani: Purba Champaran and Munger (AE 13); Odisha: Puri and Kendrapara (AE 18) and Bargarh, Mayurbhanj, and Rayagada (AE 12); West Bengal: Bankura (western) and Puruliya (AE 12) and Bardhhaman (eastern), South 24 Parganas, and South Dinajpur (AE 15).

[§] The agro-ecology zones identified were the following:
AE 9: Northern plains hot sub-humid; AE 12: Eastern Plateau Chottanagpur and Eastern Ghats hot sub-humid; AE 13: Eastern Plain hot sub-humid (moist); AE 15: Assam and Bengal Plains hot sub-humid to humid; AE 18: Eastern coastal plain hot sub-humid to semi-arid.

district, the top two rice-growing blocks were chosen, making a total of 30 blocks. In each block, five villages were randomly selected. In total, 150 villages were selected to implement the current research. In each village, rice farming households were identified using a complete census of the village. In the village census, the details of every household in the village (including caste, religion, and rice farming status) were recorded. From each village list, 10 households were selected for the household survey, in proportion to the caste composition in the village. Thus, 1500[**] households were sampled for the survey. The households were categorized into five caste categories: General, Minority, Scheduled Castes, Scheduled Tribes, and Other Backward Classes.

4. Data and Descriptives

a. Data collection

Data on household characteristics, varieties cultivated, and informal social network were collected through the household survey. Maertens and Barrett (2012) in their paper on measuring social networks' effects on agricultural technology adoption, cite methods that can be used to measure social networks. One of the methods is to define social networks through memberships in village groups, caste or gender (Foster and Rozensweig 1995, Munshi 2004). Van der Broeck and Dercon (2011), propose taking a complete census of a village and asking farmers to list their contacts as a way of measuring their social network. However this method can be costly and in terms of time and money and cumbersome if the geographical area which has to be covered is large. Santos and Barrett (2008) and Chandrasekhar and Lewis (2011) propose a method called *'network within sample'*. In this approach, each farmer is asked about their connections to every person in their network. However this method can give biased estimates by artificially truncating the network (Maertens and Barrett, 2012). Bandiera and Rasul (2006) in their study on social network and technology adoption in northern Mozambique ask each farmer to list out a particular number of people from whom they learn. However this approach can cause farmers to mention only their stronger network links and one might miss out on other weak but important networks links, thereby biasing the estimates.

In this paper we use the approach of '*random matching within samples'* to measure social networks (Maertens and Barrett 2012, Conley and Udry 2010, Santos and Barrett 2010,

[**] Because of logistical problems, one village could not be surveyed in Bihar. Thus, the final sample size is 1490 households (500 each from Odisha and West Bengal and 490 from Bihar).

Maertens 2010). This method can also lead to an omitted variable bias if an important node of a network is ignored by the random matching. However this method has been proved to do better than the '*network within sample method'* by Santos and Barett, 2008. In this method each respondent is randomly matched with another farmer from the sample and is asked questions about the farmers they are matched with. For this study, two types of social networks were estimated, one across caste groups and the other one within caste groups. Networks across caste refer to groups in which individuals belonging to different caste categories interact with one another. On the other hand, in networks within caste, the interaction is limited to members belonging to only one particular caste category. Looking at these two types of networks would help us to ascertain whether informal networks are concentrated within caste-based groups or whether they break these boundaries and spill over across caste. Out of the 10 farmers that were surveyed in each village, six were randomly selected and each respondent was matched with this random selection of six farmers. A respondent was first asked whether he/ she knew any of its six matches. If they did, then they were asked if they knew whether those matches cultivated rice. If rice was cultivated by any of the matches, then the farmer was further probed to elicit his/ her knowledge about its match's farming activities.

b. Descriptive analysis

In our sample, on average, a household consisted of five members with men and women household members of an average age of 31 years, having 18 and 15 years of experience in agriculture, respectively. In terms of caste composition, the majority of the respondents belonged to the OBC category (33.7%), followed by the General category (25.5%). Figure 1 depicts the caste composition across the three states. Bihar is highly dominated by OBC category respondents (61%) and a very small ST (1%) population. In contrast, in Odisha and West Bengal, no single caste group dominates, but at least two caste groups have a large population share (General and OBC for Odisha and General and SC for West Bengal).

(*Insert Figure 1 here*)

Education levels were defined in terms of years of education completed and they were categorized†† into non-literate, literate with no formal education, primary (grades 1 to 4), secondary (grades 5 to 10), senior secondary (grades 11 and 12), and graduate and above

†† Only individuals who were of school going age were included in this classification.

(undergraduate degree and above) as highlighted in Table 1. Within each caste category, around 40% (or more) of the household members had attained secondary education, except for those belonging to the Minority and ST category. A total of 76% of household members belonging to the General category had formal schooling whereas this was 63% for minorities and around 60% and more for the other castes (OBC, SC and ST). Members belonging to SC and ST households had the highest share of non-literates (around 32%) and low levels of education in general compared with other groups.

Following the Government of India's classification of landholdings, the households were categorized as marginal (0-1 hectare), small (1-2 hectares), semi-medium (2-4 hectares), medium (4-10 hectares), and large farmers (greater than 10 hectares) based on the area under cultivation. Data on area under rice cultivation were collected for two cropping seasons, *kharif* 2015 (June/July to October/November) and *Rabi* 2014-15 (November/December to March/April). Irrespective of the caste, the majority of the farmers were marginal, that is, their landholdings under rice were from 0 to 1 hectare, followed by farmers with small landholdings between 1 and 2 hectares. Households with large landholdings (more than 10 hectares) were very few, about 1% in the General and Minority category and negligible when it came to the SC, ST, and OBC households. Table 1 summarizes the educational attainment of household members and landholdings under rice within each caste category.

(*Insert Table 1 here*)

5. Methods

a. Caste and social networks

In order to understand the relationship between caste and social networks, we estimate the social networks index using Equation (1). Here, K_{ij} refers to respondent i knowing who person j is. It takes the value of one if the respondent knows person j and zero otherwise. C_{ij} takes the value of one if respondent i knows that person j cultivated rice, given that$\mathrm{K}_{ij} = 1$, and zero otherwise. Q_{mij} refers to the question asked of respondent i about j's cultivation habits, where $m = 1, \dots, M$. Q_{mij} takes the value of 1 if respondent i knows the answer to the question m asked about person j given that $\mathrm{C}_{ij} = 1$; otherwise, it is zero. The value of the social network index (SN) thus estimated lies between 0 and 1. w_1, w_2, and w_3 are the weights assigned.

$$SN_i = \Sigma_{j=1}^{J} \frac{\left[\mathrm{w}_1 \mathrm{K}_{ij} + \mathrm{w}_2 \left(\mathrm{C}_{ij} \middle| \mathrm{K}_{ij} = 1\right) + \left(\mathrm{w}_3 \sum_{m=1}^{M} \mathrm{Q}_{mij} \middle| \mathrm{K}_{ij}=1, \mathrm{C}_{ij}=1\right)/\mathrm{M}\right]}{J} \qquad (1)$$

The value of M is eight and $J \leq 6$ depending on the caste category of i and j. For an across caste network estimation, J is equal to the number of people belonging to a different caste than that of respolndent i. Whereas, for a within caste network estimation, J is equal of the number of people belonging to the same caste as that of respondent i. J can be zero in those cases when no individual in the network belongs to a different or a same caste category as the respondent, depending on the type of social network being estimated.[‡‡]

b. Varietal adoption

To analyze the impact caste-based social networks have on the adoption of varieties, we have classified them into three categories: traditional, improved, and hybrid. In terms of varietal selection, these are the three broad options available to farmers. A farmer may cultivate different types of varieties at one point in time. For example, it might be the case that during the same cropping season a farmer cultivates a traditional and an improved rice variety, in different plots. Hence, the dependent variable used in the econometric model is categorical in nature, taking the value of one if any variety has been cultivated by the farmer and zero otherwise. Given that one farmer can cultivate more than one type of varieties, a multivariate probit regression is used to analyze the social networks and other factors affecting varietal selection. Following Chib and Greenberg (1998), let Y_{ij} denote the binary response $0/1$ representing whether farmer i $(i = 1,2 \dots, n)$ adopted the type of variety j, and let $Y_i = (Y_{i1}, Y_{i2}, Y_{i3})'$ $(1 \leq i \leq n)$ denote the collection of responses on all three types of varietal adoption $(j = 3)$. The multivariate probit model is specified as below:

$$Y_{ij}^* = \boldsymbol{X}_i \delta_j + \epsilon_{ij} \; ; \quad \text{where} \quad Y_{ij} = \begin{cases} 1 & \text{if } Y_{ij}^* > 0 \\ 0 & otherwise \end{cases} \text{ and } \quad \epsilon_i \sim \text{MVN}(\mathbf{0}, \boldsymbol{\Sigma})$$

Here, $\boldsymbol{X}_i$ denotes the k-vector exogenous covariates, ϵ_i are assumed to be iid independent across i but correlated across j for any i, and MVN denotes the multivariate normal distribution.

6. Results

[‡‡] The questions asked in the survey to construct the social network index are listed in Appendix I.

a. Caste and varieties

During the survey, the farmers were asked to identify the varieties they cultivated. Many varieties are referred to by their different local names by farmers across eastern India. For example, Swarna, which is an improved variety and was released in 1979, is one of the most popular varieties in eastern India. But, Swarna may be identified by multiple names across these regions by farmers. In several cases, categorizing those local names of varieties that have not yet been properly identified would be very difficult. Hence, those varieties that could not be categorized or identified have been put under "*Unidentified.*"

Around 17% of the total names described by farmers and area under rice cultivation belonged to the unidentified category. In Table 2, it can be observed that farmers predominantly cultivate improved varieties (75.6%), followed by traditional (6%) and hybrid (2%) varieties. In India, Kharif is the main season for rice cultivation and Bihar, which belongs to the Indo-Gangetic plains, is dominated by the rice-wheat system; hence, it isn't surprising to observe very little Rabi rice in Bihar. However, farmers in the states of Odisha and West Bengal do cultivate some rice during Rabi, which is reflected in the sample as well. Across both seasons and within each state, the majority of the varieties that were cultivated were improved. Within all the caste categories, improved varieties were cultivated the most. The second most popular varieties were the traditional varieties for households in all the three states, except those farmers who were Scheduled Tribes; they cultivated hybrids. This contradicts our expectation that those belonging to the marginalized communities are less exposed to new technologies, but similar findings on Scheduled Tribes in Odisha adopting new stress-tolerant varieties were reported by Emerick et al (2016).

(*Insert Table 2 here*)

A faster seed replacement rate and varietal turnover are crucial to the successful diffusion of any variety. Table 3 summarizes the seed replacement rate (average number of years since seeds were replaced by famers) and varietal replacement rate (the number of years since varieties were replaced). In every state, within caste categories, farmers replace seeds mostly within a year. Farmers in Bihar belonging to the General category replace the varieties every five years, whereas in Odisha and West Bengal it is every eight years. Minorities use the same variety for a longer period of time in West Bengal (9 years) and Bihar (7.4 years), but in Odisha they replace the variety every six years. For farmers belonging to the OBC, SC, and ST

category, the number of years since the replacement of a variety is longer in Odisha and West Bengal than in Bihar.

(*Insert Table 3 here*)

b. Caste and social networks

The social network index across and within castes is estimated using equation (1) based on random sampling within the sample approach. The weights w1, w2, and w3 take the values of 0.1, 0.3, and 0.6, respectively. Knowledge about a person's cultivation habits in the respondent's network is given a greater weight. This is so because, in-depth knowledge about the variety that an individual cultivates, the source they obtain their seeds from, etc., reflects how close-knit a network is and this can help guide policy and dissemination strategies. The index was also estimated using different weights and this one was found to be robust.

Table 4 depicts the social network index within and across caste in each state, for every caste category. Overall, the social network index shows the presence of a significantly different and stronger network within caste as compared to across caste categories. However, there are significant inter-state differences as well. Social network index within caste is stronger and significantly different from the index across caste for OBCs in all the three states. The same can be said about SC farmers in Odisha and West Bengal and ST farmers in Bihar and Odisha. Thus, our hypothesis that informal networks tend to concentrate within caste-based groups is true.

(*Insert Table 4 here*)

c. Varietal adoption

Two multivariate probit models are estimated to analyze whether varietal diffusion depends on informal social networks and caste acts as a barrier in this diffusion. The first model estimates the impact of informal social networks across caste-based groups on the adoption of rice varieties and the second one analyzes at the impact of informal social networks within castes. The variables used in the regression analysis are explained in detail in Table 5.

(*Insert Table 5 here*)

First, we look at the results of the model that capture the impact of informal social networks across caste-based groups on varietal diffusion. The results are summarized in Table 6. Informal social networks among farmers across caste categories significantly affect the adoption of traditional rice varieties negatively and that of improved rice varieties positively. Thus, social networks across caste, have a positive impact on the adoption of improved varieties but discourage the adoption of older traditional varieties.

Compared with marginal rice farmers, small rice farmers tend to cultivate more traditional varieties, as is evident from the significant and positive dummy used for small landholdings under rice. Marginal farmers mostly cultivate a crop for generating income and in such a scenario they tend to choose improved varieties as they guarantee a higher yield. In our sample, we find that, out of the total number of marginal farmers who cultivated rice, 75% of them cultivated improved varieties.

Compared with other farmers, when farmers acquire seeds from the public system, the adoption of traditional varieties significantly decreases and when they acquire seeds from general shops, the adoption of improved varieties increases. This result can be supported by the fact that the public system in India has extensive programs on dissemination of new and improved seeds and the private sector (shops) also sells improved varieties.

Farmers belonging to the Minority and ST categories compared with those who belong to the General category cultivate fewer traditional varieties. The result that marginalized communities adopt improved technologies more than the general community may not be an expected one. However, if one looks at the social network index in Table 4, it is clear that, on an average, marginalized castes have stronger networks within caste. In such a concentrated and deep network, we would expect an already existing technology like improved rice varieties, to spread much faster through informal channels and hence we see these communities adopting more improved varieties.

Compared with Bihar, farmers in Odisha cultivate more improved varieties and less traditional varieties. This result can be explained by the fact that, as opposed to Bihar, in Odisha the public system is well established in terms of its initiatives in disseminating new and improved varieties. The results from this survey also corroborate this fact as 46% of the traditional varieties cultivated in our sample were from Bihar and only 10% from Odisha and further in our sample 92% of the seeds acquired from the public system, were in Odisha. Finally, the state

dummy for West Bengal is significant for improved varieties in this model and has positive impact on the adoption of improved varieties. This result can be attributed to the fact that West Bengal has a strong private sector, which is a major player in the dissemination of improved varieties. In our survey as well, we find that, out of all the seeds acquired from the private sector, 46% of them are from West Bengal.

In this model, we do not see the variables significantly affecting the impact of hybrid varieties. This could be because of the limited number of hybrids in our sample (overall adoption of hybrid rice in India is less than 5%). The estimated covariance between the adoption of improved and traditional rice varieties have a significant and negative coefficient (-0.722, significant at 1% level of significance) as shown in Table 6. This implies that farmers who adopt more improved varieties than what the model predicts are more likely to adopt less traditional varieties than what the mode predicts. Similarly, the covariance between adoption of hybrid and improved varieties is also negative and significant (coefficient of -0.352, significant at 1% level of significance).

(*Insert Table 6 here*)

In the second model, we regress the social network index within caste categories on categories of varietal adoption. The results are summarized in Table 7. Like model 1, the social network index within caste has a positive and significant impact on the adoption of improved varieties and a negative and significant impact on traditional varieties. What is different here is that the social network variable affects the adoption of hybrids negatively and is significant. Thus, networks a within caste tend to discourage the adoption of hybrids. From Table 4 it was clear that networks are deeper and more concentrated within a caste, and in such a situation we expect a greater dependency on informal channels of seed dissemination or farm-saved seeds. Here hybrids do not qualify, as their seeds have to be replaced every year. Additionally, one can also argue that hybrids are a relatively newer technology than improved varieties and a strong social network within caste will act as an entry barrier for any new technology and hence it would take time to become absorbed within the network. It becomes difficult for new technologies to break these caste-based networks as farmers tend to stick to practices that are already established and tested.

With some exceptions, the other independent variables have a similar impact as in the first model. The dummy for small and medium to large rice farmers has a significant and positive

impact on the adoption of hybrid varieties in comparison to marginal rice farmers in this model. Hybrids are expensive to cultivate, given the high prices of their seeds and input requirements, and therefore it is not surprising to find larger farmers adopting them. In this model compared to marginal farmers, medium to large farmers cultivated more traditional varieties. Farmers belonging to the OBC and SC categories also tend to cultivate fewer traditional varieties than the farmers belonging to the General category.

The state dummy for West Bengal, in comparison to Bihar, is significant for both traditional and hybrid varieties in this model but has a negative impact on the adoption of both. As mentioned in the first model, a strong private sector presence in West Bengal explains this phenomenon. In our sample only 13% of the hybrids were found to be cultivated in West Bengal which can explain the negative sign for hybrids.

In this model, like the previous one, estimated covariance between the adoption of improved and traditional rice varieties and the adoption of hybrid and improved varieties is negative and significant. However the covariance between the adoption of hybrid and traditional varieties in this model is also negative and significant (coefficient of -0.186 and is significant al 10% level of significance). This means that farmers who cultivate more hybrid than what the model predicts are more likely to cultivate less traditional varieties than predicted.

Thus social networks within caste, as compared to across caste have an impact on the adoption of all the three categories of varieties. In both the models, we can see that diffusion of new technology does depend on informal social networks among farmers and moreover caste acts as a barrier to this diffusion since networks are concentrated within caste-based groups.

(*Insert Table 7 here*)

7. Conclusions and Policy Implications

Agricultural productivity depends on the effective targeting and dissemination of new and improved technologies. At the policy level, these dissemination efforts mostly concentrate on formal channels such as extension services, national and state systems, and the private sector. However, informal channels of dissemination, or farmer-to-farmer exchange of information and technology, make up a substantial portion of how technologies spread and are adopted. These exchanges are made up of individual networks among farmers that are further

characterized by social, political, and economic factors. In this article, we look at caste-based informal social networks among farmers and find that the networks that farmers have with one another tend to be deeply concentrated within caste-based groups as opposed to networks across castes. Further, we look at the adoption of rice varieties as an example of technology diffusion and find that both networks across castes and within castes cause farmers to adopt more improved varieties. For a technology that has already been stabilized (e.g., improved variety), a strong within caste network facilitates the spread of this technology. Whereas, for a new technology (e.g., hybrid variety), stronger networks negatively impact the penetration of such technologies.

Strong informal social networks prevail in rural India and this can potentially act as a barrier to the dissemination of technology unless appropriate methods of dissemination are used. Identifying the central leadership and influential point persons in strong social network systems is the first and foremost dissemination strategy for new technologies such as hybrids. Moreover, in our sample, respondents who belong to the marginalized communities adopt more improved varieties, which shows that, the more concentrated a network is in terms of its caste composition, the faster will be the spread of any established technology. Therefore, in order to ensure better targeting of technologies, informal networks among farmers required to be identified, keeping in mind the caste composition of the members of such networks, among other things. If a technology is introduced to farmers who belong to a common social network and have similar characteristics, in terms of their caste, we can expect faster uptake and diffusion of that technology. Further, as interactions across caste-based networks happen over time, technology diffusion would be accelerated.

References

Bandiera, O., & Rasul, I. (2006). Social Networks and Technology Adoption in Northern Mozambique. *The Economic Journal*, 869-902.

Banerjee, A., & Munshi, K. (2004). How Efficiently is Capital Allocated? Evidence from the Knitted Garment Industry in Tirupur. *Review of Economic Studies*, 19-42.

Banerjee, A., Chandrasekhar, A. G., & Duflo, E. (2016). Gossip: Identifying Central Individuals in a Social Network.

Bidner, C., & Eswaran, M. (2015). A gender-based theory of the origin of the caste system of India. *Journal of Development Economics*, 142-158.

Broeck, V. K., & Dercon, S. (2011). Information flows and social externalities in a Tanzanian banana growing village. *Journal of Development Studies*, 231-252.

Case, A. (1992). Neighborhood influence and technological change. *Regional Science and Urban Economics*, 491-508.

Chandrasekhar, A. G., & Randall, L. (2011). Econometrics of Sampled Networks.

Chib, S., & Greenberg, E. (1998). Analysis of multivariate probit models. *Bimoetrika*.

Conley, T. G., & Udry, C. R. (2010). Learning about a New Technology: Pineapple in Ghana. *The American Economic Review*, 35-69.

Debnath, S., & Jain, T. (December 2015). *Social Networks and Health Insurance Utilization.* International Growth Centre, Working Paper.

Desai, S., & Dubey, A. (2012). Caste in 21st century India: competing narratives. *Economic and Political Weekly*, 40.

Deshpance, M. S. (2010). *History of the Indian Caste System and its impact on India today.* Social Science Department, College of Liberal Arts, California Polytechnic State University, San Luis Obispo.

Emerick, K., Janvry, D. A., Sadoulet, E., & Dar, M. H. (2016). Technological Innovation, Downside Risk, and the Modernization of Agriculture. *American Econimic Review*.

Foster, A. D., & Rosenzweig, M. R. (1995). Learning by doing and learning from others: Human Captala and Technical Change in Agriculture. *Journal of Political Economy*, 1176-1209.

Freitas, K. (2006). The Indian Caste System as a Means of Contract Enforcement. Northwestern University, unpublished manuscript.

Glendenning, C. J., Babu, S., & Asenso-Okyere, K. (December 2010). *Review of Agricultural Extension in India. Are Farmers; Information Needs Being Met?* International Food and Policy Research Institute Discussion Paper 01048.

Goel, D., & Deshpande, A. (2016). *Identity, Perceptions and Institutions: Caste Differences in Earnings from Self-Employment in India.* IZA Discussion Paper 10198.

Government of India. (2014). *All India Report on Number and Area of Operational Holdings.* New Delhi: Agricultural Census Division, Department of Agriculture and Co-operation, Ministry of Agriculture.

Ligon, E. (1998). Risk sharing and information in village economies. *Review of Economic Studies*, 847-864.

Maertens, A. (2010). Social Networks, Identity And Economic Behavior: Empirical Evidence From India. Cornell University Ph.D. dissertation.

Maertens, A., & Barrett, C. (2012). Measuring Social Networks' effects on Agricultural technology Adoption. *American Journal of Agricultural Economics*.

Magnan, N., Spielman, D. J., Lybbert, T. J., & Gulati, K. (2013, November). Leveling with Friends-Social Netwoks and Indian Farmers' Demand for Agricultural Custom Hire Services. *IFPRI Discussion Paper 01302*.

Matuschke, I., & Qaim, M. (2009). The impact of social networks on hybrid seed adoption in India. *Agricultural Economics*.

Mitra, S. K., & Venkatachalam, R. (2016). Caste and Credit: A woeful tale?

Munshi, K. (2004). Social learning in a heterogeneous population: technology diffusion in the Indian Green Revolution. *Journal of Development Economics*, 185-213.

Munshi, K. (2014). Community Networks and the Process of Development. *Journal of Economic Perspectives*, 49-76.

Munshi, K., & Rosenzweig, M. (2016). Networks and Misallocation: Insurance, Migration, and the Rural-Urban Wage Gap. *American Economic Review*, 46-98.

Murendo, C., Wollni, M., Brauw de, A., & Mugabi, N. (February 2015). *Social network effects on mobile moeny adoption in Uganda.* Global Food Discussion Papers, No. 58.

Santos, P., & Barett, C. B. (2008). What do we learn about social networks when we only sample individuals? Not much.

Santos, P., & Barrett, C. B. (2010). Identity, Interest and Information Search in a Dynamic Rural Economy. *World Development*, 1788-1796.

Serrat, O. (2010). *Social Network Analysis.* Washington DC: Asian Development Bank.

Ward, P. S., & Pede, V. O. (2014). Capturing social network effects in technology adoption: the spatial diffusion of hybrid rice in Bangladesh. *Australian Journal of Agricultural Resource Economics*, 225-241.

Tables and Figures

Table 1: Sample household characteristics

Characteristics	*General (%)*	*Minority (%)*	*OBC (%)*	*SC (%)*	*ST (%)*
Education level completed by household members (n) *** [†]					
Non-literate (1736)	12.5	29.7	26.0	32.4	32.7
Literate with no formal education (175)	2.2	2.3	1.8	3.1	4.4
Primary (885)	11.2	15.5	12.5	13.4	13.2
Secondary (3080)	50.7	39.0	44.3	40.3	38.8
Senior secondary (695)	13.8	8.6	9.8	7.2	7.3
Graduate and above (411)	9.5	4.8	5.5	3.6	3.6
Landholdings under rice cultivation (n) *** [†]					
Marginal farmers (0-1 ha) (947)	57.8	61.3	58.2	75.6	72.3
Small farmers (1-2 ha) (325)	23.2	26.1	26.8	15.2	14.5
Semi-medium farmers (2-4 ha) (141)	11.4	8.1	9.6	7.4	10.1
Medium farmers (4-10 ha) (65)	6.6	3.6	5.2	1.5	3.1
Large farmers (10 ha and above) (7)	1.1	0.9	0.2	0.3	0.0

[†] *Comparisons were made between household members belonging to different caste groups and their level of educational attainment and landholdings using the chi-square test.*
**** indicates that the corresponding differences are significant at the 1% level of significance.*

Table 2: Varieties cultivated

Varieties	Overall (n=2775)	**Caste[ξ], *****				
		General (%)	Minority (%)	OBC (%)	SC (%)	ST (%)
Improved (n=2097)	75.6	77.5	72.8	69.2	76.6	90.6
Traditional (n=165)	6.0	7.2	4.6	7.1	5.6	0.4
Hybrid (n=46)	1.7	1.1	1.0	2.8	1.0	1.5
Unidentified (n=467)	16.8	14.1	21.5	20.9	16.8	7.6

[ξ] *Comparisons were made between varieties cultivated and the caste categories using chi-square test.*
**** indicates that the corresponding differences are significant at the 1% level of significance.*

Table 3: Seed replenishment and varietal replacement (average years) †

Variety cultivated	Bihar						Odisha						West Bengal					
	General	Minority	OBC	SC	ST	Signi-ficance	General	Minority	OBC	SC	ST	Signi-ficance	General	Minority	OBC	SC	ST	Signi-ficance
Seed replacement																		
Improved	0.3	0.2	0.3	0.2	1.4		1.0	2.4	0.9	0.8	1.2		1.1	1.2	1.6	1.0	1.0	***
Traditional	0.1	0.0	0.2	0.4	0.0	*	1.3		0.0	0.3	1.0		0.4	0.0	0.0	0.3	0.0	**
Hybrid		0.0	0.1	0.2			0.0	0.0	0.4	0.7	1.8		0.5		0.0		0.0	
Others	0.1	0.3	0.5	0.4	0.0	***	0.8	2.5	0.7	0.6	0.7	*	0.9	0.5	0.3	0.6	0.0	*
Total	0.3	0.2	0.3	0.3	1.0		1.0	2.4	0.9	0.7	1.2		1.0	1.0	1.3	0.8	0.9	
Varietal replacement																		
Improved	4.8	9.3	5.3	6.8	1.5	**	9.1	6.7	9.3	7.8	7.0	***	8.3	10.8	10.6	8.0	7.8	*
Traditional	6.0	7.0	4.6	6.2			10.3			5.3	17.0		7.9	4.4	5.5	3.9	6.0	
Hybrid		2.0	4.5	4.0			2.0	0.0	2.4	2.3	3.0	*			2.5	-	0.5	
Others	4.8	5.5	4.5	6.6	5.0		3.9	2.8	4.6	2.3	4.8		5.6	6.1	5.0	6.0	7.5	
Total	5.0	7.4	5.0	6.5	2.7		8.4	6.0	8.4	7.0	6.8		7.9	9.0	9.3	7.3	7.6	

† *The Kruskal-Wallis test was used to see if the seed replacement and variety replacement rates differ significantly within all the caste categories for a given variety in each state.*

*, **, *** *indicate that the corresponding differences are significant at the 10%, 5%, and 1% levels, respectively*

Table 4: Social network index (averages) †

Type of Network	Bihar		Odisha		West Bengal		Overall	
	Across caste	Within caste	Across caste	Within caste	Across caste	Within caste	Across caste	Within caste
Caste								
General	0.4518	0.4873	0.4304**	0.4802	0.2882***	0.3650	0.3780***	0.4300
Minority	0.3718***	0.5838	0.2525**	0.4633	0.1860**	0.3666	0.2688***	0.4406
OBC	0.3696**	0.3880	0.4169***	0.5011	0.3121*	0.3732	0.3797***	0.4186
SC	0.3822	0.4158	0.4097***	0.4961	0.2630*	0.3042	0.3400***	0.3843
ST	0.4225**	-	0.4277*	0.4757	0.3145	0.3829	0.3819**	0.4321
Overall	0.3856	0.4174	0.4182	0.4885	0.2758	0.3498	0.3622	0.4168

† *Comparisons were made between across caste and within caste social network indices, for every caste category, in each state using the paired t-test.*

, **, * indicate that the corresponding differences between the social network index across caste and within caste are significant at the 10%, 5%, and 1% levels, respectively*

Table 5: Variable names, definitions, and descriptive statistics

Variables	Description	Mean (SD)	Min	Max
Dependent variables: technology adoption[†***]				
Improved	Takes the value of 1 if improved variety was cultivated, 0 otherwise.	0.96 (0.19)	0	1
Traditional	Takes the value of 1 if traditional variety cultivated, 0 otherwise.	0.11 (0.31)	0	1
Hybrid	Takes the value of 1 if hybrid variety cultivated, 0 otherwise.	0.03 (0.18)	0	1
Independent variables				
Social network across caste (Model I) [†***]	Social network index estimated across caste-based groups.	0.37 (0.30)	0	1
Social network within caste (Model II) [†***]	Social network index estimated within caste-based groups.	0.43 (0.22)	0	1
Other independent variables (used in both models)				
Rice area (% cultivated area)	Rice area cultivated as a percentage of total cultivated area, in both seasons.	73.10 (37.24)	1.3	100
Primary income	Income earned from primary source (000 INR), in last 12 months from date of survey	72.45 (93.05)	0	1200
Average monthly expenditure	In 000 INR.	6.10 (5.22)	0	100
Average expenditure on food	In 000 INR.	3.79 (5.89)	0.4	150
Rented-in land	Total land rented in (area in ha), in Kharif 2015.	0.35 (0.75)	0	9.45
Rented-out land	Total land rented out (area in ha), in Kharif 2015.	0.05 (0.40)	0	7.17
Varietal preferences				
Yield	Varietal preferences: characteristics that the respondent took into consideration about a variety before deciding which one to cultivate: yield, cooking quality, vigor, and marketability of the variety (yes/no).	0.98 (0.14)	0	1
Cooking quality		0.95 (0.22)	0	1
Vigor		0.75 (0.43)	0	1
Marketability		0.72 (0.45)	0	1
Rice area (dummy)				
Marginal Farm (0-1 ha)	Dummy for total area under rice, aggregated for both seasons. Reference category is Marginal farms (0-1 ha).	0.62 (0.48)	0	1
Small Farm (1-2 ha)		0.23 (0.42)	0	1

Medium to large farm (>2 ha)		0.15 (0.36)	0	1
Seed source (dummy)				
Fellow farmer	Dummy for source for acquiring seeds of the varieties cultivated in both seasons. Reference category is fellow farmers.	0.19 (0.39)	0	1
Agri-input shop		0.46 (0.50)	0	1
Public system		0.14 (0.35)	0	1
General shop		0.14 (0.35)	0	1
Others		0.06 (0.24)	0	1
Caste Group (dummy)				
General	Dummy for caste category of the households. Reference category is General category.	0.27 (0.44)	0	1
Minority		0.07 (0.26)	0	1
OBC		0.31 (0.46)	0	1
SC		0.23 (0.42)	0	1
ST		0.11 (0.32)	0	1
Primary income source (dummy)				
Agriculture	Dummy for primary source of income of the household. Reference category is agriculture.	0.43 (0.49)	0	1
Self employed		0.15 (0.35)	0	1
Salaried employment		0.06 (0.24)	0	1
Wage labour		0.28 (0.45)	0	1
Other jobs		0.08 (0.26)	0	1
Location (dummy)				
Bihar	Dummy for the state in State which the survey was conducted. Reference category is the state of Bihar.	0.28 (0.45)	0	1
Odisha		0.36 (0.48)	0	1
West Bengal		0.35 (0.48)	0	1

[†] *Comparisons were made using paired t-test.*

*** *indicates that the corresponding differences are significant at 1% level of significance.*

Table 6: Model I: across caste groups

Variables	Traditional		Improved		Hybrid	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Social network across caste	-1.850***	0.306	1.893***	0.507	-0.184	0.426
Rice area (% cultivated area)	-0.003	0.001	-0.001	0.003	-0.001	0.002
Primary income (000 INR)	0.000	0.0006	-0.001	0.0009	0.000	0.0009
Average monthly expenditure (000 INR)	0.011	0.009	0.052	0.048	0.006	0.013
Average expenditure on food (000 INR)	0.001	0.009	0.023	0.067	-0.008	0.021
Rented-in land (area in ha)	-0.054	0.080	0.136	0.169	0.056	0.087
Rented-out land (area in ha)	0.336*	0.195	-0.190	0.190	0.084	0.287
Landholding under rice dummy (small, 1-2 ha)	0.275*	0.144	-0.171	0.234	0.165	0.198
Landholding under rice dummy (medium to large, >2 ha)	0.289	0.196	-0.124	0.353	0.304	0.246
Seed source dummy (agri-input shop)	0.151	0.179	0.137	0.252	-0.061	0.234
Seed source dummy (public system)	-0.595**	0.298	4.256	206.769	-0.078	0.239
Seed source dummy (general shop)	0.146	0.208	0.640*	0.337	-0.440	0.360
Seed source dummy (others)	-0.242	0.299	0.079	0.422	-0.459	0.409
Caste dummy (Minority)	-0.610**	0.250	4.215	151.292	0.106	0.380
Caste dummy (OBC)	-0.032	0.147	0.183	0.228	0.214	0.209
Caste dummy (SC)	-0.237	0.156	0.291	0.226	0.052	0.241
Caste dummy (ST)	-1.173***	0.382	0.913*	0.476	0.042	0.324
Primary income source (self-employed)	-0.665***	0.253	0.520	0.425	-0.073	0.227
Primary income source (salaried employment)	-0.590*	0.313	0.126	0.414	-0.045	0.358
Primary income source (labor)	0.243	0.155	-0.304	0.238	-0.224	0.236
Primary income source (other)	0.189	0.190	-0.252	0.290	-4.022	169.575
State dummy (Odisha)	-0.409*	0.237	1.170***	0.449	0.039	0.325
State dummy (West Bengal)	-0.220	0.186	0.631*	0.325	-0.247	0.281
Preferences: varietal characteristics						
Yield	-0.754**	0.370	1.489***	0.463	-0.390	0.626
Cooking quality	0.201	0.301	-0.441	0.405	3.723	193.871

Vigor	0.136	0.194	-0.036	0.352	-0.125	0.212
Marketability	0.111	0.156	-0.125	0.241	0.018	0.212
Constant	0.010	0.433	-0.663	0.599	-4.938	193.871
Estimated covariance	$\rho(\varepsilon_I, \varepsilon_T)$= -0.722***		$\rho(\varepsilon_H, \varepsilon_T)$ = 0.012		$\rho(\varepsilon_H, \varepsilon_I)$ = -0.352***	
Number of observation = 1181	Log likelihood= -546.118			Chi-square = 154.14***		

, **, * indicate that the corresponding differences are significant at the 10%, 5%, and 1% levels, respectively*

Table 7: Model II: within caste groups

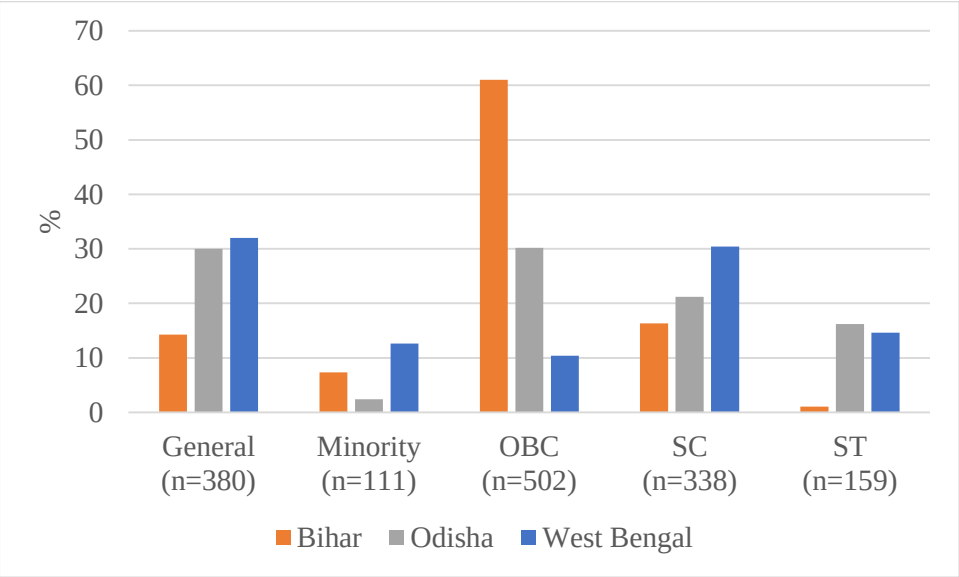
Variables	Traditional		Improved		Hybrid	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Social network within caste	-1.893***	0.291	1.591***	0.431	-0.657*	0.367
Rice area (% cultivated area)	-0.002	0.001	-0.002	0.003	-0.002	0.002
Primary income (000 INR)	0.001	0.0007	-0.002***	0.0008	-0.001	0.0009
Average monthly expenditure (000 INR)	-0.002	0.010	0.051	0.044	0.007	0.014
Average expenditure on food (000 INR)	-0.002	0.012	0.071	0.062	-0.006	0.016
Rented-in land (area in ha)	-0.276**	0.108	0.286*	0.166	-0.088	0.120
Rented-out land (area in ha)	0.270**	0.113	-0.242**	0.104	0.076	0.119
Landholding under rice dummy (small, 1-2 ha)	0.168	0.153	-0.038	0.227	0.407**	0.186
Landholding under rice dummy (medium to large, >2 ha)	0.567***	0.196	-0.280	0.295	0.587**	0.239
Seed source dummy (agri-input shop)	0.024	0.181	0.211	0.241	-0.126	0.224
Seed source dummy (public system)	-0.929***	0.353	1.042	0.697	0.014	0.234
Seed source dummy (general shop)	0.066	0.209	0.473	0.294	-0.278	0.304
Seed source dummy (others)	-0.506	0.315	0.273	0.395	-0.587	0.416
Caste dummy (Minority)	-0.979***	0.306	3.824	108.236	0.048	0.339
Caste dummy (OBC)	-0.360**	0.154	0.170	0.218	0.232	0.202
Caste dummy (SC)	-0.374**	0.163	0.326	0.227	-0.072	0.261
Caste dummy (ST)	-1.261***	0.363	0.901*	0.478	0.221	0.283
Primary income source (self-employed)	-0.693	0.270	0.627	0.399	0.075	0.221
Primary income source (salaried employment)	-0.732**	0.313	0.162	0.384	-0.410	0.401
Primary income source (labor)	0.228	0.156	-0.205	0.224	0.009	0.211
Primary income source (other)	0.161	0.202	-0.167	0.277	-0.733	0.451
State dummy (Odisha)	-0.544**	0.256	1.090	0.424	-0.098	0.317
State dummy (West Bengal)	-0.447**	0.197	0.738**	0.315	-0.563**	0.272
Preferences: varietal characteristics						
Yield	-0.974**	0.397	1.95***0	0.495	0.040	0.641
Cooking quality	0.384	0.330	-0.792*	0.429	0.259	0.442

Vigor	0.197	0.211	-0.164	0.357	-0.136	0.206
Marketability	0.013	0.156	-0.303	0.250	0.057	0.201
Constant	0.595	0.449	-0.729	0.568	-1.599**	0.724
Estimated covariance	$\rho(\varepsilon_I, \varepsilon_T)$= -0.693***		$\rho(\varepsilon_H, \varepsilon_T)$ = -0.186*		$\rho(\varepsilon_H, \varepsilon_I)$= -0.342***	
Number of observation = 1181	Log likelihood= -565.833			Chi-square = 201.87***		

*, **, *** *indicate that the corresponding differences are significant at the 10%, 5%, and 1% levels, respectively*

Figures

Figure 1: Caste Composition across States***[†]



[†]*Comparisons were made between the caste categories in each state using the chi-square test.*
**** indicates that the corresponding differences are significant at 1% level of significance.*

Supplementary material

Appendix I: Questions asked in the survey to construct the social network index.

The questions below illustrate how the social network index was constructed. In this example *Dilip Roy*, who is the respondent was randomly matched with six other rice farmers from his village who were a part of the households that were interviewed for the survey. One of the matches was *Bijoy Roy*. *Dilip Roy* (the respondent) was asked ten questions about him. The same questions were asked about the other five matches.

† - Refers to the question which tells us if the respondent knows any of its matches. This question is represented by K in Equation (1).
ŧ – Refers to the question which tells us if the respondent knows whether its matches cultivated rice. This question is represented by C in Equation (1). The question is asked if answer to Q1 is a '*Yes'* (i.e., K=1).
- Refers to the questions that elicit the quality of knowledge that the respondent has about its matches. These questions are represented by Q in Equation (1). These questions are asked if answer to Q2 is a '*Yes'* (i.e., C=1).

Farmer name – *Dilip Roy*

Match name (1) – *Bijoy Roy*

Q1. Do you know *Bijoy Roy*? † *Codes below*	Q2. Did *Bijoy Roy* cultivate rice in Kharif 2015? ŧ *Codes below*	Q3. Which variety did *Bijoy Roy* cultivate in Kharif 2015? #	Q4. Did *Bijoy Roy* cultivate the same variety in Kharif 2014? # *Codes below*	Q5. Where did *Bijoy Roy* purchase/ obtain seeds from? # *Codes below*	Q6. Do you know the quantity of seeds *Bijoy Roy* used? # *Codes below*	Q7. If yes to Q6, then how much was used? #	Q8. Did *Bijoy Roy* purchase the seeds? # *Codes below*	Q9. Do you know the total amount *Bijoy Roy* paid for it? # *Codes below*	Q10. If yes to Q9, how much did *Bijoy Roy* pay per kg? #

Q1, Q6, Q8, Q9 Codes: (1) Yes, (2) No
Q2, Q4 Codes: (1) Yes, (2) No, (80) Don't know
Q5 Codes: (1) Agri-input shop, (2) General Shop, (3) Department (Government), (4) Own seeds, (5) Other farmers, (6) Mini-kits, (7) Demonstrations, (8) NGOs, (9) Research Institutes, (10) Weekly market, (11) Rice miller, (12) Rice trader, (13) Paddy trader, (14) Seed Producer, (15) Person at door, (16) Government Programs (NFSM), (80) Don't know, (90) Others (specify)