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Adoption, diffusion and impact

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System of Rice Intensification in Rural Bangladesh: Adoption, Diffusion and Impact*

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1. Introduction and Background

Facing intensifying pressure on land and water resources, increasing rice productivity is critical for improving food security and alleviating poverty in developing Asia and Africa. Bangladesh has witnessed significant reduction in poverty over the last two decades; however, there still remains widespread food insecurity. Out of a total population of 165 million people in Bangladesh, 33 million were classified as lacking food security in 2010 and by 2020 it is estimated that this number will increase to 37 million (USDA 2010; Islam et al. 2015). A 2012 survey by the Economist Intelligence Unit of 105 countries ranked Bangladesh 81st in terms of the Global Food Security Index (Economist, 2012).

Crop yields in developing countries remain low due to limited adoption of new innovations by farmers. A novel and promising new approach to increasing productivity in rice cultivation, the System of Rice Intensification (SRI), has demonstrated dramatic potential for increasing rice yields without requiring additional purchased inputs (seed, fertilizer, etc.). First developed by Father Henri de Laulanie in Madagascar in the 1980s, SRI[1] works by changing the management of the plants, soil, water and nutrients utilized in paddy rice production. SRI is often billed as a pro-poor innovation as neither a new seed variety nor additional external inputs are required.

A number of studies based on non-experimental evaluation suggest significantly higher yields and increased profits associated with SRI. Takahashi and Barrett (2014) show that SRI generates average yield gains of around 64% relative to conventional methods in a study of Indonesian farmers. Sinha and Talati (2007) find average yield increases of 32% among farmers who partially adopted SRI in West Bengal. Styger et al. (2011) show 66% increases in yields in SRI relative to experimentally controlled plots using farming methods similar to local rice farmers in Mali and 87% increases in SRI yields relative to surrounding farmer rice fields. Barrett et al. (2004) study yield differentials for SRI and non-SRI cultivation strategies for Malagasy farmers and find SRI yields 84% higher than alternative strategies practiced by farmers. A pilot project

[1] A brief introduction to the background, significance and evolution of the SRI idea can be obtained from http://sri.ciifad.cornell.edu/aboutsri/origin/index.html. During droughts experienced in 1983, he experimented with transplanting very young seedlings of only 15 days old (Stoop et al., 2002). The surprising results Father Henri de Laulaníe achieved were refined over the next decade until clear principles emerged that could guide others in their efforts to plant using SRI. It wasn't until the late 1990's and early 2000's that the proliferation of SRI in various environments prompted agricultural research scientists to take interest in how SRI works (Stoop et al., 2002).

conducted in Bihar, India—the state with the lowest agricultural productivity and highest share of marginal farmers in India, and very similar to Bangladesh in many respects, have recorded increases in rice productivity of 86% from SRI adoption. Another pilot project by BRAC in Bangladesh (see Islam et al. 2012) shows higher yields of around 50%, among those who adopt SRI. Noltze et al. (2013) find that while there are significant increases in yields among SRI farmers, the farmers face negative income effects upon adopting.

SRI has also faced widespread scepticism within the conventional rice breeding community (Sheehy et al. 2004, McDonald et al. 2006). There is also controversy about measuring the effects of SRI adoption on rice yields. Glover (2011) explains that much of the controversy among scientists "hinges partly on questions of scientific rigour and measurement accuracy." Takahashi and Barrett (2014) and Sinha and Talati (2007) demonstrate that higher yields can in fact result from varying degrees of adherence to SRI principles. Furthermore, the use of SRI methods has been shown to be susceptible to processes of social learning, though there is very little research on the role of social networks in the SRI literature.

Diffusion of SRI has been sluggish and uptake rates have been low in many areas where it has been introduced as a potential catalyst for improving productivity, integration and food security (Moser and Barrett 2006). Moser and Barrett (2006) claim that farmers facing liquidity constraints during planting season are less likely to adopt SRI methods since they are unable to hire extra labor to account for increases in labor intensity. Given its purported productivity and earnings potential, low uptake of SRI technology seems rather puzzling even in countries with surplus labour and presence of unemployed family labour.

The primary impediments to adoption appear to revolve around learning the principles and practices involved in this knowledge-intensive method and possible social constraints to adopting visibly different rice production and water management methods within ostensibly homogenous production communities (Moser and Barrett 2006), or, what we now term 'homophily' (Banerjee et al., 2013). SRI is a knowledge-intensive cultivation technique that requires significant local adaptation and managerial skills but requires time and aptitude. There is evidence that farmers are constrained by information and skills necessary for local adaptation.

Yield risk appears greater under SRI than traditional cultivation methods (Barrett et al. 2004), thus farmers have to be willing and able to absorb increased output risk. Finally, in the absence of inter-household coordination of uptake there may be social stigma effects associated with adopting visibly different rice production and water management methods within ostensibly homogenous production communities (Moser and Barrett 2006).

Because SRI fields differ visibly from traditional rice fields, social norms and conformity pressures may likewise discourage adaptation and the ultimate adoption decision. In the rural Bangladeshi context of resource constraints on extension and adaptive research facilities and limited access to formal finance sources, social (i.e., village, kinship or friendship) networks may offer a viable alternative. Social networks in village economies therefore could potentially play an important role for agricultural technology adoption and social acceptability needed for SRI to diffuse quickly. A number of studies documenting that existing social networks may play a prominent role in mediating the learning, informal credit and insurance (Case, 1992; Foster and Rosenzweig 1995; Cox and Fafchamps 2008; Conley and Udry 2010; Centola, 2010, 2011; BenYishay and Mobarak, 2015).

The main objective of this study is to understand the network characteristics and incentive mechanism for successful adoption and diffusion of SRI. We examine whether village level social networks among farmers can be used to promote information, as well as the uptake of SRI. We also analyse whether and how a farmer's decision to adopt a new technology depends upon the adoption decision of other farmers in his social group. We then examine the impact of SRI on rice yield and profitability. The latter enables us to examine if the observed productivity gains measured elsewhere using observational studies (Barrett et al. 2004, Noltze et al. 2013, Takahashi and Barrett 2014) can be substantiated using a large randomized control trial (RCT). To date there has not been any experimental study examining the impact, adoption and diffusion mechanism of SRI technology in any setting. So, this study is the first examining the effects, take-up and diffusion of SRI to a wider scale using randomized controlled field experiments.

2. Related Studies: Social Networks, adoption and diffusion

We divide the related studies into three main sections. First, we explore the nature of social network and diffusion models and how information flows within them. Secondly, we narrow it down by focusing on the extensive literature that investigates how the different centrality measures of these networks' nodes can have an effect in the information flow and the decision to adopt. Finally, we analyze the findings of literature that focus on more specific factors influencing the diffusion and adoption process, particularly peer influence, endorsement effect, and incentives.

Prevailing literature has modeled diffusion mainly though different variations of the contagion model and through the use of influential nodes. It has been consistently found that strong ties in a network help the flow of information and that leaders work as a catalyst for information sharing. The evidence generally suggests that the greater the centrality of the initial injection node, the greatest the reach of the information and resulting adoption rates. Finally, peer influence, endorsement effects and incentives have also been widely recognized as mechanisms behind diffusion and adoption in contexts as diverse as education, agriculture and health.

The nature of diffusion models and information passing:

Application of Social Network Theory and Diffusion Models

The literature has explored and analyzed ideas that capture the diffusion of information. It has been discussed in terms of both market mechanisms and via non-market indicators such as social learning, imitation, information sharing, social pressure and other non-market externalities (Topa, 2001). Despite the development of numerous diffusion models, studies have often sought to explain diffusion in the form of contagion. This stems from the idea that in order to become "infected" with new information, an individual's neighbor must also be infected with new information. For example, Kermack and McKendrick (1927), who construct a model which could arguably be considered the basis for the mathematical treatment of epidemics, attempt to understand how and why a virus spreads across a network. The process involves dividing the population into susceptible individuals, Infectious individuals, and Recovered individuals (SIR model). This model has proved to be very useful outside the context of epidemics, and has been applied in a variety of papers studying diffusion of information and technology adoption. Essentially, the study provides a general description of the transmission of a disease in a homogeneous population, which can form the foundation for a model of diffusion of information.

This is in contrast to the study by Centola (2010) that uses a controlled experimental approach to study the spread of health behavior through an artificially structured online community. The study explores the effects of network structure on diffusion and the spread of behavior, taking into numerous topological structures featuring for example the presence of "clustering" within social networks and various degrees of separation. As noted by Aral, Muchnik, and Sundararajan (2009), this study also suggests further research into new experimental designs that test interaction effects resulting from homophily and strong interpersonal effects, alongside other variables such as gender, memory and frequency of interaction. On the other hand, Jackson and Rogers (2007) aims to present a dynamic model of network formation where nodes find other nodes by randomization or through searching through the existing structure of network. They find that as the random/network-based meeting ratio varies, the resulting degree distributions could be ordered in the sense of stochastic dominance. The analysis allows to infer how the formation process affects average utility in the network. Importantly, the model and analysis highlights the need to understand the differences in network settings and how this in turn affects the network formation process.

Information Passing

Previous studies have attempted to identify and observe the effects of pure information transmission, or what we describe to be information passing. An example of this is a study by Bond et al. (2012) that utilizes results from a randomized controlled trial of political mobilization messages delivered to 61 million Facebook users during the 2010 US congressional elections to investigate social influence effects in a network in both an online and real-world community structure. The authors find that the effect of social transmission on real world voting is greater than the direct effect of messages, which occurs mostly between "close friends". The results suggest that "strong ties", such as close friendships in a social network, play an instrumental role in spreading both online and real-world behavior. It outlines that the ability to influence behavior is not only impacted by a direct message but also the likelihood that a message is spread across the social network.

Besley and Case (1994) study the underlying forces of technology adoption in the introduction of cotton seeds in a rural Indian village, developing a dynamic “learning model” to explain the patterns of adoption when the profitability of the technology is uncertain. They conclude that the first stages of the introduction of a new technology have a considerable effect: if these are not successful; even if the technology is profitable farmers may choose not to adopt it. Furthermore, if information flows are weak, then technology adoption might not be homogenous across the village. In contrast, Mita and Simmons (1995) introduce the need to overcome culture-specific factors in spreading information. They do this they analyse the effect of grass-roots, female based program, similar to a study by Goldman, Pebley and Beckett (2010), using personal and impersonal channels of communication. One of their main forms of communication is through female-led community groups, and specifically on telling and sharing personal stories. Their data suggests that the diffusion of these new ideas of contraception was dependent on preconceptions of social change. New information is thus transferred through the interaction of peers and family members, which is found to be the most salient form of networks for women in rural areas.

Centrality

Despite the breadth of existing research there appears to be little that models the process of diffusion and empirically identifies the various nodes involved in information transmission. Thus, centrality and the ability to identify "initial injection points" is another key theme in Banerjee et al. (2013) which focuses on ascertaining exogenous variation in the community leaders in diffusion of microfinance. Banerjee et al. (2013) study the diffusion though social networks in India, where they exogenously define injection points in a network. They observe that the participation rate in microfinance increases when those injection points have a greater eigen vector centrality measure. A structural model of diffusion is constructed, discriminating between the passing of information between friends and acquaintances and the endorsement effect, as well as between the effect of participants and non-participants. The results yielded by the model show that the likelihood of participants diffusing the information is greater than for informed non-participants, although the latter represent a greater proportion of the network so their overall effect is very significant. They find that the decision of an individual to participate in microfinance program does not depend on the participation of their neighbors once this member has knowledge about the available technology already.

However, this idea of centrality and identifying the initial contact nodes in explaining diffusion has previously been explored by Kitsak et al (2010). Kitsak et al (2010) extend the notion of centrality by highlighting that the topology of the network in question plays a role in information dissemination with various levels of social linkages. Another study by Valente and Davis (1999) aims to develop a model to show how much more effective the diffusion of innovation is when technology is diffused by opinion leaders. Ballester, Calvo-Armengol and Zenou (2006) develop a network model that observes how "peer effects" are heterogeneous and subject to an individual's exposure to a group. In turn, the centrality measure that is identified considers both personal centrality and their influence over the centrality of others.

An example of the role of centrality, leaders and technology adoption within the context of the agriculture sector, is a study conducted in Bangladesh by Alamgir Hossain and Crouch (1992). The study investigates the differences in adoption of farming practices between leaders and followers in a rural area in Bangladesh, as well as the innovation capacities of these leaders. They find that the adoption rates of leaders does not exhibit a significant difference with that of followers, nor are they found to be more innovative. Rather, farm income results in the most significant factor influencing the adoption of new technology. Abdulai and Huffman (2005) show how cross-bred cow technology diffuses across farmers in Tanzania, utilizing survey data form 406 randomly selected farmers. The results suggest the importance of the centrality of the household in the eventual adoption of the technology, as well as the farmer’s contact with extension agents.

This notion of centrality has also been applied to education policy development. A study by Mintrom & Vergari (1998) explores the impact of innovation diffusion within policy networks with respect to education reforms. The results support the hypothesis that the use of an external policy network increases the likelihood of state legislative consideration of school choice, but not necessarily approval. The authors interpret this finding to mean that external networks play a pivotal role in supporting and introducing innovation in policy making, but approval is due to other factors. On the other hand, use of an internal policy network increases the likelihood of both consideration and approval of state legislation regarding school choice.

In the health intervention context, centrality within social networks and the role of 'sanitation entrepreneurs' (which can be likened to an 'initial injection point') is discussed in a study by Ramani, SadreGahzi and Duysters' (2011). The study investigates why "sanitation entrepreneurs" have had more success in the diffusion of household sanitation units, toilets, than other systems of diffusion. The problem with organic diffusion is that improving sanitation required behavioural change on the part of the members of the studied society, located in India. As such, delivery methods are found to be as important as the technological models.

Other factors behind technology diffusion and adoption:

Application of Peer Influence

Previous studies have used empirical data to discuss and explore the mechanisms for information transmission, notably in the context of technology adoption in developing countries with a focus on peer influences. There is considerable research that investigates the factors leading to the eventual adoption of new agricultural technology in various countries. Past studies have utilized data on sunflower adoption by farmers in Northern Mozambique (Bandiera & Rasul, 2006), pineapple plantation farmers in Ghana (Conley and Udry, 2010), and olive plantation farmers in Greece (Genius et Al., 2013), while other notable studies have focused on the diffusion of hybrid corn seed in Iowa since the 1930s (Ryan and Gross, 1943) and the take-up of agricultural weather insurance in rural China (Cai, de Janvry and Sadoulet, 2015).

The application of peer influence and imitation effects within a social network has also been applied to the effectiveness and transmission of information in relation to health initiatives such as through studies on menstrual cup usage in Nepal (Oster and Thorton, 2012), malaria prevention in Sub-Saharan Africa (Apouey and Picone, 2014) and fighting cases of intestinal worms (Kremer and Miguel, 2007).

In terms of an education intervention, Asadullah (2008) examines the social determinants of children's schooling, in the context of Bangladesh. Utilizing social data, the study finds no evidence that parental sociability and NGO membership positively impacts the child directly as an input in the education production function or indirectly via maternal social knowledge. These notions are also applicable to health policy, as exemplified in a study from Guatemala, conducted by Goldman, Pebley and Beckett (2001). The paper explores the diffusion effects of information regarding personal hygiene and contamination in Guatemala. Goldman, Pebley and Beckett (2001) find that interpersonal contacts in social networks play a significant role in the spread of beliefs regarding childhood diarrhea, a significant cause of childhood mortality which is also linked to preventable hygiene problems within households. Recent decreases in mortality rates in developing countries has been attributed to two factors; an increase in income and living standards, and exogenous factors such as public works, health interventions and medical developments.

Endorsement Effects

The idea of "endorsement effects", as discussed in Banerjee et. al's paper can be seen as an extension of the "better match" theory in economics. This is an area central to the longitudinal study by Emilio Castilla (2005), which discusses this notion in the context of employee referrals and the performance of new employee, using hiring and performance data from a large call centre in the United States. The theory proposes that social connections provide high quality information that improves the "match" between job and person. Therefore, social relations act as a "proxy" for information about a job candidate which is too difficult or expensive to observe directly. In contrast, a study conducted by Aral, Muchnik, and Sundararajan (2009) proposes a new framework that finds that the significance of peer effects has been generally overestimated in previous literature due to the existence of homophily. Homophily refers to the fact that individuals tend to establish social links with others who share some or many of their own characteristics and thus, leading to choices that may have a high correlation to the choices of their social connections.

Incentives

BenYishay and Mobarak (2015) identifies the role of "communication dynamics" between agents as well as small incentives for key communicators as being critical in the process of information dissemination. Aside from the commonly discussed financial incentive, there is also a growing body of literature that explores social incentives. Bandiera, Barankay and Rasul (2010) explores the role of social incentives within the workplace and its' impact on worker and firm performance. They find that there exists social incentives, whereby friends in a firm conform to what is deemed a "common productivity norm", factoring in their individual ability. This implies that when a worker has social ties with her co-workers, and he/she is less able than his/her friends, his/her productivity is significantly higher. On the other hand, when the worker is more able than his/her friends, then his/her productivity is significantly lower. Despite this, the "net effect of social incentives" on the firm's aggregate performance is positive. They attribute this as the outcome to "social pressure and mutual monitoring", which compels workers to meet a certain level of productivity.

3. System Rice Intensification:

SRI involves changing a range of rice management practices in which the management of soil, water, plant and nutrients is altered in order to achieve greater root growth and to nurture microbial diversity resulting in healthier soil and plant conditions. The SRI practices enhance the rice plants' growing conditions by reducing the recovery time seedlings need after transplanting; reducing crowding and competition; promoting greater root development; and optimizing soil and water conditions. Specifically, it involves transplanting single young seedlings with wider spacing, carefully and quickly into fields that are not kept continuously flooded, and whose soil has more organic matter and is actively aerated. These practices improve the growth and functioning of rice plant's root systems and enhance the numbers and diversity of the soil biota that contribute to plant health and productivity (Stoop *et al.*, 2002; Uphoff, 2003; Randriamiharisoa *et al.*, 2006). Neither a new seed variety nor additional external inputs are required. SRI is, however, knowledge intensive and commonly requires more labor for field preparation, water management, weeding and harvesting. SRI proponents claim that it (i) increases farm productivity and income, and ii) enhances household food security, iii) lifts up otherwise marginalised producers (see Africare, Oxfam America, WWF-ICRISAT (2010)).

SRI farming typically follows a locally adaptable set of principles rather than packaged instructions associated with distinct farming technologies. SRI is "not a complete product" as it is continuously being shaped by the farmers and other actors through their practice. Practitioners recommend the importance of location-specific technologies and solutions developed with the active involvement of the farmers. SRI is a "system" rather than a "technology" because it is not a fixed set of practices. Over time, the expansion of SRI occurred with much more flexibility promoting a package of practices for farmers to test, modify and adopt as they see fit. While a number of specific practices are basically associated with SRI, these should always be tested and varied according to the local conditions rather than being simply adopted (Uphoff *et al*, 2002). We adopt the approach taken by BRAC in Bangladesh through experimentation over the last few years. SRI is more appropriate for use during Boro season in Bangladesh as irrigation management is easier during this period. It's very difficult to do so in other season such as Aus/Aman when there is heavy rainfall. However, as boro season coincides with winter season when plants grow very slowly, BRAC recommends comparatively older (about 20 days) seedlings in Bangladesh than that recommended in Africa (12- 15 days). For the purpose of this study, we follow the basic principles adopted by BRAC regarding SRI practice in *Boro* season. These are:

1. Transplanting younger seedlings (20-days-old seedlings)
2. Transplanting single seedling per hill
3. Transplanting in wider spacing (25 × 20 cm)
4. Providing organic matter as much as possible
5. Following alternate wetting and drying method of irrigation, and
6. Practicing mechanical weeding at regular intervals.

4. The Experimental Design, and Data

The field experiment was conducted in collaboration with BRAC in a total of 180 villages from five different locations of Bangladesh. A total of 120 villages were selected randomly for treatment groups while the remaining 60 villages were designated as control. A census was conducted on all the farmers in these villages who cultivated rice on their own/leased land, and owned at least 0.5 acre but not more than 10 acres of land. There were about 30-32 farmers surveyed from each village. The baseline survey include survey of 3672 farmers from 120 treatment villages and 1866 farmers from 60 control villages. All of them were followed up in post-harvest data collection. There is no attrition. In case of absence of a farmer in post-harvest data collection, BRAC staffs revisited the family several times or interviewed another member in the household. Of 3672 farmers from treatment villages, a total of about 2243 from received training on SRI, and 1429 did not receive any training.

Farmers were trained in two batches. The first batch was selected randomly and the second batch was chosen by farmers in the first batch. Below we provide details how each of these groups were selected. In the first batch, 1193 farmers out of a total 1200 farmers participated in the training. The remaining 7 farmers were absent either because of sickness or were outside home in that particular day of training in the village.

In order to understand the differential impact of alternative SRI adoption instruments to promote uptake and to identify the most cost-effective mechanisms, the farmers were randomly assigned to one of the following three treatment groups:

Treatment A: Training and Information on SRI: A day-long training program was organized to train farmers on SRI techniques, and information about potential gains and costs associated with SRI.

Treatment B: Treatment A+ Flat Incentives for referral: A fixed amount of financial incentive to refer a friend, relative or acquaintance to attend training sessions in the same village.

Treatment C: Treatment A+ Incentive for referral based on adoption: financial incentives only for referrals who ultimately adopt the SRI (so no payment if the referent does not adopt SRI).

These treatments resemble experiments on job referral by Beaman and Magruder (2012) in Kolkata, India. The trainers for SRI were recruited from existing BRAC staffs who work as agricultural officers at the field level. They were trained by agriculture scientists of BRAC in a five day-long course. These scientists have previously worked in SRI in Bangladesh[2]. The trainers were supported by enumerators and field workers to conduct the training session and interviews before and after the training. Two members of the research team were also in the field during the entire period of training to guide the trainers and understand the farmers' willingness to adopt the SRI. The training at the village level was given through a multimedia presentation,

[2] These scientists previously worked at Bangladesh Rice Research institute (BRRI) and also experienced working on SRI there.

and a video demonstrating the principles and practices of SRI in other places of Bangladesh.[3] All farmers received a fee (taka 300) for their participation in the training. This fee is slightly more than rural agricultural daily wage. In addition, they were given lunch and snacks for the day. A certificate was also given to all farmers attended the training as recognition from BRAC to participate in the training.

In all the treatments, the first batch of farmers, who were selected randomly (regardless of whether they ultimately participate in training or not) for the SRI training referred another farmer in the subsequent (and final) training. We provided the batch farmers with a complete list of farmers from their own village/community who were surveyed during baseline. Each farmer in the first batch was asked to nominate another farmer from the list. The referred farmers were then invited by BRAC staffs/trainers to receive the same training. They were told the following: "BRAC is providing training about a new rice cultivation method in your village. At first, we selected a few farmers from your village through lottery, and gave them training this week. They recommended your name to receive the training (specific name of the individual referred was also given). We are requesting you to please come and receive the training next week in place X at morning 9 am. It will be a day-long training. You will receive a participation fee of taka 300. We will also organize your lunch and snacks for the day." BRAC staffs/trainers also reminded them the day before the training.

So, there were two trainings in each village in two successive weeks. The first batch of farmers received training in the first week, and the second batch in the following week. Note that only the first batch of farmers made the referrals, and the second batch just received the training. BRAC personnel continued to provide technical support and guidance throughout the season to help farmers with planting, weeding, watering, etc.

The training was conducted in two sessions- in morning and in afternoon. The morning session discussed about the different components of SRI, associated potential costs and benefits. It also discussed about experienced BRAC has from its program on SRI, and findings from other developing countries. In the afternoon, farmers discussed with each other and with the trainer

[3] Though BRAC already worked on SRI in different locations of Bangladesh, the presence of SRI is very thin as of today. Also, the approach adopted for adoption of SRI by BRAC is significantly different. BRAC provides large subsidies to farmers who have adjacent plots of land, and it only operates when *all* the farmers agree to adopt SRI

about the issues and constraints in implementing the SRI in their own plots of lands. This was followed by a review of the training materials. The afternoon session was followed by a survey to understand how much farmers learned from training on SRI. We conducted a test comprising of 20 questions on SRI to assess farmer's understanding of SRI from the training. All farmers who attended the training were assessed about their knowledge on SRI using a list of (mostly multiple choice) questions.

The first batch of farmers was selected using stratified random sampling from the baseline survey/farmers list from the village. The stratification was based on age (whether above or below 45 years old) and farm size (holds more than median sized farm land of 1.2 acres). This means that the number of farmers receiving training from each village was not fixed. There were 5-15 farmers from each village to take part in the training for the first batch.[4] As each farmer nominated another farmer, there were about the same number of farmers in 2nd batch as that of in the first batch.

The incentives were available only for batch 1 farmers (referee). The amount of incentives in treatment B differs from that in treatment C. In treatment C, the amount of incentive depended on the adoption decision of those referred. However, we kept the total payment for treatment C similar to what we paid all farmers in first batch in treatment B. If, for example, adoption rate is 40% in treatment C, the payment would be 2.5 times that of flat incentives in treatment B (300 taka*2.5=750 taka). We needed to announce the payoffs among farmers in treatment C before we could ultimately see the actual adoption rate. As ex-ante we did not know the adoption, we use the likelihood of adoption in treatment B to guestimate the incentives for treatment C. Training of farmers in Treatment B villages took place before treatment C. After training farmers in treatment B, we asked farmers if they would now adopt SRI. The fraction of farmers that respond 'yes' or 'more likely' for the adoption of SRI determined the payoff for treatment C. The offer was made based on the initial assessment of adoption in treatment B (50% adoption based on farmers' willingness to adopt in treatment B, and an assessment by trainers and field workers).

[4] In case of a large and populated village we divided the village into two or more (paras/neighbourhoods) for both baseline (social network) survey and for the training. We surveyed only one neighbourhood from that village. In case of social network survey, we gave them the list of names of farmers from the respective para to identify their relationship with other farmers. The farmers from each para were invited accordingly.

So, the payment for referrals in treatment C was double that of incentives paid for the same in case of treatment B.

The incentives for referrals for treatment B and C were made a few weeks after the training were conducted. This was done just after the transplantation of rice following verification of the adoption by BRAC field staffs. Though the payment in treatment B was not conditional on adoption, the payment was delayed which enabled us to compare with the referral incentives in treatment C which was tied to the adoption. We paid the incentives for referral in treatment C only if the referred farmer adopts SRI. Farmers who referred another farmer were registered to receive money from BRAC at a later date upon knowing the ultimate adoption of the latter. There were subsequent visits by BRAC field staffs after the plantation period, and the payment to farmers was made 4 weeks after the plantation was over.

We collected the information about the entire network among all the farmers participated in the baseline survey. Such detailed mappings of network enable us to study the effects of pre-existing social networks on the referral decision and the quality of the referral. In addition, at the time of baseline survey, each farmer was asked to nominate up to five friends from the list of eligible farmers within their village on new rice cultivation method. The later enables us to understand who refers whom in each of the three treatments. A person could not be nominated twice. When a farmer was already nominated by another farmer, then the farmer was asked to nominate among the farmers not nominated up until that point. Farmers in the first batch were interviewed randomly, and the order with which they were interviewed was random which determines, at any given point, how many farmers are available to make referral.

BRAC staffs visited the rice field in the treatment villages and surveyed the farmers following the transplantation period to verify the extent adoption. This was done to check if the principles (e.g., seedling age, spacing of plantation and number of seedling) of SRI recommended during training were properly followed by the farmers.

Since some of the principles of SRI (e.g., irrigation, fertilizer and weed management) need to be followed till harvest time, we also surveyed all the farmers after the harvest season to understand the production and adoption decision of the farmers. Thus, we have several measures of SRI-adoption: one following immediately after transplantation verified in person field visit by BRAC staffs, and second through farmers' own assessment following harvest. In addition, we also use if farmers adopted each component of SRI, and the amount of land they used to cultivate boro rice under SRI. The post-harvest dataset asks farmers about their knowledge and experience about SRI, whether they adopted SRI and to what extent and what problems they faced with the implementation of the new rice technique. The dataset also contains detailed information about the socio-economic and demographic profile of these households, including information about their current crop production techniques, their knowledge about existing method of cultivation and their attitudes towards adoption of a new technique such as SRI. In addition, detailed questions were asked about production techniques adopted for each plot of land owned or cultivated, different types of costs incurred, income, expenditure, family and hired labour use and food security situation of these households. During the baseline survey, we also played the standard risk-taking game following Binswanger (1980) to study the individual attitudes toward financial risk. In addition, we know their cognitive ability which is measured using numerical reasoning (simple deduction), counting, memory, and charts to understand their IQ level.

5. Results

Table 1 reports the basic demographic and socio-economic characteristics of farmers in treatment and control groups. It also reports the same for farmers in the treatment villages who were in the first batch or second batch, and those did not receive any training (untreated). The farmers who were selected for the first batch of training are similar in terms of their age, education, family size, and farm size (amount of cultivable land). By looking at the characteristics between treatment and control groups in terms of their age, education, cultivable land, and household size, we see there is negligible difference among treatment groups, and between farmers in treatment and control villages. Table 1 also shows that the randomization was successful since the difference across different treatment groups and treatment-control difference is not significant.

Below we present results on SRI adoption, the quality of referral based on different treatments. We focus on the role of social networks and the role of peers in technology adoption. We then discuss the impact of SRI adoption on per decimal production, input costs such as expenditure on seeds, fertilizer, irrigation, pesticides, weedicides etc and finally labour cost (including both hired and contractual labour).

5.1 Adoption and Referral:

The summary statistics for SRI adoption by different treatment status is presented in Table 2. We examine if peer farmers can effectively identify other farmers who are most likely to adopt the SRI technique, and the role of financial incentives in referrals. As discussed earlier, farmers who were offered training in the first batch was asked to refer one farmer who will receive the same training, subject to the condition that this farmer was not referred by the farmer interviewed earlier, i.e. this farmer was still available to be referred from the list of eligible farmers within the village. While farmers in Treatment A was offered no incentive to make the referrals, those in treatments B and C were offered financial incentives to make such referrals.

Table 2 shows that higher adoption rates among farmers in treatment B and C. We find significant differences between SRI adoption rates in Treatment villages A and those in villages B and C. While 37% of farmers who received training in Treatment village A adopted SRI, the corresponding adoption rates were about 50% and 49% in Treatment villages B and C respectively. The adoption rates do not differ much between farmers in batch 1 and batch 2. We see significantly lower adoption rates among untreated farmers in treatment villages. The results indicate that while SRI training has significant effects on adoption. It also shows that incentives matter for referral quality as we see the difference in adoption rates between treatment A and treatment B or C are 12-13%. When the more restricted definition of SRI adoption (followed 50% SRI principle) is used, we find that overall 32% has adopted SRI. Of them, only 26% are treated farmers in Treatment villages A, and while 35% are from both Treatments B and C. Overall, the different measures of adoption presented here provide consistent results.

We also see similar pattern when we evaluate the different components of SRI separately. There is higher percentage of people who followed the age of seedlings, number of seedlings per bunch and irrigation as recommended. However, as our subsequent field visits and discussion with farmers revealed a large number of farmers could not adopt SRI or abandon the all principles because of issues with irrigation. The irrigation system, though privately managed, requires collaboration among farmers of nearby plots of land to pump water at the same time. Farmers in neighbouring plots need to agree on timing of irrigation to pump underground water. Hence, in many cases irrigation was not timely available as farmers could not agree on timing. SRI adoption requires different seedling age and hence seedling and transplantation period would be different than the traditional cultivation. Due to the constraints in the irrigation system, land preparation and transplanting were not as timely as recommended by the SRI practice.[5]

However, incentives also induce people to refer relatives or friends more (related to family) as presented in Table 3. Using detailed information collected during the baseline (before they received the training and any knowledge about SRI or incentives for referral), while 15% farmers in treatment A village referred their relatives, it is 21% and 20% for farmers in treatment B and C respectively. These farmers are also more likely to refer someone who they thought has better knowledge on agriculture and rice cultivation, or with whom they discussed financial matters or regularly socialize. Overall, as presented in Table 1, we find that farmers who were referred by farmers in batch1 are of better quality compared to the referee themselves. Farmers in batch2 fare better in terms of SRI related post-training test and cognitive ability measures based on flipcharts. Thus, there is some evidence that the referral quality is a little better when incentives are tied to the adoption of referral. However, such difference is not always significant.

We estimate a dyadic model following Fafchamps and Gubert (2007) where the dependent variable Y_{ij} takes a value of 1 if farmers *j* is referred by farmer *i*. We use two types of attributes from the household level census data to analyze who refers whom. For the purpose of our analysis we use both physical (geographic) distance and social (relationship) distance, in addition to standard controls such as age, education and land size, treatment status and interactions between treatment status and distance indicators. These information were collected at the baseline survey, well before the treatment was announced for training, and referral made by farmers. Table 4 reports the results related to referrals, where each column relates to a different set of controls. The results suggest that farmers are more likely to be referred by another farmer if they are relatives or neighbours. The results presented in Table 4 suggest that both geographic and social distance matter and relationship between farmers play a role an important role in referral process. Farmers do not seem to be more likely to refer someone with whom they talk about financial matters but they do refer someone with whom they discuss rice cultivation or other agriculture related issues. Interestingly, these effects do not vary significantly across treatment groups. Farmers from treatment B are more likely to refer someone who has

[5] Considering the winter season, BRAC recommends 15-20 days of seedlings for transplantation which in many cases were 20-25 days.

neighbouring land while those from treatment C are more likely to look farther away from home, though both are significant only at 10% level of significance-. The difference in education, farm size, knowledge related to SRI and cognitive ability all seem to matter for the referral process. The probability to refer another farmer decreases as the gap in education and land ownership with that farmer increases. We also see the knowledge gap and difference in cognitive ability matters. The larger the gap in post-training test scores and cognitive ability, the less likely to be referred by someone else. This indicates assortative referring - farmers are referring other farmers with similar characteristics. However, they are also more likely to refer people with more experience or who are just close to them, either socially or just geographically.

We estimate the probability of adoption using regression which controls for age, education, size of the land holding (in decimals), household size, household income and cognitive abilities. We are particularly interested in understanding if such ability to detect those most likely to adopt the new technology is most effective under financial incentives. We would like to note that there are two effects working in opposite directions: the quality of referrals (measured in terms of the adoption decision of the referred) is expected to fall in general as the list of available and eligible farmers shrinks, while the financial incentives can provide the required impetus to put in more effort to identify and refer a good quality farmer for the second batch training. The adoption rates of the second batch farmers across three different treatments are presented in Figure 1 (a). We find evidence that while the ability to predict good quality peers for farmers from treatment village A is adversely affected by the restricted choice set, farmers receiving training as part of the first batch in treatment village B and C are referring good quality farmers for their respective second batch training. It is likely that despite limited options for those farmers who were trained later, farmers in treatment village B with fixed payment for referrals and those in treatment village C with conditional payment are actually making an effort to choose the right peers, suggesting that incentives both conditional and unconditional might be quite effective in identifying good quality referrals who are more likely to adopt SRI. Figure 1(b) also presents us with a similar picture. SRI adoptions rates of those referred are lower as the rank of those interviewed increases (as the available options to choose farmers to refer from the list decreases) but incentives as provided via treatments B and C can be quite effective in countering that effect.

To assess the extent to which social networks affect the adoption decision we run regressions with different measures of SRI adoption as dependent variables. We control for observable characteristics like age, education, size of the land holding (in decimals), household size, and household income. We also examine peer effects in technology adoption by using: (i) "treated friends", which refer to the number of friends trained with a particular farmer and (ii) "friends" which control for the total number of friends a farmer has in the entire network. The regression results, presented in Table 5, reports the marginal effects from the probit model, separately for batch 1 and batch 2 farmers. Panel A of Table 5 reports the SRI adoption results for those trained initially as batch 1 while Panel B present the same for batch 2 farmers. Overall, the results are similar to descriptive evidence presented above. Probability of adoption, after controlling for covariates, is higher in treatment B and C compared to treatment A. The marginal effects are slightly higher for batch 2 farmers than batch 1 farmers. However, in most cases, the difference is not significant economically. The results suggest strong peer effects in technology adoption. Number of friends receiving training has strong effects on technology adoption. Controlling for network size (total number of friends in network) an additional friend in the training increases the likelihood of SRI adoption by 2-3 percentage point.

5.2 Impact of SRI on Yield and Profitability

Table 6A reports the impact of SRI (intent-to-treat (ITT) estimates) simply by considering all farmers (whether they received training or not) from treatment villages and their counterparts from control villages. The results show that there is about 14.8% increase in production in treatment villages, and the expected revenue is 14.22% higher. The cost is significantly higher (10.9%) for these farmers. It turns out that even after accounting for the increased cost related to labour and fertilizer, irrigation, the estimated profit is still significantly positive for farmers in treatment villages. The estimated profit is therefore in favour of SRI technique. We also find similar results when we compare the randomly selected batch1 farmers and the referred batch 2 farmers with their counterparts from the control village (Tables 6B and 6C).

The ITT estimates are likely to be biased downward since (1) not all farmers adopted SRI; (2) some farmers who adopted SRI did not adopt for all plots of land. Table 6D shows that there is some spillover effects from farmers within the treatment villages to the other farmers who did not adopt SRI. This Table compares group of farmers who adopted SRI on at least one plot of land to those who did not within the treatment villages. Farmers who did not adopt SRI are found to have higher average production per decimal land compared to those in control village (as in Table 6A). We see the average production per decimal land for these non-adoptee in treatment villages are 25.33 kg compared to 22.37 kg for farmers in control villages. The difference in yield per decimal of land between those who adopted and those did not within the treatment village is 4% and still statistically significant.

Table 6E compares plots with only SRI with plots cultivated using traditional/non-SRI methods in treatment villages. When we consider the plots of land under SRI and compare them with those not under SRI, we find that production is 11.5% more on SRI plots. As SRI is a set of principles and these farmers could follow some principles in the non-SRI plot of land, this gain is likely to be underestimated. We therefore consider the (1) all farmers from treatment villages who adopted SRI; and (2) only plots of land under SRI in treatment villages. We then compare these with the similar size plot of land owned by farmers in control villages. Tables 6F reports the results. The yield gains is 17.75% if we compare all the plots for a farmer who adopted SRI for at least one plot with the farmers in control villages. The difference is about 25.48% when we consider only plots of land under SRI by farmers in treatment villages and then compare them with non-SRI plots in control villages (presented in Table 6G). Thus we see the yield gains associated with SRI could be as high as 25%.

When we report the results using regression methods which control for baseline level production, farmers' characteristics, we see the results are almost identical (presented in Table 7). The ITT estimate suggests that yields in treatment villages is 3.24 kg or 14.5% per decimal of land compared to control villages. This eventually translates into increased revenue of 108 taka per decimal which is statistically significant at 1% level. The profit even after adjusting for the increased cost for the treatment villages is significantly more, about 74 taka per decimal of land.

When we use randomization into treatment and control villages as an instrument for adoption, we find that the treatment effect on the treated (TOT) is significantly larger- almost three times that of ITT estimates. The results are however similar whether we use adoption measure assessed by BRAC's field staffs or self-assessed by farmers. This translates to about 50% gain in yield per decimal of land compared to control farmers. When we use proportion of land allocated under

SRI method as the measure of the adoption, we also see significant treatment effects. Farmers who contribute more than 50% of their cultivable land to SRI experience about 135% gain in production. When we examine the heterogeneity in treatment effects we see similar TOT effects across treatments A, B, and C farmers (Table 7A). This is expected since once a farmer adopts SRI, the effects should not depend on whether he receives financial incentives for adoption or not.

We also present the regression results for spillover effects from SRI- adoption in Table 8. In this case, we consider the un-treated farmers (who did not receive training) from treatment villages and all farmers in control villages. Panel A reports results using adoption measure when we consider a farmer is adoptee if he followed SRI in at least one plot of land. In panel B, we consider the proportion of land under SRI as the measure of adoption. The results in column 1 and 2 suggest that being an un-treated farmer in a treated village is associated with increased adoption of SRI, and the adoption rate is higher if there are more farmers who received training in that village (columns 3-4). The results do not differ when we add controls.

6. Conclusion and future work

Crop yields in developing countries remain low due to limited adoption of new innovations by farmers. The "System of Rice Intensification" (SRI), developed in Madagascar in the 1980s for smallholder farmers like those in Bangladesh, has demonstrated dramatic potential for increasing rice yields without requiring additional purchased inputs (seed, fertilizer, etc.), nor increased irrigation. But these gains, although widely documented in observational data from a variety of countries, are yet to be verified with adequate scientific rigour. In this project, we show, for the first time, the impact of SRI using a large scale RCT. We use the village level social networks along with financial incentives for referral and adoption of SRI. Our results suggest that adoption level is considerably high given that the project involves only a onetime training and the fact that farmers in countries like in Bangladesh are traditionally risk-averse, less inclined to adopt a new technology as SRI fields look visible different from traditional rice fields. The yield gains, though not as significant as many other observational studies, are quite high. We find that the yield gains are 14-25%. Though SRI technique involves some additional labour for managing practices, and hence the cost is higher, we find that profit remains significantly higher than the traditional farming. Profits are as high as 33%. This is despite the less-than-perfect adoption of

SRI. The main constraint for adoption appears to be manging irrigation which many farmers could not follow as per SRI technique. The irrigation system, though privately managed, requires collaboration among farmers of nearby plots of land to pump water at the same time.

While delighted at the prospects of such extension services being provided in rural Bangladesh, it is not clear whether this adoption resulting from a onetime intervention would be sustained and if other farmers seeing this adoption and higher yield would successfully adopt SRI. Previous research undertaken by Moser and Barrett (2003) in Madagascar has shown that while farmers readily adopt the high yielding variety when introduced, there was significant abandonment of the variety in subsequent years. Duflo et al (2011) also show that in Western Kenya, adoption of fertilizers among farmers receiving a one-time subsidy dropped back to the same rate as among the comparison group as soon as the subsidy stopped, suggesting that such one-time subsidy does not lead to persistent technology adoption but only has a temporary effect on fertilizer adoption.

While studies on adoption of improved technologies abound, little evidence exists on the continued use of improved technologies. In the next phase of this study, we attempt to bridge this gap by focusing on the mechanics of adoption and abandonment of improved and better technology among poor households in rural Bangladesh. The next phase (which is now ongoing in the fields) of the project has two objectives: (i) understanding the factors that might lead to sustained adoption of the "new" technology, so that the there is no subsequent reversion to the non-adoption equilibrium and (ii) finding the most cost-effective channel that would lead to rapid diffusion of the technology. To meet the first objective, farmers from half of the 120 villages (which were under the treatments in the first phase of the program) will receive an extension service on SRI, to be provided another round of training on SRI, including dissemination of information of successful SRI adoption, and continuation of extension expert. This will enable us to investigate whether extension services provided by BRAC needs to be continued for more than a single period or a one-time intervention is sufficient for farmers to adopt the new technology permanently. In the remaining of the 60 villages no services will be provided. For the latter, we are using a different diffusion mechanism farmers from their respective village nominate a set of opinion leaders or role models. With key farmers identified, the project then subsequently trains them, and asks them to diffuse the technology among those community members who initially chose them as their leaders.

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Table 1: Basic characteristics of different groups of farmers by treatment Status

	Treatment A			Treatment B			Treatment C			Control	All
Variable	Batch 1	Batch 2	Un-treated	Batch 1	Batch 2	Un-treated	Batch 1	Batch 2	Un-treated		
Age	45.41	45.87	45.58	45.70	45.39	45.87	44.38	43.64	44.21	46.15	45.47
Education	4.25	4.47	4.43	4.25	4.86	4.17	4.65	4.41	4.39	4.20	4.25
Farm size	150.58	165.61	169.16	154.21	164.63	173.40	165.34	175.21	161.84	168.23	165.72
Household size	5.22	5.09	5.19	5.19	5.06	5.21	5.13	5.29	5.03	5.25	5.19
Household income (taka)	13049.5	11249.5	14293.3	11971.3	12149.9	12742.5	12309.6	11660.5	12439.7	11434.5	12144.6
Knowledge of SRI	11.26	12.01		11.66	12.05		11.91	12.26			11.86
Cognitive score	4.13	4.79		4.37	4.56		4.47	4.81			4.53
Cognitive deduction test	1.96	2.28		2.29	2.48		2.10	2.01			2.19
Cognitive counting	1.42	1.62		1.51	1.56		1.48	1.52			1.52
Risk-averse	48.34%	46.41%		51.96%	47.75%		46.60%	46.04%			47.87%

Notes: Batch 1 includes the farmers chosen randomly to train on SRI. Batch 2 was referred by batch 1 farmers. Un-treated are those did not receive the training within the treatment villages. Control includes the farmers from control villages where no training was available. Cognitive score includes numerical reasoning (simple deduction), counting, memory, and charts to understand IQ. Risk taking is defined as farmers taking less risky option in a gamble choice as in Binswanger (1980)

Table 2: Summary Statistics of SRI-Adoption by Treatment status

	Treatment A			Treatment B			Treatment C			Control	All
Variable	Batch 1	Batch 2	Un-treated	Batch 1	Batch 2	Un-treated	Batch 1	Batch 2	Un-treated		
SRI Adoption (farmers' self-assessed in post-harvest)	0.36	0.38	0.08	0.50	0.51	0.09	0.48	0.49	0.06	0.00	0.19
Extent of SRI adoption (if followed 50% SRI Principle)	0.25	0.27	0.04	0.36	0.35	0.05	0.35	0.36	0.03	0.00	0.13
Self-assessed SRI adoption (during post-transplantation survey)	0.43	0.47	0.10	0.51	0.53	0.10	0.51	0.52	0.07	0.01	0.22
Enumerator-assessed SRI adoption	0.33	0.34	0.06	0.39	0.41	0.07	0.41	0.41	0.07	0.00	0.17
Age of seedlings (in days)	0.41	0.44	0.22	0.52	0.51	0.27	0.47	0.51	0.24	0.22	0.33
Number of seedlings in bunch	0.40	0.42	0.16	0.50	0.54	0.22	0.50	0.55	0.27	0.18	0.31
Use of organic fertilizer	0.22	0.26	0.13	0.31	0.29	0.12	0.34	0.32	0.18	0.11	0.19
Use of irrigation	0.69	0.68	0.60	0.83	0.86	0.69	0.74	0.80	0.64	0.49	0.64
Frequency of weeding	0.17	0.23	0.18	0.22	0.20	0.19	0.22	0.19	0.17	0.03	0.14

Notes: Treated are those received training in either batch 1 or batch 2. Untreated did not receive training from within the treatment villages

Table 3: Summary Statistics related to farmer's referral

Referred someone	Treatment A	Treatment B	Treatment C	Total
who was also referred during census	23%	24%	25%	24%
who is a relative	15%	21%	20%	18%
with better knowledge of agriculture	41%	47%	43%	44%
with whom he discusses agriculture	49%	39%	44%	44%
with whom he has adjacent land	19%	26%	20%	22%
with whom he discusses financial matter	13%	21%	21%	18%
with whom he regularly socializes	52%	57%	56%	55%

Table 4: Who refers whom? Dyadic Regressions on Referral

	(1)	(2)	(3)	(4)
Relative (R)	0.282***	0.292***	0.387**	0.342*
	(0.096)	(0.095)	(0.180)	(0.191)
Discuss frequently on agriculture (A)	0.228***	0.221***	0.246**	-0.120
	(0.056)	(0.057)	(0.102)	(0.108)
Discuss frequently on finance (F)	0.006	0.017	0.095	0.037
	(0.085)	(0.087)	(0.200)	(0.182)
Has neighbouring land (L)	0.320***	0.320***	0.189	0.243
	(0.090)	(0.091)	(0.144)	(0.179)
Geographical distance (G) (1=close, 0 otherwise)	0.191**	0.181**	0.246*	0.324**
	(0.078)	(0.079)	(0.129)	(0.131)
Treat B		-0.099	-0.137	0.001
		(0.068)	(0.135)	(0.119)
Treat C		-0.078	0.043	0.204**
		(0.064)	(0.132)	(0.103)
Treat B*R			-0.332	-0.316
			(0.235)	(0.254)
Treat C*R			0.107	-0.077
			(0.229)	(0.263)
Treat B*A			-0.020	0.127
			(0.146)	(0.149)
Treat C*A			-0.021	0.082
			(0.135)	(0.145)
Treat B*F			0.020	-0.149
			(0.243)	(0.231)
Treat C*F			-0.202	-0.123
			(0.237)	(0.219)
Treat B*L			0.355*	0.386*
			(0.201)	(0.234)
Treat C*L			-0.007	-0.092
			(0.221)	(0.232)
Treat B*G			0.109	0.021
			(0.178)	(0.180)
Treat C*G			-0.330*	-0.329
			(0.198)	(0.230)
Difference in age				-0.002
				(0.002)
Difference in education				0.018***
				(0.007)
Difference in farm size				-0.000**
				(0.000)
Difference in knowledge of SRI				-0.165***
				(0.026)
Difference in cognitive ability				-0.045**
				(0.018)
Constant	-4.855***	-4.794***	-4.827***	-3.870***
	(0.052)	(0.069)	(0.104)	(0.082)
Observations	111,563	111,563	111,563	34,261

Sample size drops dramatically in column4 as cognitive measures and post-training SRI knowledge is available only for those who received training (ether referee or referred). Robust standard errors in parentheses and clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Determinants of SRI adoption in Bangladesh

	SRI adoption	Extent of SRI adoption	Self-assessed SRI adoption	Enumerator-assessed SRI adoption
Panel A: Treated as Batch1 vs untreated in Treatment village				
Treated in Treatment village A	0.345***	0.289***	0.406***	0.349***
	(0.046)	(0.050)	(0.046)	(0.051)
Treated in Treatment village B	0.482***	0.388***	0.482***	0.387***
	(0.041)	(0.042)	(0.040)	(0.048)
Treated in Treatment village C	0.455***	0.375***	0.459***	0.390***
	(0.053)	(0.054)	(0.055)	(0.058)
# Treated Friends	0.027***	0.018**	0.034***	0.019*
	(0.010)	(0.007)	(0.011)	(0.010)
# Friends	0.013	0.022	0.021	0.046**
	(0.015)	(0.014)	(0.017)	(0.020)
Number of Observations	2,449	2,449	2,160	2,160
Pseudo R-squared	0.211	0.205	0.208	0.190
Panel B: Treated as Batch2 vs untreated in Treatment village				
Treated in Treatment village A	0.392***	0.312***	0.450***	0.350***
	(0.050)	(0.052)	(0.046)	(0.053)
Treated in Treatment village B	0.504***	0.388***	0.512***	0.413***
	(0.038)	(0.043)	(0.039)	(0.044)
Treated in Treatment village C	0.468***	0.379***	0.484***	0.395***
	(0.052)	(0.052)	(0.047)	(0.053)
# Treated Friends	0.024**	0.018**	0.026**	0.021**
	(0.010)	(0.008)	(0.011)	(0.011)
# Friends	0.004	0.010	0.017	0.032
	(0.016)	(0.015)	(0.018)	(0.021)
Number of Observations	2,442	2,442	2,164	2,164
Pseudo R-squared	0.219	0.209	0.220	0.194

Note: Each regression also controls for age, age square, level of education, logarithm of land (in decimals), logarithm of household size, income and dummies for occupation categories. The regression results present the relevant marginal effects for different measures of SRI adoption. “Treated friends” refer to the number of friends trained with the referee while “Friends” refer to number of friends. The coefficients are marginal effects from the probit model. Robust standard errors in parentheses and clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

Table 6A: Comparison between treatment vs control village (ITT) (per decimal land)

	Treatment village	Control village	Difference	% difference
Production (KG)	25.68	22.37	3.31***	14.80
Total Revenue	832.62	728.96	103.66***	14.22
Total Cost	314.90	283.94	30.96***	10.90
Estimated Profit	517.72	445.01	72.71***	16.34
No of observation	8209	4088		

Table 6B: Comparison between treated under first batch in treatment village vs pure control village

	First batch in Treatment village	Control village	Difference	% difference
Production (KG)	26.08	22.37	3.71***	16.58
Total Revenue	846.59	728.96	117.63***	16.14
Total Cost	319.18	283.94	35.24***	12.41
Estimated Profit	527.42	445.01	82.41***	18.52
No of observation	2686	4088		

Table 6C: Comparison between treated under second batch in treatment village vs pure control village

	Second batch in Treatment village	Control village	Difference	% difference
Production (KG)	25.76	22.37	3.39***	15.15
Total Revenue	832.89	728.96	103.93***	14.26
Total Cost	308.41	283.94	24.47***	8.62
Estimated Profit	524.48	445.01	79.47***	17.86
No of observation	2472	4088		

Table 6D: Comparison between SRI adoption and SRI non adoption within treatment village

	Adopted	didn't adopt	Difference	% difference
Production (KG)	26.34	25.33	1.01***	3.99
Total Revenue	837.18	830.20	6.98	0.84
Total Cost	291.06	327.56	-36.50***	-11.14
Estimated Profit	546.13	502.65	43.48***	8.65
No of observation	2847	5362		

Table 6E: Comparison between SRI adopted Plot and Non-SRI plot in treatment village

	SRI Plot	Non-SRI plot	Difference	% difference
Production (KG)	28.07	25.18	2.89***	11.48
Total Revenue	891.33	820.23	71.10***	8.67
Total Cost	295.32	319.03	-23.71***	-7.43
Estimated Profit	596.01	501.20	94.81***	18.92
No of observation	1431	6778		

Table 6F: Comparison between SRI adoption in treatment village with farmers in control village

	adopted SRI	Control vill	Difference	% difference
Production (KG)	26.34	22.37	3.97***	17.75
Total Revenue	837.18	728.96	108.22***	14.85
Total Cost	291.06	283.94	7.12**	2.51
Estimated Profit	546.13	445.01	101.12***	22.72
No of observation	2847	4088		

Table 6G: Comparison between SRI adopted Plot in treatment village and control village

	SRI Plot	Non-SRI plot In C village	Difference	% difference
Production (KG)	28.07	22.37	5.70***	25.48
Total Revenue	891.33	729.11	162.22***	22.25
Total Cost	295.32	284.04	11.28***	3.97
Estimated Profit	596.01	445.07	150.94***	33.91
No of observation	1431	4068		

Notes: adoption: if SRI is adopted for at least in one plot then we will consider that the farmer has adopted SRI.

Table 7: Effects of intervention at the village level and on those adopted/received training

	(1)	(2)	(3)	(3)
	Production	Total Revenue	Total Cost	Profit
ITT (Treatment vs Control village)	3.238***	107.5***	29.06**	74.27***
	(0.427)	(13.58)	(12.96)	(15.33)
ITT (Treated under batch1 vs Control village)	3.702***	122.5***	34.37***	84.28***
	(0.460)	(14.52)	(13.19)	(16.96)
ITT (Treated under batch2 vs Control village)	3.332***	106.5***	22.13	80.60***
	(0.485)	(15.13)	(13.45)	(16.44)
TOT (adopted at least one plot)	9.429***	312.9***	84.63**	217.0***
	(1.419)	(47.27)	(39.52)	(46.46)
ToT (BRAC-assessed adoption measure)	11.97***	399.2***	107.6**	277.0***
	(2.039)	(68.72)	(52.47)	(61.29)
ToT (self-assessed adoption measure)	9.426***	312.8***	84.60**	216.9***
	(1.418)	(47.26)	(39.50)	(46.45)
ToT (extent of SRI adoption)	30.16***	1,001***	270.1**	692.6***
	(5.587)	(185.2)	(130.7)	(165.3)

Notes: Each cell represents estimated coefficients from separate regression of yield (production), total (expected) sales value, total cost, and estimated profits. Each regression controls full set of covariates such as age and its square, education, total cultivable land, lag value of the dependent variable of the same season. Standard errors are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

Table 7A: Heterogeneous effects by treatments

	Production	Total Revenue	Total Cost	Profit
Treat A	13.55***	493.8***	213.8**	272.8**
	(3.882)	(135.7)	(89.20)	(106.9)
Treat B	12.46***	386.8***	26.67	335.3***
	(3.101)	(99.48)	(61.31)	(75.51)
Treat C	10.78***	340.0***	114.8	218.2***
	(2.987)	(103.4)	(69.34)	(78.34)

Notes: includes full set of controls. Sub-sample analysis for different treatments.

Table 8: Spill-over effects (Effects on Adoption)

	(1)	(2)	(3)	(4)
Panel A: adopted at least in 1 plot				
Untreated in treat village=1	0.909***	0.906***		
	(0.132)	(0.132)		
Total trained farmers			0.0518***	0.0520***
			(0.00623)	(0.00628)
Panel B: proportion of land adopted				
Untreated in treat village=1	3.558***	3.565***		
	(0.566)	(0.565)		
Total trained farmers			0.247***	0.248***
			(0.0398)	(0.0398)
Control for covariates	No	Yes	No	Yes
Observations	3,026	2,992	3,026	3,026

Figure 1(a): Referral quality based on availability of choices under different treatments

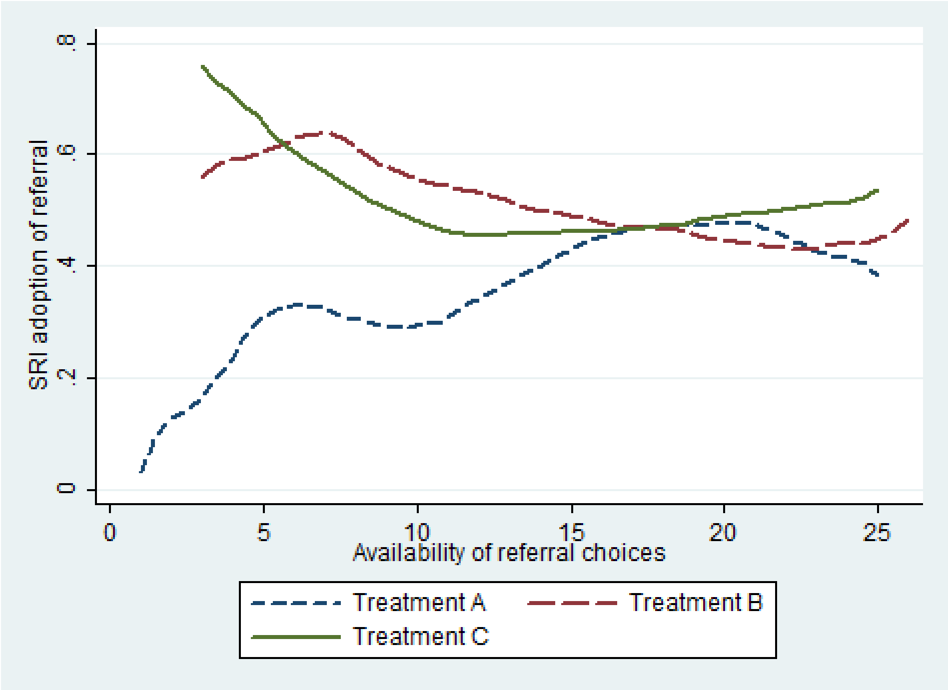

Figure 1(b): Referral quality based on the rank of referral selection under different treatments